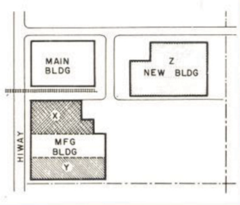
Fourth Edition – revised and enlarged

Systematic Layout Planning

by Richard Muther
and Lee Hales

A total system of layout planning

I



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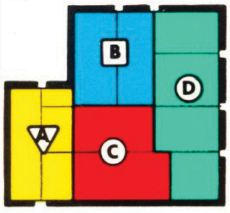

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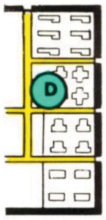

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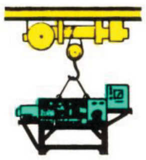
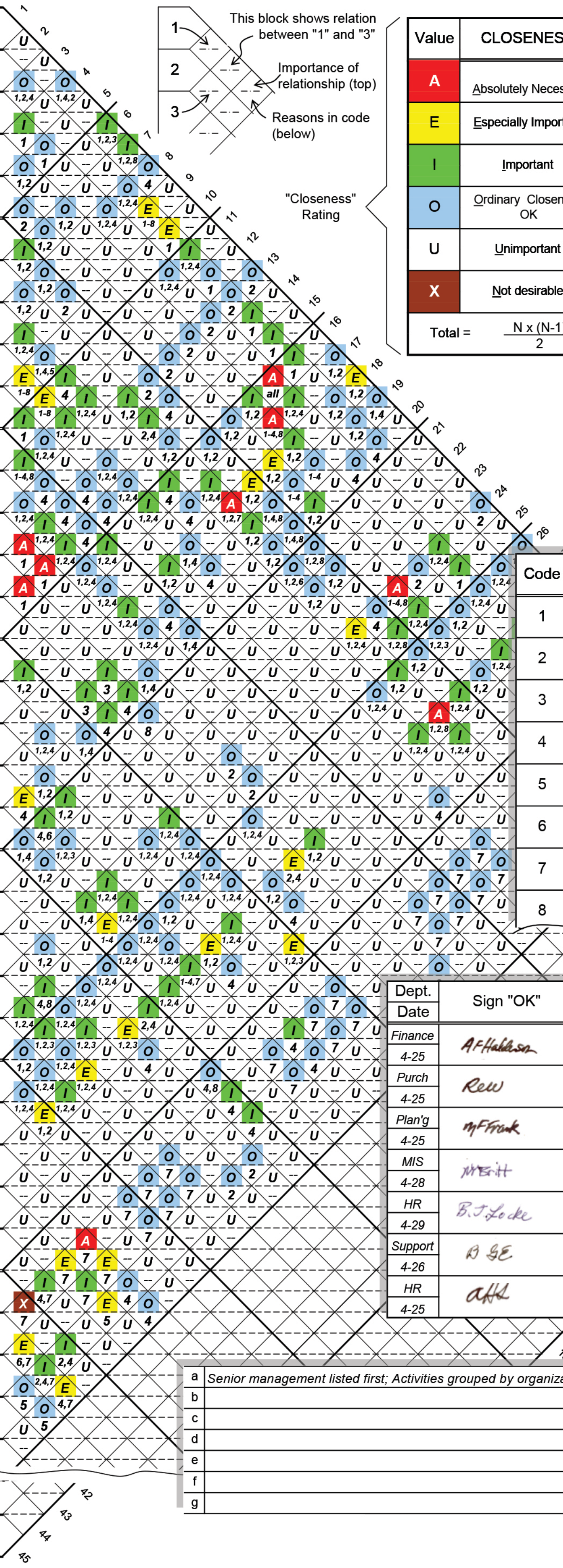


RELATIONSHIP CHART

Plant (Company) *Texas Operations* Project *Office Lay*

Source - Reference *Survey Apr. 12; Mtgs. Apr. 23* Date *Apr.25*

1 *Vice President -- Texas Operations* ⓐ
2 *Director -- Finance (incl. Budget & Bus. Info. Analysts)*
3 *Director -- Purchasing*
4 *Sr. Mgr -- Production Planning*
5 *Sr. Dir. -- Quality Compliance*
6 *Sr. Dir. -- Manufacturing Support*
7 *Site Director -- Main Plant, incl. Staff*
8 *Finance -- Cost Accounting Main*
9 *Finance -- Comptroller, Acctg. Svcs. & Gen. Acctg.*
10 *Finance -- Payroll*
11 *Finance -- Accounts Payable; Accounts Recievable*
12 *Central Order Processing*
13 *Director -- MIS, incl. IT Audit*
14 *MIS Tech. Operations, incl. Computer Room*
15 *MIS Business Process & Applications*
16 *Purchasing*
17 *Production Planning*
18 *Human Resources, incl. Director*
19 *Engineering*
20 *Calibration*
21 *Facilities Security/SHE*
22 *Process Improvement & Lean Promotion Office*
23 *Document Control*
24 *Quality Assurance, Sterility & QC*
25 *Analytical & Technical Services (Validation)*
26 *Immunology & Clinical Studies*
27 *Pharma Regulatory Affairs*
28 *Plant Production Operations & Maintenance*
29 *Training*
30 *Mail Room*
31 *Reception Lobby (incl. Visitors Rest Rooms)*
32 *Employee Entrance (incl. RR, Lockers & Showers)*
33 *Lunch Room with Vending*
34 *Large Conference Room*
35 *Fitness Center*
44
45



Value	CLOSENESS	Color	No. of Ratings
A	Absolutely Necessary	RED	*9*
E	Especially Important	OR-YEL	*22*
I	Important	GREEN	*69*
O	Ordinary Closeness OK	BLUE	*138*
U	Unimportant	U	*356*
X	Not desirable	BROWN	*1*
Total =	N x (N-1) / 2	=	*595*

Code	REASON
1	*Face-to-Face Personal Contact*
2	*Meetings, Teamwork*
3	*Shared staffing*
4	*Convenience*
5	*Common type of space*
6	*Receception of Visitors*
7	*Flow of people*
8	*Ease of Management/Supervision*

Dept. Date	Sign "OK"	Dept. Date	Sign "OK"
Finance *4-25*	AFHaldesn	*Facil.* *4-26*	
Purch *4-25*	Rew		
Plan'g *4-25*	MFFrank		
MIS *4-28*	MBritt		
HR *4-29*	B.J.Locke		
Support *4-26*	B GE		
HR *4-25*			

a *Senior management listed first; Activities grouped by organizational responsibility.*
b
c
d
e
f
g

Systematic Layout Planning

Fourth Edition

Richard Muther (1913 – 2014)

Founder, Richard Muther & Associates. Founder, Muther International. Founder, Institute of High Performance Planners. Author or co-author of the books and videos *Production Line Technique, Practical Plant Layout, Systematic Handling Analysis (SHA), Systematic Planning of Industrial Facilities (SPIF), Volumes I and II, Simplified Systematic Layout Planning, Simplified Systematic Handling Analysis, Simplified Systematic Planning of Manufacturing Cells, Plant Floor Layout, Creating Personal Success, Planning Basics, More Profitable Planning, Reaching, Planning by Design…*

Lee Hales

President, Richard Muther & Associates. Founder and President, High Performance Concepts, Inc. Author or co-author of the books and videos *Systematic Planning of Industrial Facilities (SPIF), Volumes I and II, Computer-Aided Facilities Planning, Planning Manufacturing Cells, Plant Floor Layout…*

M I
R P

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Dedication

This fourth edition of Systematic Layout Planning (SLP) is dedicated to the late Richard Muther, developer of the SLP method, and to three groups:

First, to the memory of our earliest contributors and supporters:

Harold Bright Maynard
Erwin Haskell Schell
René de Vallière

Their belief in sound basic principles, their insistence on meeting practical realities, and their personal encouragement to Richard Muther were warmly appreciated and helpful during the initial development of SLP in the 1950s.

Second, to the consulting staff of Richard Muther & Associates. For more than 50 years, their constructive applications of SLP on hundreds of projects have resulted in valuable improvements and clarifications to this and prior editions.

Third, to our clients – past, present and future. Your needs and applications of SLP have stimulated its continuing improvement and made this fourth edition possible.

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Preface

This book has one objective: to tell and show managers and layout planners how to plan the arrangement of their facilities. It does not dwell on principles nor delve into academic viewpoints. Rather, it presents *a universal approach* and *a specific set of procedures to follow* for use by the person who is facing a layout planning project and who wants to execute it in a sound, effective, and systematic way.

Layouts of working areas must be as old as trades and crafts themselves. As factory systems and modern business developed, more attention had to be given to space utilization. German ore-processing and chemical engineers, meat packers in Chicago, Canadian rail-car producers, automobile makers in Detroit, and British shipbuilders all made advances with unusual layouts. Industrial architects learned to relate their structures to the long-term functional use of the space inside them. But it took industrial engineers like Taylor, the Gilbreths, Barnes, Maynard, and Mogensen to bring us efficiency concepts and process-visualizing techniques that we could use as a basis for attacking industrial layouts.

Even with these significant contributions and with modern industry's recognition of the cost savings that result from sound planning, layout planning never developed into a clear procedure. On many layout planning jobs, I groped for an effective pattern to follow. Like most analysts, I wrestled with the problem of having so many factors, considerations, physical features, and objectives in my layout projects that I often felt bewildered. Therefore, I have striven to develop a universal layout planning procedure. I wanted a logical approach, sound techniques of analysis, a simple set of conventions or sign language, and a straightforward, easy-to-follow pattern of procedures – a pattern that would integrate and put into perspective the many good, though isolated, techniques already in use.

Systematic Layout Planning (SLP) basically attains these objectives. It is not perfect; it is not a substitute for judgment or intelligence; and even after 50 years of use, it can still be improved. Indeed, this Fourth Edition includes several new developments, lays increased emphasis on certain points, incorporates a revised pattern of procedures, and makes extensive use of electronic spreadsheets. All of these indicate that SLP is being refined and added to as it continues to be used.

Systematic Layout Planning (SLP) consists of *a framework of phases* through which each layout project passes; *a pattern of procedures* for step-by-step planning; and *a set of conventions* for identifying, visualizing, and rating the various activities, relationships, and alternatives involved in any layout project.

The *phases* were originally identified and described in my earlier book, Practical Plant Layout (New York: McGraw-Hill Book Co., 1955). They seem well recognized today.

The latest pattern of procedures is now in its fourth edition. Based originally on experience gained in over 200 layout planning projects, the SLP pattern has now been applied by the authors and their associates to more than 1000 projects. Today there is no doubt that, properly applied, the procedures pattern helps to avoid errors, save time, and produce better solutions.

Further, the pattern's structure has been standardized to integrate with companion methods developed since SLP first appeared. These include: Systematic Handling Analysis (SHA), Systematic Planning of Manufacturing Cells (SPMC), and Systematic Planning of Industrial Facilities (SPIF). Thus, the planner who masters SLP will find it easy to master a family of methods addressing the full scope of industrial facilities planning.

The SLP conventions are, whenever possible, adopted directly from standards approved by professional societies in North America or from other long-established codes. However, layout planners do not have to adopt these conventions in order to follow the phases and pattern. In fact, there are times when the SLP conventions may be modified slightly to provide special meaning.

This book is really an instruction manual. Perhaps it is too specific – but we have designed it so. We have included more than 200 illustrations, check lists, and examples from a wide variety of projects. The working forms in the last section (including cross references to their text explanations) in particular are aimed at providing direct, practical assistance. But it is the total SLP package – the complete planning system – that should bring experienced planners their biggest gain.

During the 50 years since the first printing of *Systematic Layout Planning*, it has been translated into seven foreign-language editions; its techniques have been widely adopted by planners throughout commerce and industry. I sincerely hope that this edition will prove of direct and significant benefit to you.

Richard Muther
Kansas City, Missouri

Foreword

You have been asked to conduct or lead a layout planning project. Where do you begin? What inputs do you need? How do you proceed? Whom should you involve? How much time will you and they need to spend? When will you have plans ready for review? How will you get agreement on which plan is best? How will you gain the necessary acceptance and approvals? How will you plan and manage the rearrangement or installation? These are everyday questions in layout planning. But how do you answer them without years of layout planning experience?

Most texts on layout planning are of limited help. They contain many pages of mathematical algorithms, some pictures of common material handling equipment, and smatterings of dimensional reference data. While their flow diagrams, charts, and tables are instructive, their attempts to cover all of facilities planning make them a mile wide but only inch-deep on the process of layout planning itself.

This book is different. More than a text about layouts and facilities, it is a highly-visual project guide or manual for those who need a plan. Its structure and chapters will walk you through your project, step by step. We present specific procedures and identify the outputs and key documents that you need to complete at each step. Even the book's comb-bound, lay-flat design is intended to promote active use. More than 200 illustrations from a wide range of actual projects will help you adapt the prescribed procedures to your industry and situation.

Systematic Layout Planning (SLP) does not require or presume higher mathematics, algorithms or computer software to get results. Rather it applies common-sense "thoughtware" in an orderly way. Math is limited to arithmetic and software use largely to spreadsheets and visualization. Rather than exalt in technical know-how, SLP encourages planners to involve and lead others often lacking in technical training but better-informed on the practical details of the areas being planned. In this way, SLP builds organizational commitment to the new layout.

This book is now more than 50 years old and yet it is still in daily use throughout the world. Likely it will remain in use for another 50. That is because its procedures are sound, easy to understand and learn, and they work every time. As a result, layouts developed with SLP get done more quickly, are qualitatively better plans, and thus more likely to be approved. And those who plan with SLP gain credibility and respect within their organizations.

With this book in hand, you are ready to plan – even before you know what the project is! You are ready to induce creativity as a by-product of the planning process itself. And you are ready for the inevitable uncertainties and surprises, with little or no loss in planning efficiency or time.

H. Lee Hales
President
Richard Muther & Associates

Part One

Chapter 1
Basics

This chapter covers some basics of layout planning. Chapter 2 sets forth the actual procedure to follow.

Why Layout Planning?

The primary purpose of any plant layout is to facilitate the manufacturing process. Additional objectives include:

Minimizing material handling, especially travel distance and time
Maintaining flexibility of arrangement and operation as needs change
Promoting high turnover of work-in-process – keeping it moving
Holding down investment in equipment
Making economical use of floor space
Promoting effective utilization of labor
Providing for employees' safety, comfort and convenience

Layouts for distribution centers, offices, laboratories, and facilities of all kinds share several of these objectives even though their processes are quite different.

The purpose of layout planning is quite simply to achieve the objectives above. Its value and necessity is obvious when setting up a new facility. Over the facility's life, layout planning remains essential. Rearranging in the absence of a sound plan, will, in practically every case, result in lost time, idle equipment, and disruption of personnel. In addition, it may well lead to serious blunders in the use of a company's available land, in costly re-arrangements, in actually tearing down buildings, walls, or major structures which are still usable but which subsequently turn out to be roadblocks to efficiency and low-cost operation.

A little time spent in planning the arrangement before it is installed can prevent such losses. Moreover, it allows the integration of subsequent moves and rearrangements into a logical overall program. Planning makes facilities arrangements an orderly, logical sequence. Layout planning pays off: Obviously, it is much easier to move templates or replicas of facilities and equipment around on a piece of paper or computer screen than it is to move the actual buildings, machinery, or equipment around. "Mistakes" caught in this way pay for themselves if they avoid mistakes in the physical installation.

Actually, from an installation standpoint, it is about as inexpensive to put in a good layout as to put in a poor one – frequently much less expensive. However, once a poor layout is installed, the cost of rearranging, disrupting production, and fighting your way through a new financial appropriation prohibit remaking it into a good layout.

The Key to Unlocking Layout Problems

There are two basic elements on which every layout problem rests:

1. Product (or material or service) – what is to be made or produced
2. Quantity (or volume) – how much of each item is to be made

Directly or indirectly, these two elements underlie all other features or conditions in layout work. Therefore, facts, estimates, or information about them are essential.

> By *Product* (or material or service) we mean the goods produced by the company or area in question, the starting materials (raw materials or purchased parts), the formed or treated parts, the finished goods, and/or service items supplied or processed.
>
> Products may be termed items, varieties, models, styles, part numbers, formulations, product groups, or material classes.
>
> By *Quantity* (or volume) we mean the amount of goods or services produced, supplied, or used.
>
> Quantity may be termed number of pieces, tons, cubic volume, or value of the amount produced or sold.

In terms of unlocking layout problems (see Figure 1-1), these two elements represent the handle of any key we must grasp. For it seems obvious that if we are planning the layout of a plant or department, the layout must accomplish something. That "something" is certain products in certain quantities.

After obtaining the product and quantity information, we must next learn about the routing (or process). The routing refers to how the product or material will be made.

> By *Routing* we mean the process, its equipment, its operations, and their sequence.
>
> Routing may be defined by operation-and-equipment lists, process sheets, flow sheets, and the like.

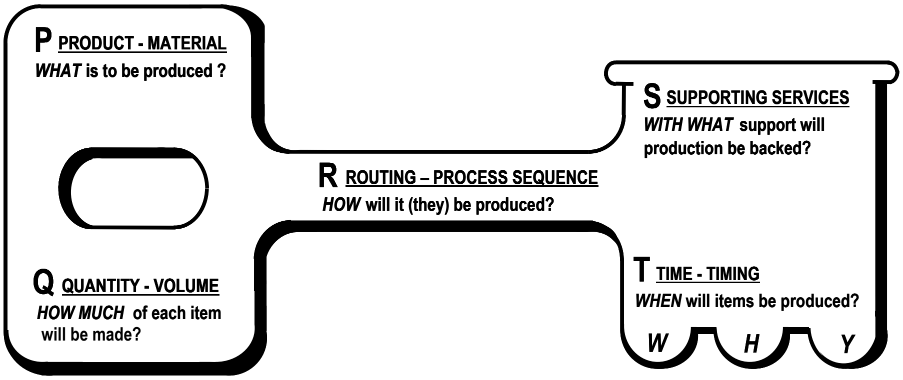


Figure 1-1. The key – PQRST – to unlocking layout problems.

> The machinery and equipment used will depend on the operations selected to change the form or characteristics of the material. Similarly, the movement of work through the area to be laid out is dependent upon the sequence of the operations. Therefore, the operations involved in the process and their sequence become the body (or stem) of our key.

Backing up the direct forming or assembly operations – the producing activities or areas – are a number of supporting services. In a sense, these are the things that give strength to the producing operations, for without adequate support, the producing equipment and workers could not function adequately.

> By *Supporting Services* we mean the utilities, auxiliaries, and related activities or functions that must be provided in the area to be laid out, so that it will function effectively.
>
> Supporting services include: maintenance, machine repair, tool room, toilets, locker rooms, cafeteria, first aid, and frequently shop offices, rail siding, receiving dock, shipping dock, receiving (or "in area"), and shipping (or "out area"). It is common to include storage areas as a part of the supporting services as well.

Taken all together, the supporting services often occupy more floor area than the producing departments themselves. Therefore, adequate attention must be given to them.

One other basic element of the key to unlocking layout problems is Time (or timing). By Time (or timing) we mean when, how long, how often, and how soon.

> Time or timing involves *when* products will be produced or *when* the layout being planned will operate (one shift only, during harvest season, Christmas rush).
>
> Many planners use the term “takt time” (from the German “taktzeit” or “cycle time”). Customarily defined as processing time available divided by the average demand rate, takt time is the maximum time allowable to keep pace with demand. Processing and takt times for the producing operations determine how many of a given piece of machinery or stations are required, which in turn determines the space required, staffing, and operation balancing.
>
> Urgency (of delivery or action) is also a part of timing, as are the frequency of lot or batch "run" and the response of supporting services.

Also important, time affects us – the layout planners. Every layout project takes a certain amount of time to accomplish, and usually there is a deadline to meet.

Figure 1-1 shows these elements as a key – to have an easy method of remembering them. But note three letters at the business end of the key: W H Y. These are an essential reminder to the layout planner to question the basic data – to check with reliable sources or have top management "say grace over" the basic figures on which layout planning will depend. Therefore, a few challenging "why's" may be necessary to be sure the starting data are sound.

Five elements – P (Product), Q (Quantity), R (Routing), S (Supporting Services), and T (Timing) – form the basis for layout planning. They are recapped in Figure 1-2.

This sequence of letters is essentially a new alphabet for the layout planner – one that no longer begins with A, B, C. From the start, each project involves P, Q, R, S, and T.

A play on letters, true – but it is the heart and soul of what eventually becomes millions of dollars of new construction, modernization, and plant rearrangement.

With this alphabet, everyone planning new or rearranged facilities has a place to start – and starting is sometimes the hardest part of a project.

P	Product (Material)
Q	Quantity (Volume)
R	Routing (Process sequence)
S	Supporting Services
T	Time (Timing)

Figure 1-2. The layout planner's alphabet, which begins with the basic input data (or key input) used in layout planning.

Product-Quantity Data Sheet

Based on the above, it is easy to recognize that, for the person who is planning a layout, the basic sources of data must be the company's design engineering group or product planning group on the one hand and the sales or marketing department or research people on the other. A plant layout, therefore, does not begin in the "plant." Rather, the planner must first seek out the P and Q information.

For the layout planner who does not have an organized system for securing product and quantity information, we suggest the Product-Quantity Data Sheet (see Figure 1-3). (Note: For each Figure in the text having a form number in the lower left corner, the reader will find a fresh unused form in the Working Forms section at the back of this book. Electronic versions are available at no charge from www.RichardMuther.com)

The Product-Quantity Data Sheet merely offers an organized way of gathering P and Q information. The form is divided into several parts. The left side deals with the product data; the right side, with the quantity data. The top two-thirds of the form covers the data for one product; the lower third, for several products. Only the top or the lower portion of the form is used on any one project.

The product information at the top left of the form is for one product where only forming and treating is involved. That is, when no assembly or disassembly takes place. This calls out the identification of the product or material and its physical characteristics, nature, quality features, and degree of standardization in design.

On the right side is space for gathering information about the quantities to be produced.

At the middle left are statements similar to those on the top left, although the middle left is prepared so that it is easy to get information for a product involving assembly operations as well as forming and treating.

The bottom of the form calls for the same information regarding products at the left and quantities at the right for a company producing a line of several products.

Generally speaking, the "plan layout for" product(s) and quantity(ies) should be endorsed by the appropriate management representatives. The planner should get the formal endorsement of figures in question from the company officials in charge of these activities. Obviously, to plan a layout which will not produce the desired products in the desired amounts is not achieving management's overall objective.

In addition, trends in products and quantities for the future are incorporated on this form to give the layout planner a picture of the direction in which things are going. Seasonal fluctuations, peak loads, and number of shifts are picked up also so that they will not be overlooked in the planning and so that official approval or endorsement can be given at the outset of any project.

While this form alone is seldom sufficient for a thorough analysis of product and quantity information, it does serve as a universal point of beginning. It has been said that the way to begin is to begin. Therefore, if you are an inexperienced layout planner this form can get you started on your project quickly – although you may soon depart from it to get more specific information on worksheets having more room and more meaning for the particular project in question.

Depending upon the nature and scope of your project, additional worksheets should capture trends and expected changes in sourcing, inventory policies, scheduling practices, process technology, methods, technical and personnel services, and operating times – that is to say R, S, and T in addition to P and Q.

PRODUCT-QUANTITY DATA SHEET

Plant *Chicago*
Data gathered by *R.C. Mills*
Date *8-9*

Project *427-C3*
With --
Sheet *1* of *1*

Fill-in as applicable **PRODUCT INFORMATION**

For ONE PRODUCT - Form and/or Treat only

Product Name & Description *Blade forging*
Finished condition (fluid, delicate, hazardous, etc.) *Nick free*
Size-shape *2" to 8" long; .10" to 0.375" thick; 1/2" to 2-1/2" wide.*
Normal unit of measure *Piece (blade)* Weight/unit *1/4 to 1/2 lb.*
Starting material condition *Extrusion*
Size-shape *3-1/2" to 8" long; 1" to 2" head diameter* Weight/unit 1/4 to 1/2 lb.
Normal container: as received *On skid* as shipped: *On skid*

For ONE PRODUCT - Assemble and/or Disassemble involved

Product Name & Description
Finished condition
Size-shape Weight/unit

Major Components:	Material Condition	Size-shape	Weight/unit
a.			
b.			
c.			
d.			
e.			

☐ See Parts list(s) or Component Breakdown

PRODUCTION REQUIREMENTS

Quantity produced this year *150,000* Source *Sales*
Quantity anticipated next year *150,000* Approved *J.C Allen*
Quantity anticipated in 5 yrs. *250,000* Est. by *W. N. Weker*
Length of time present product or model will be produced *Indefinitely*
Seasonal variation *Negligible*
Expansion Plans *Next addition at new site; not here.*

Trends in product:
Size *None* Diversification *None*
Weight *None* Simplification
Materials *Higher temperatures*
Rec'g. & Shipping amounts and frequencies *Smaller & more frequent*
Refinements *More accurate finish*
Other

Operating hours *8* per shift *16* per day
80 per week

Plan Layout for (no. of units) *25,000/week* ⓐ
per hour, day, week

For SEVERAL PRODUCTS

Name of Product or Group	Condition	Size-shape	Weight/unit	Quantity: This Yr.	Last Yr.	Next Yr.	5 Yrs	Per Order or Lot	% of Production	Plan Layout for
A.										
B.										
C.										
D.										
E.										
F.										
G.										

Trends in Product:
Seasonal Variation
Expansion Plans
NOTES: ⓐ *Excess capacity due to military requirements*

Layout as a Product

From the standpoint of the person responsible for planning a layout, the output is the layout plan. Therefore, the layout planner is a designer of a product and the plan becomes the blueprint and specification for that product. This product is the physical, installed layout.

One difference lies in the fact that a design engineer usually creates specifications and prints for a product to be made in lots or batches. The plant layout engineer designs a product which will be individual – for fundamentally each layout is unlike any other. In this sense, the layout engineer is more like an architect. If we compare the work of a product design engineer with that of the layout engineer we find the following sequences of steps:

Product Design Engineer	*Layout Engineer*
1. Research & Development	1. Location of area to be laid out
2. Engineering & Design	2. General Overall Layout
3. Production Design	3. Detailed Layout Plans
4. Processing & Tooling	4. Installation (Planning & Moves)

In still another sense, a plant layout is a product. A product design is the consolidation of a number of components, parts, or ingredients into one functional end product. It is assumed that this product, either because of its shape, its chemical characteristics, or integration of components, has value such that it can be sold and used profitably by the customer. In the same way, the layout is a combination of different departments, areas, or functioning activities which when put together function properly. It is assumed that this layout has value when installed for the benefit of the users, which in this case would be the operating people and the owners of the company.

Note that the layout plan is not an end in itself. There is a great tendency on the part of planners, particularly in fairly large organizations, to think of their layout plan as the "end of the line". "Once the layout is done, that's it," they say – and they feel no further responsibility for it. This is a great pity, for actually no product does any good merely in the design stage. It is not until the designed product is put into production and distributed to users that it really does anyone any good and really becomes a profitable venture for the manufacturing company. In the same sense, a layout plan does little if any good until it is sold to management and operating personnel, installed, and put to work by them.

Therefore, the layout planner must realize a responsibility to sell the plan and to have it installed and used as it was conceived and designed to be put to use. Not until this is done does the money spent for layout planning come home as savings for the company.

Figure 1-3. Data gathered for Product and Quantity. At left, this example shows the most significant information about the product in question – a blade forging for aviation gas turbine. At right is basic information about the quantity, together with design trend data. This form is a starting point for getting P-Q data. It provides space on left for product (or material) information; on right for quantity (or volume) requirements. The appropriate area of the form will be used depending on whether P is a single product, form only or assembly, or includes several products.

Phases of Layout Planning

The four steps that the layout planner takes may be translated into what is known as the "Four Phases of Layout Planning." These include the following:

Phase I – Location

Determine the location of the area to be laid out.

This is not necessarily a new site problem. More often it is one of determining whether the new layout (or re-layout) will be in the same place it is now, in a present storage area which can be made free for the purpose, in a newly acquired building, or some other potentially available space.

Phase II – General Overall Layout

Establish the general arrangement of the area to be laid out.

Here the basic flow pattern(s) and the areas allocated are brought together in such a way that the general size, relationships, and configuration of each major area are roughly established.

Phase II is sometimes termed block layout or area allocation or merely rough layout.

Phase III – Detailed layout Plans

Locate each specific piece of machinery and equipment.

In detail planning, the actual placement of each specific physical feature of the area to be laid out is established. And this includes utilities and services as well. The detailed layout plan is customarily an electronic drawing or sheet or board with replicas of the individual machines or equipment placed or drawn thereon.

Phase IV – Installation

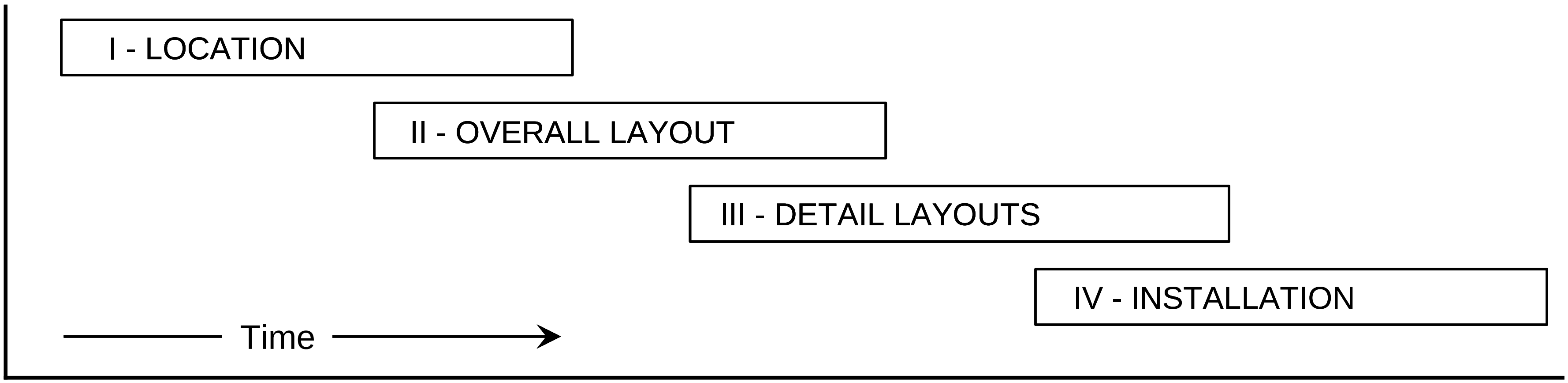
Plan the installation, seek the approval of the plan, and make the necessary physical moves.

Once the detailed layouts are completed (Phase III), considerable detailing of installation drawings and planning of moves must be worked out. Funds for the installation must be appropriated and the actual moves to install the machinery, equipment, and the services as planned must be made.

These four phases come in sequence, but, for best results, they should overlap each other. This is indicated by Figure 1-4. Every layout project passes through these four phases – even though the layout planning analyst may not be specifically charged with the

Figure 1-4. The four phases of Systematic Layout Planning. Every layout planning project passes through the four phases. As shown against the time scale, these phases should generally come in sequence and for best results the planner should make them overlap.

The Phases of Systematic Layout Planning



I - LOCATION

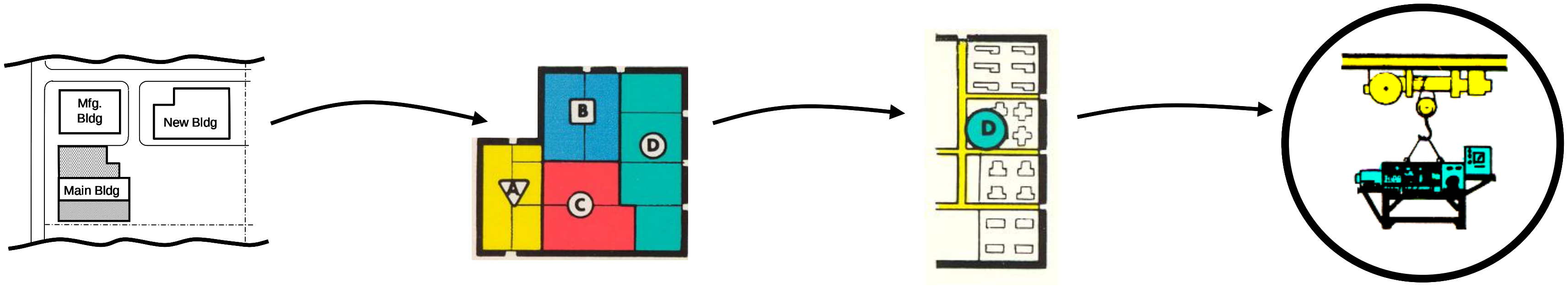
II - OVERALL LAYOUT

III - DETAIL LAYOUTS

IV - INSTALLATION

Time

Phase I: **Phase II:** **Phase III:** **Phase IV:**



responsibility for Phase I and/or Phase IV. That is, the planner must make sure that Phase I has been agreed to, or that a specific decision has been, or will be, made as to where the layout is to be located. Obviously, the planner cannot be very specific about detailed layout planning without information about number of floors, ceiling heights, column spacing, and building features. All are generally dependent upon a location – or a reasonably acceptable assumption as to the location – having been established.

In many cases, the Phase I work actually involves a plant location study or a new site analysis. In such cases, the person actually responsible for making the layout plan may or may not be involved directly in Phase I.

Likewise, in Phase IV some other group may do the physical installation. However, in any case the layout planning engineer should be aware of this four-phase sequence and should be prepared to integrate work with Phases I and IV.

In plans for a major project, there is another phase. This is explained in Figure 1-5. Here the total site or the integration of several buildings at different locations may be involved. Once the major arrangement of areas or complex of buildings has been blocked out, a general overall layout must be made for each building within the total site arrangement. This blocks-within-blocks enlargement of Phase II precedes the usual Phase III detailed layout plan for each department within each building – the detailed layout thus always remaining "the location of specific pieces of machinery and equipment."

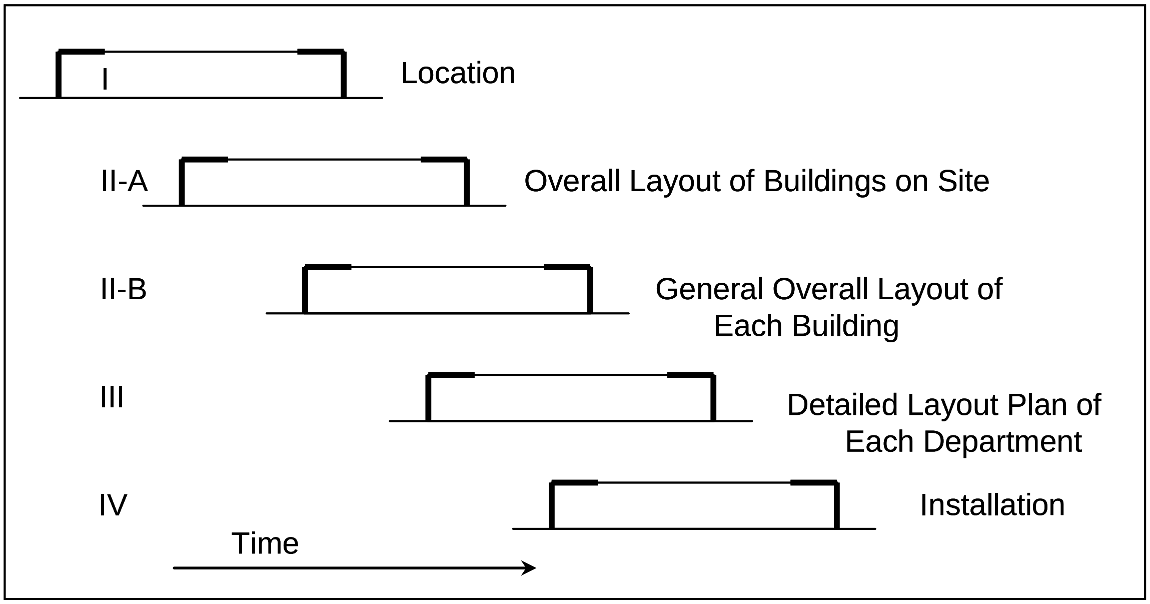


Figure 1- 5. Adjustments in four-phase framework for major or multi-building layout project. With major or multi-building layout projects, an extra phase enters the picture, for as well as an overall layout of each building into which the layout details can be fitted, an overall arrangement is needed for the total complex of buildings on the site. The overall site plan becomes Phase II-A; the overall layout of each building becomes II-B. And if the buildings are multi-story, the overall layout of each story (or floor) of each building would become II-C.

Similarly, it is important to note that the amount of detailed information required for planning increases as the layout project progresses. In the location phase, rough estimates and general considerations are involved. But in Phase IV installation drawings must be accurate, in some cases to a fraction of an inch. This degree of detailed information as a function of the layout phases is indicated in Figure 1-6.

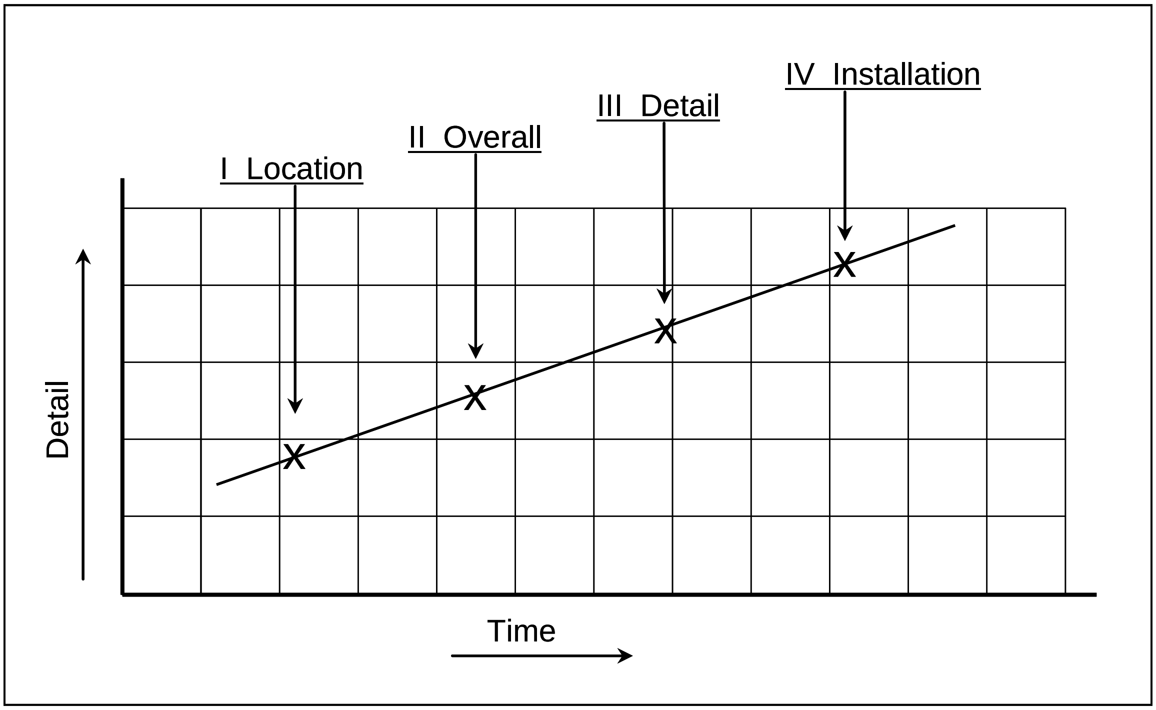


Figure 1-6. Degree of detailed information. The amount of detailed information, and the specificity of layout data and of planning techniques, increases as the layout project progresses through the framework of phases toward actual physical reality.

From the standpoint of planning the work to be done in making a new layout plan, the planner can use the four phases as a guide. First of all, it is possible – indeed logical – to schedule the project in terms of the four phases. This means that the layout planner should seek approval from superiors at least at these four places. Likewise, the person responsible for the overall project should check with associates and subordinates at these same four places.

Chapter 2

The Systematic Layout Planning Pattern

Systematic Layout Planning is an organized way to conduct layout planning. It consists of a framework of phases, a pattern of procedures, and a set of conventions for identifying, rating, and visualizing the elements and areas involved in planning a layout.

We explained the framework of four phases in Chapter 1. In this chapter, the Systematic Layout Planning *pattern of procedures* is described. The conventions will be introduced at the appropriate places in later chapters.

The strictly "layout planning" phases of any facilities rearrangement involve creating a general overall layout (Phase II) and, subsequently, a detailed layout plan (Phase III) for each portion of the general overall layout. In both Phase II and Phase III, the pattern to be followed is essentially the same.

Every layout rests on the three fundamentals:

1. Relationships – the relative degree of closeness desired or required among things
2. Space – the amount, kind, and shape or configuration of the things being laid out
3. Adjustment – the arrangement of things into a realistic best fit

These three are always the heart of any layout planning project, regardless of products, processes, or size of project. It is therefore logical and to be expected that the pattern of layout planning procedures is based directly on these fundamentals. See Figure 2-1.

The SLP Pattern

Planning follows box-by-box the five sections of the pattern, beginning with analysis of the *Inputs* and the possible types of layout (the left-hand box of Section 1). From this, the division of total space being laid out is clarified. The output of this section is a list of *Activity-Areas* (departments, cells, work groups, product value streams and breakouts, and physical features such as shipping docks and main entrance).

The second section establishes and visualizes the relationships to be honored by the layout. In process-dominated industries often the most significant aspect of layout planning is *Flow of Materials*. By planning the layout around the sequence and intensity of material moves, we attain a progressive flow through the area(s) involved, hopefully with the minimum material handling effort and cost.

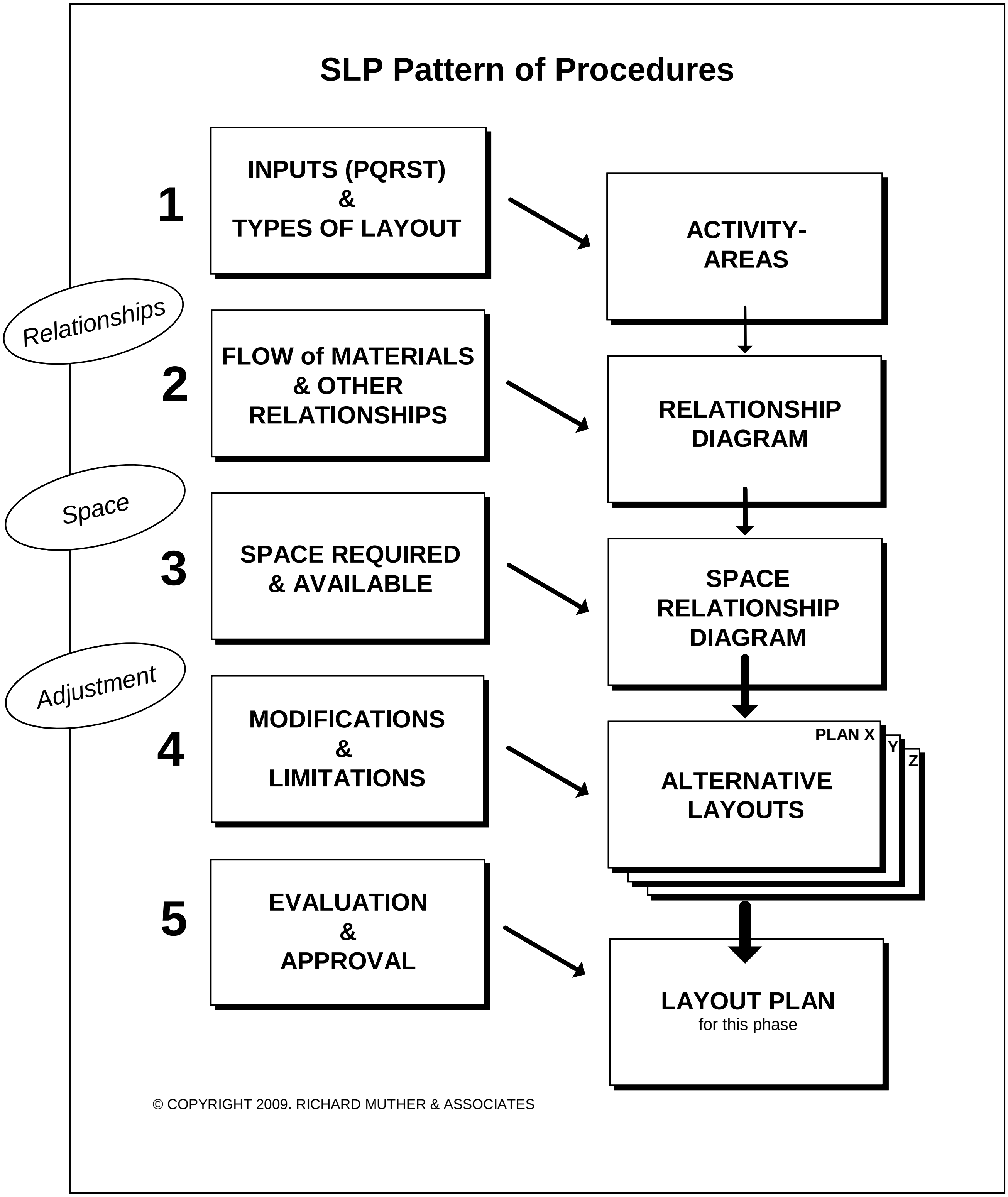


Figure 2-1. The Systematic Layout Planning Pattern of Procedures.

In addition to the operating or producing areas, many supporting-service areas must be integrated and planned. As a result, developing or charting the *Other Relationships* – that is, the relationships among the service or support activities or functions – is frequently of equal or greater importance than relationships based on flow of materials alone.

These two investigations are then combined into a flow and/or activity *Relationship Diagram*. Here the various activities, departments, or areas are geographically related to each other, without regard to the actual space each requires.

In the next Section 3 comes the *Space Required* for each activity-area. This is developed from analysis of the process machinery and equipment necessary and from the service facilities involved. Area requirements must, however, be balanced against the *Space Available*.

Then the area allowed for each activity is "hung" on the activity relationship diagram to form a *Space Relationship Diagram*.

The space relationship diagram is essentially a layout. But, in all likelihood, is not an effective layout until it is adjusted and manipulated in Section 4 to accommodate any modifying considerations. *Modifications* may typically be made for such basic considerations as the handling method, operating practices, storage, scheduling, and the like. As each potentially good idea is proposed, it must face the challenge of practical *Limitations* such as cost, safety, and employee preference.

As the integrating and adjusting of the various modifying considerations and practical limitations are worked out, one idea after another is probed and examined. The ideas that have practical value are retained and those that do not stand the test are discarded. Finally, after abandoning those plans which do not seem worthy, we end up with two, three, four, or five alternative layout proposals. Each of them will work; each has value. The problem lies in deciding which of these plans should be selected. These *Alternative Layouts* may be termed Plan X, Plan Y, and Plan Z.

In Section 5, a cost analysis of some kind should be made for purposes of comparison and justification. In addition, some evaluation of intangible factors should also be made. This is called an evaluation of alternative layouts or an *Evaluation* of Costs and Intangibles. As a result, one of the alternatives is chosen – although frequently a modification or combination of two or more layouts may actually result from the evaluation process itself.

After *Approval*, the alternative that is chosen becomes the *Layout Plan*. With the selection of the general overall layout, Phase II is completed. (In Phase III, basically the same pattern holds, once for each area blocked out in the overall layout, but we shall discuss that later.)

Tie-in of P, Q, R, S and T

We have seen how the pattern of Systematic Layout Planning is constructed. Now let us relate it to the basic input data, P, Q, R, S, and T.

P, Q, R, S, and T underlie most of the calculations needed for layout planning. The preparation of the data for the various boxes in the SLP pattern starts with these five base elements. The product designs and sales forecasts must be woven together and integrated with a P-Q analysis – sometimes called volume-variety analysis or study of product mix. The logical splits and combines of various products or product groups or layout groupings are derived from the P-Q analysis. Specifically, this analysis of product mix, along with analyses of Routing (R), Services (S), and Times (T), leads us to an identification or delineation of the individual activities (areas, machine groups, work places) involved, and thus often to the actual type of layout. We will discuss this more-fully in Chapter 3.

In Section 2, P, Q, and R are then woven together to develop the flow of materials. Then P, Q, and S are analyzed to identify service activities and relationships other-than-flow. From the flow of materials or the activity relationship chart, or a combination of the two, the layout relationships are then diagramed.

It is Routing (R), together with Time (T), which essentially determines the machinery and equipment required. Similarly, the services (S) called for are translated into the various service facilities required. The process machinery and equipment and the service facilities are then translated into space requirements. These space requirements are then worked into Section 3 of the SLP pattern as described above.

Tie-in of Phase III – Detailed Layout Plans

The general overall layout is developed in Phase II. The next phase, III, involves making detailed layout plans of each piece of machinery and equipment, aisle, and storage area, for each of the activities, departments, or areas which have been roughed out in the general overall layout.

By reference to Figures 1-4 and 2-2, we see that Phase II overlaps Phase III. This means that before actually finalizing the general overall layout, certain details will have had to be considered. For example, the orientation of a conveyor system may have to be analyzed in detail in order to arrive at a satisfactory solution to the general overall layout. This kind of overlapping investigation takes the layout planning engineer into detailed Phase III work in certain areas before Phase II is selected. Such overlapping was noted earlier, but it should not be lost sight of merely because we have discussed here the general overall layout, Phase II, as a distinct pattern, separate from Phase III, detailed layout planning.

Note also that a detailed layout plan must be made for *each* of the departmental areas involved. This means not only that adjustments are made within these detailed areas, but that some readjustment of the general overall layout selected

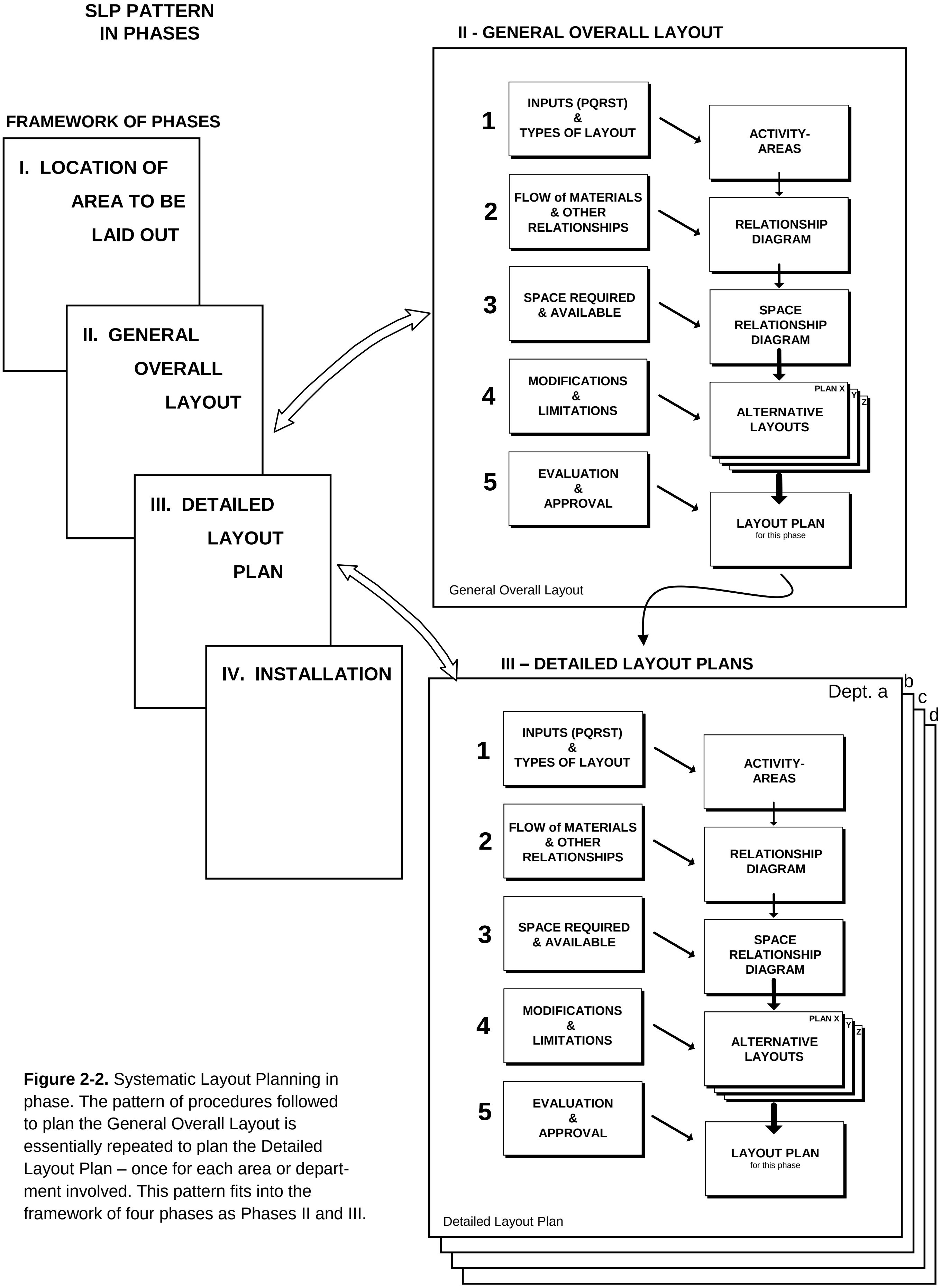


Figure 2-2. Systematic Layout Planning in phase. The pattern of procedures followed to plan the General Overall Layout is essentially repeated to plan the Detailed Layout Plan – once for each area or department involved. This pattern fits into the framework of four phases as Phases II and III.

may also be called for. That is, even though a basic general overall layout has been agreed to, it can be adjusted and changed within limits, as the details are worked out.

In planning detailed layouts, the same pattern used in Phase II is repeated. However, now the flow of materials becomes the movement of materials within the department in question; the activity relations, those of the activities within the department in question. Similarly, the space requirements now become the space required for each specific piece of machinery and equipment; and the space relationship diagram, a rough arrangement of templates or other replicas of machinery and equipment, men, and materials or products.

Again the planner ends up with several alternatives, and must evaluate the alternative plans (for each department) to select the one most satisfactory.

This same pattern is repeated for each departmental area which is to be laid out in detail. And, as shown in Figure 2-2, these patterns fit into the logical development of the four phases through which each layout project passes.

SLP – An Example

In order to clarify the concept of SLP, we trace a sample planning case in Figure 2-3.

Phase I involves determining where the area to be laid out will be located. In this case, it could be in the north side of the manufacturing building (X), along the south side of the manufacturing building (Y), or in a new building (Z).

Before deciding on the *location*, the planner should have a fairly reasonable idea of what the layout would look like if placed there. As a result, the planner overlaps the study into Phase II, *general overall layout*.

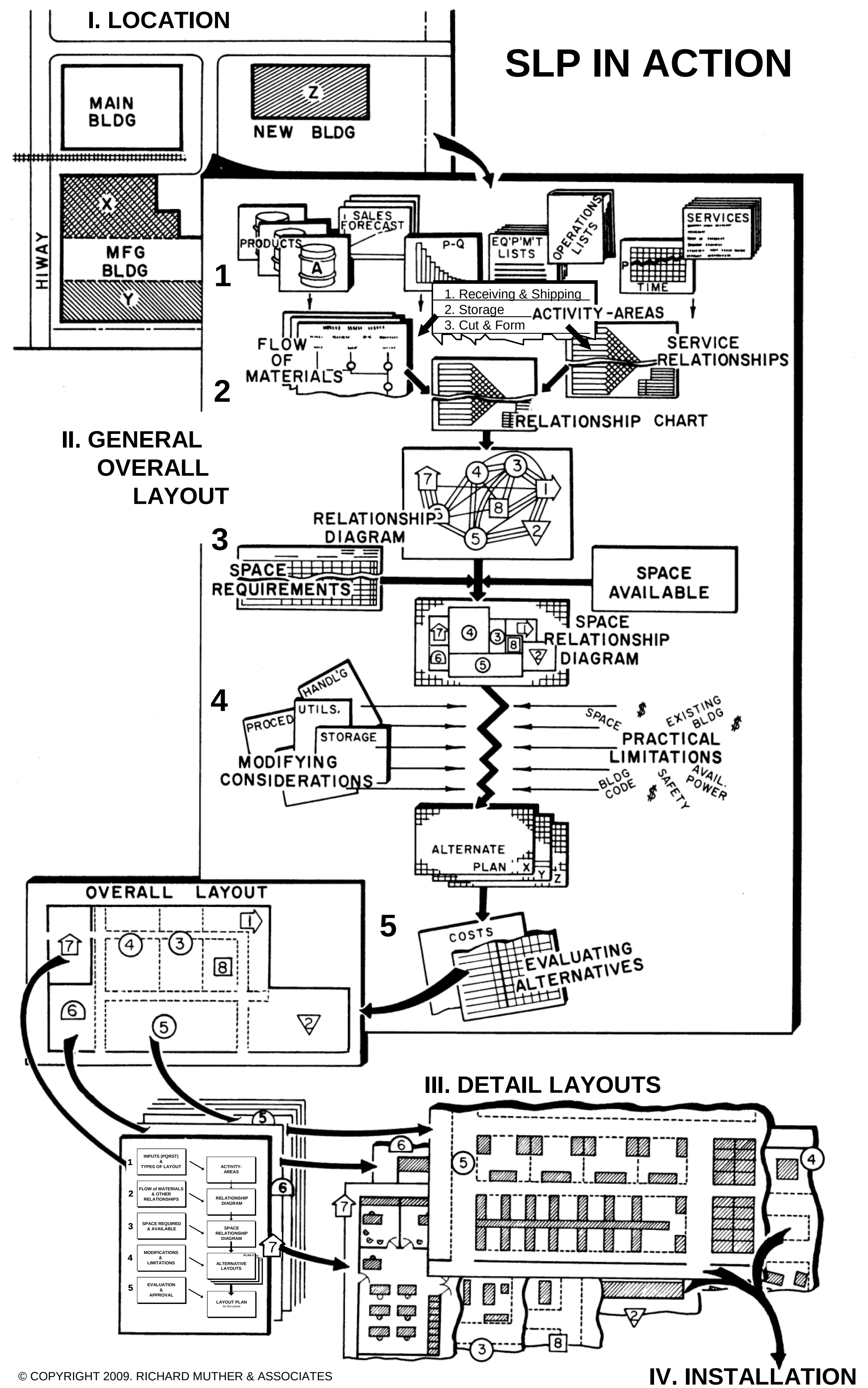
In Phase II, the planner pulls together basic input data; indeed, this has likely been accomplished by collecting the input data for Phase I (though perhaps not in as much detail). Figure 2-3 shows the Phase II inputs as products, sales forecast, product mix analysis, equipment lists, operations lists, projection of product changes against time, and a list of the services required. (The example cannot show all inputs, but it illustrates them.)

The planner then analyzes flow-of-materials, gathers service (or other-than-flow) relationships, and makes a combination of the two in the form of a combined activity relationship chart. Then the planner converts the charted *relationships* into a "picture" by developing an activity relationship diagram.

Next the planner determines space requirements and balances them against the space available. Then *space* data is married to the diagram of relationships in order to derive a space relationship diagram.

Figure 2-3. A condensed pictorial example of S L P.

SLP IN ACTION



The planner then *adjusts* the space relationship diagram under the influence of the modifying considerations (handling methods, storage equipment, utility distribution, and operating procedures) and the practical limitations (cost, safety, building code, existing building, and available power). The adjustments lead to several alternative block layout plans. The planner evaluates the alternatives, in view of costs and intangible factors, to arrive at an overall layout plan.

In arriving at the overall layout, the planner has undoubtedly looked ahead at certain critical features or critical areas of Phase III – *detailed layout plans.* Regardless of the planning schedule, each area blocked out in Phase II is subjected to the same pattern of procedures. By this time, the location will have been selected so that the planner can proceed with detail layouts with full knowledge of building features, column locations, position of main aisles, main utility distribution, and the like.

With detailed layouts for each area approved, the planner then moves the project toward *installation*, Phase IV.

Short-form Procedure

Some layout planning projects are small enough in scope and their open issues so limited that there is no need for four phases and a repeating five-section pattern of planning procedures. For these types of projects, a short-form, six-step procedure called Simplified Systematic Layout Planning can be used. Simplified SLP condenses the phases, levels and tasks of the full methodology into the following steps:

1. Chart the relationships
2. Establish space requirements
3. Diagram activity relationships
4. Draw space relationship layouts
5. Evaluate alternative arrangements
6. Detail the selected layout plan

Appendix XIV explains these steps in more detail and when to use them.

Capsule Summary of SLP

The outside back cover of this book presents a one-page capsule summary of SLP. It consists of the framework of phases; the pattern of procedures in both full, five-section format and six-step short or simplified form, and includes a set of conventions for rating, recording, and visualizing layout plans. The capsule summary is thus a concise one-page guide to layout planning. Electronic copies may be obtained under “Methods” at www.RichardMuther.com.

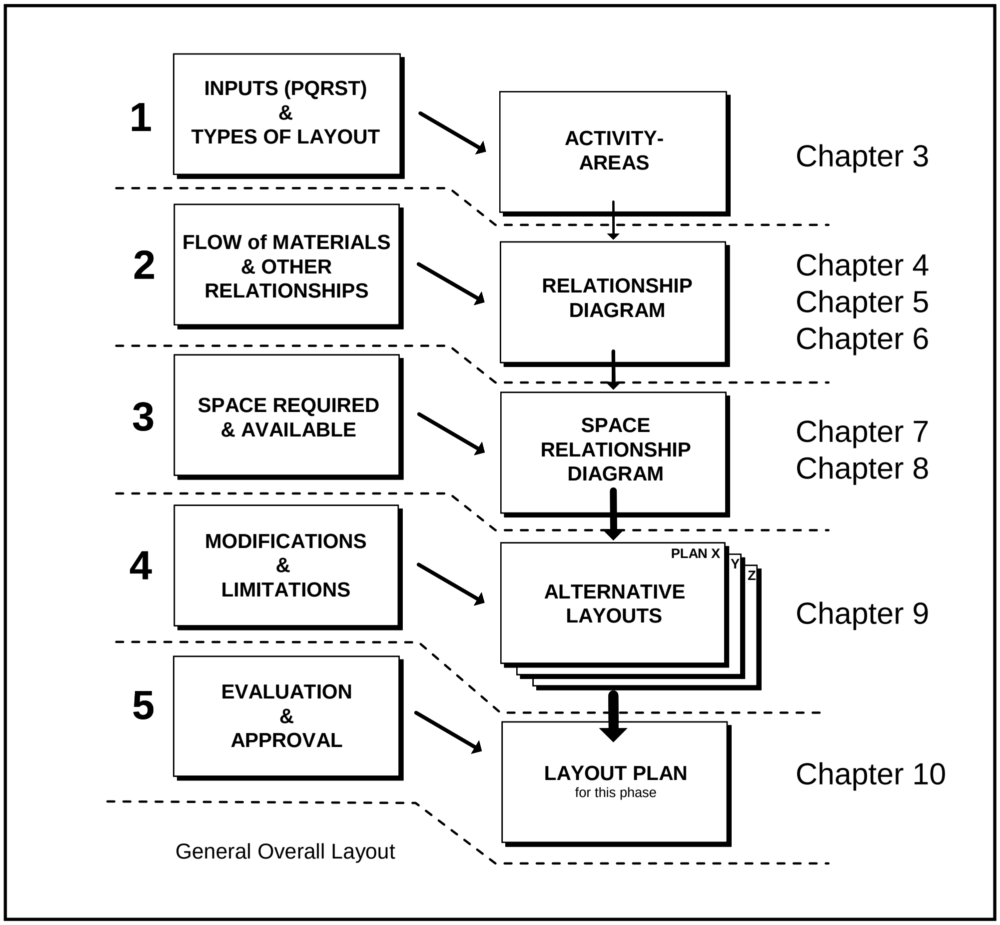
Part Two

Introduction to Part Two

Logically, in this next part of the book, we should discuss Phase I, Location of the Areas to be Laid Out, the first of the phases in the SLP framework, which would in practice be planned before Phases II and III. However, in our effort to concentrate on layout and how to plan it, a discussion of location of the layout will be more helpful after Phases II and III are understood. Therefore, Location – along with Phase IV, Installation – appears in Part Four of this book.

The next eight chapters, which make up Part Two, take us through the SLP pattern. They describe step-by-step the procedure and techniques of analysis to use. Each chapter is devoted to a specific section of the pattern. (See sketch below).

II - GENERAL OVERALL LAYOUT



Note that the chapters in Part Two discuss procedures and applications for Phase II. Procedures and applications for Phase III are somewhat different. (They are discussed in Part Three.) In most layout projects, the big savings in both investment *and operating costs are made in overall planning, Phase II – General Overall Layout, rather than working out the Phase III details. So, logically, we place greater emphasis on Phase II planning.*

This emphasis on Phase II should be recognized by both the novice and the experienced layout planner. Most popular literature on layout planning leads to overemphasis of detailed techniques – not infrequently drawing even the experienced analyst into using templates or three-dimensional models long before developing the reasons for placing them in a meaningful, thought-out way.

Here are the outputs and key documents that you will need to complete your Phase II – General Overall Layout. Each is illustrated and explained in the chapters of Part Two.

Pattern of Procedures Section Number	*Key Document(s); Must do*	*Other potentially useful documents; Do if helpful*	*Form of Output*
1 *Activities*	*P-Q Analysis*	• *P-Q Data Sheet* • *Checklist of splitting or combining factors*	*List of Activity-Areas*
2 *Relationships*	*Relationship Chart*	• *Operation Process Chart* • *Multi-product Process Chart* • *From-To Chart* • *Relationship Survey*	*Activity Relationship or Flow Diagram*
3 *Space*	*Activity Areas and Features Sheet*	• *Survey of current space assigned* • *Machinery & Equipment Area & Features Sheet* • *Office Layout Requirements Data* • *Space Requirements – Converting form*	*Space Relationship Diagram*
4 *Adjustment*	*Block Layout Drawings*	• *Scaled and grid-lined templates of activity-areas*	*Alternative Layouts*
5 *Evaluation*	*Evaluation of Alternatives*	• *Cost estimates and comparisons*	*Selected Overall Layout*

Chapter 3

Input Data, Layout Types and Activity-Areas

Chapter 1 set forth the key input data on which every layout problem rests: P, Q, R, S, and T. In Chapter 2, we addressed the pattern of procedures and phases of SLP. Now, in this chapter 3, we will explain the interrelationship of P and Q, the division of total areas into distinct activities or sub areas, and the projection of input data into the future. These planning activities occur in Section 1 of the SLP Pattern of Procedures.

The first key data involve:

1. Product (or material or service) – what is to be produced
2. Quantity (or volume) – how much of each item is to be produced

Figure 1-3 showed a Product-Quantity Data Sheet – one simple way to gather facts about Product and Quantity. This is a beginning point, but veteran layout analysts know they must dig far deeper.

Volume-Variety Analysis

In almost all aspects of industry, there is a disproportionate balance between P and Q. In a typical situation, 20% of a company's customers account for 80% of the net sales, or 30% of the output is spread over 70% of the products.

This disproportion is well known by economists, statisticians, and market-research analysts. For example, in a mill producing mixed feeds for animals, 10% of the formulae (mixes) account for 65% of the tonnage produced; 20% of the formulae account for 82%; and the last 1 % of the tonnage is made up of 31 % of the formulae.

In terms of production planning, this relative proportion is the basis of product-mix problems and the so-called ABC concept of inventory control (control according to value). Others term investigation of these relationships "volume-variety analysis." Relatively, the same proportions usually prevail – depending in part on how the items, groups, or lines of product are divided.

For the facilities planner or layout analyst, this volume-variety balance has a significant meaning, because it is the basis for deciding which fundamental type of layout arrangement to use – line production, job-shop, a combination, or a split of two or more basic arrangements.

The P-Q Chart

Generally, Product-Quantity analysis takes the form of (1) Some division or grouping of the various products, materials, or items involved; and (2) A tally or count of the quantity of each division or grouping, or of each product, item, or variety within each division or grouping.

For ease in visualizing the findings, the count is arranged in sequence and the results plotted on a graph. The result is the P-Q chart, so called for the terms Product and Quantity. (See Figure 3-1.) Note that the curve is plotted in the order of decreasing quantities, items having the largest quantities placed first, and that individual quantities (rather than cumulative figures) are used. The typical P-Q chart approximates a hyperbola – generally being asymptotic to both axes.

In identifying P and in counting Q for any product, item, variety, or product group, the actual count is ordinarily used rather than percentage conversion of the count. The highest-quantity item is placed first, then the next highest, and so on. The count is generally best given in number of pieces, weight, or cubic volume, rather than in dollars. Note that Q is implicitly a rate of demand or usage, i.e. units per hour, day, month or year. The actual unit of measure depends on the nature of the product or items involved and on the unit used in company records available or in forecast projections. Often two or three measures for Q are plotted, including number of orders or jobs. The letter Q also refers to inventory quantities on hand when planning storage area layouts.

What the P-Q Chart Tells Us About Type of Layout

The P-Q chart has a fundamental relationship to the layout being planned. At one end of the curve are large quantities of relatively few products or varieties: essentially mass production conditions. Such products tend to favor mass production methods, especially production lines or layouts by product.

At the other end of the curve are a great many different products, each with but small quantities: job-order or job-shop methods – typically favoring layout by process for forming, and treating and layout by fixed position (fixed location) for assembly. (See Figure 3-2 for descriptions of the basic types of layout plans.)

The curve demonstrates, then, that some products lend themselves to a conveyorized, automatic type of layout while others require highly flexible handling methods and standardized equipment, arranged for universal operations.

As a result, by dividing the products and producing them in two different types of layouts, efficiency may be obtained for both, whereas to make one layout plan for all products may be a less effective compromise.

A "shallow" P-Q curve indicates, on the other hand, one general layout for all the items with universal handling methods. (See Figure 3-3.) Because most of the production is in the center area of the curve, we plan for efficiency on those quantities, even though items at both ends of the curve may not be produced with complete effectiveness.

Whereas a "deep" curve suggests dividing products and their production areas into two different layouts and handling systems, and a shallow curve into one general layout,

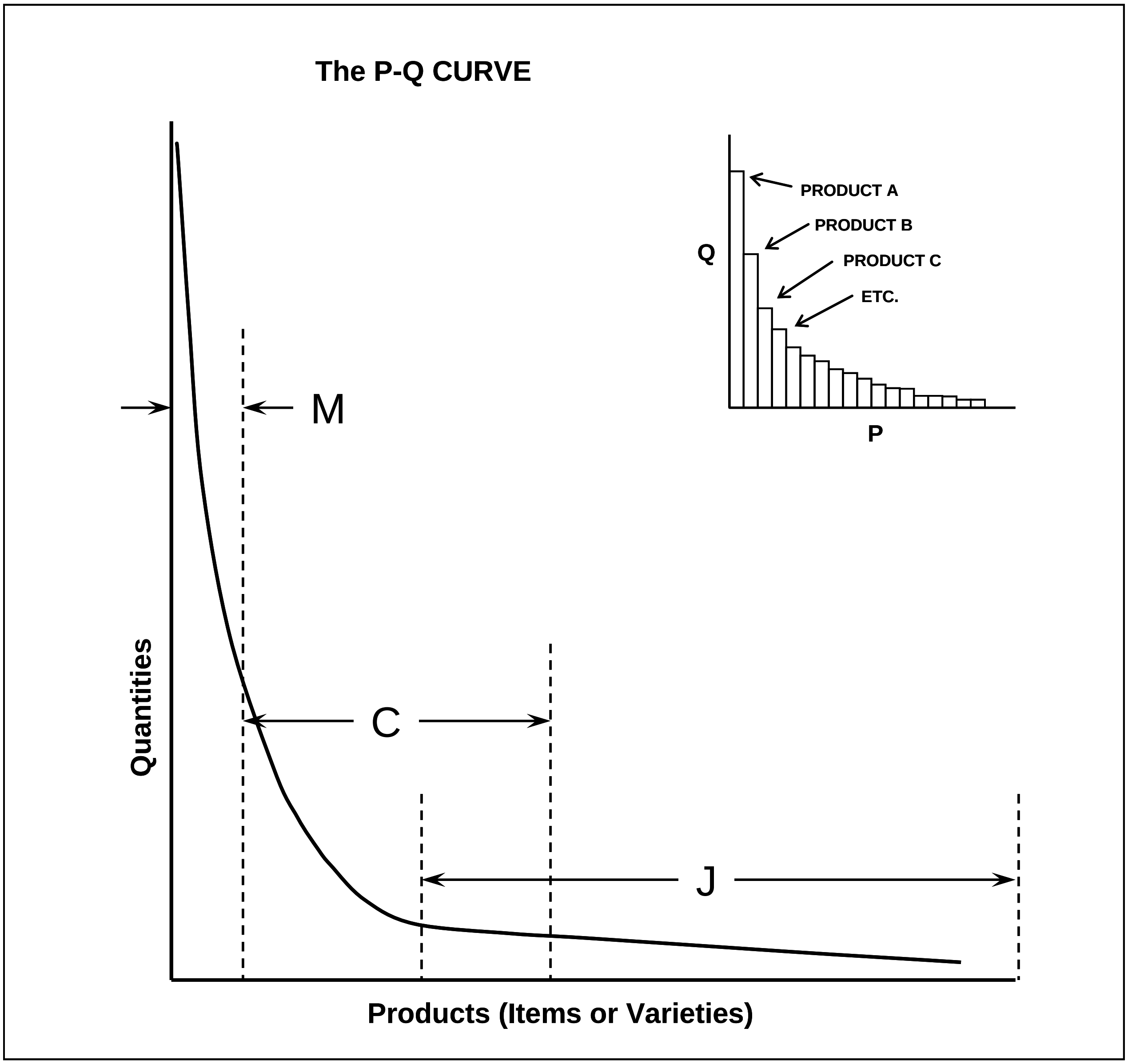
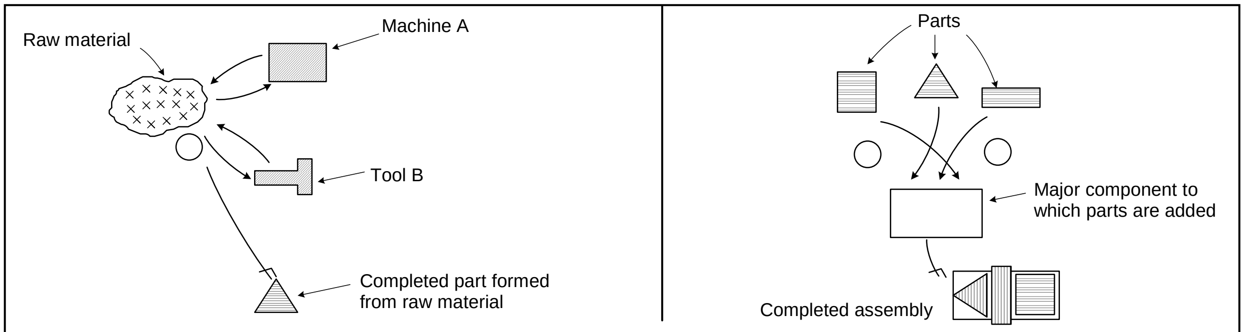


Figure 3-1. The Product-Quantity Curve (P-Q Chart) drawn on a non-cumulative basis. Typically, this curve reveals the product varieties that are "fast-movers" and those that are "slow-movers".

The items in area M frequently lend themselves to Mass Production techniques while those in area J must consistently be produced in a Jobbing or job-lot type of layout.

Items falling in area C – between and overlapping M and J – will generally lead to a combination or in-between type of layout such as a modified production line, lined-up process departments, group or work-cell production.

The insert at top shows the usual method of construction of the curve, with each individual item or variety arrayed in order of decreasing quantity.

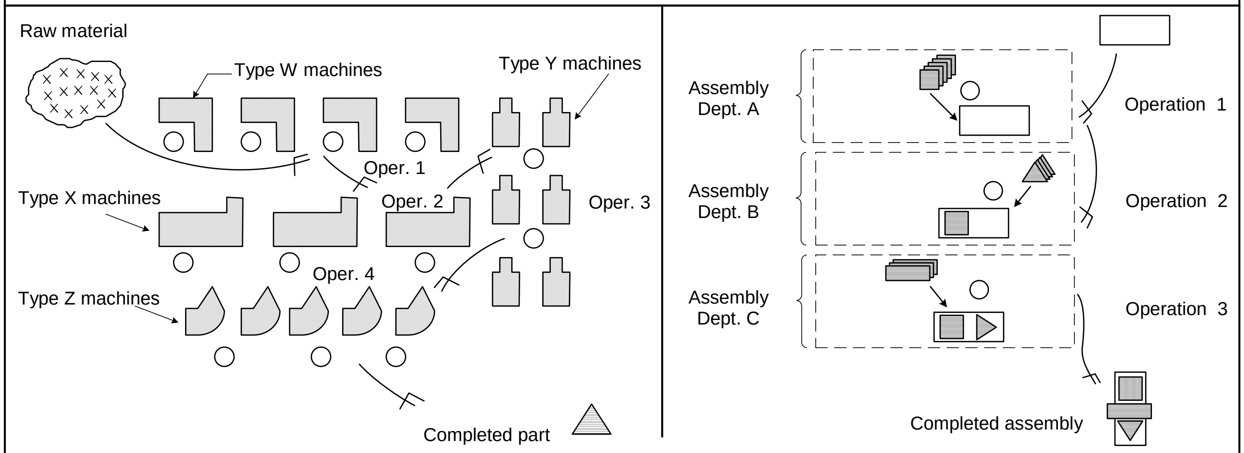


Layout by fixed position. All operations are performed with the material (in the case of forming or treating) or major component (in the case of assembly) remaining in one fixed location. That is, hold the material at a fixed position.

– Examples –

Forming and treating – specialty shoe-making; tool-making; any artisan making a complete unit.

Assembling – hand embroidery work; building a battleship or constructing a special machine.

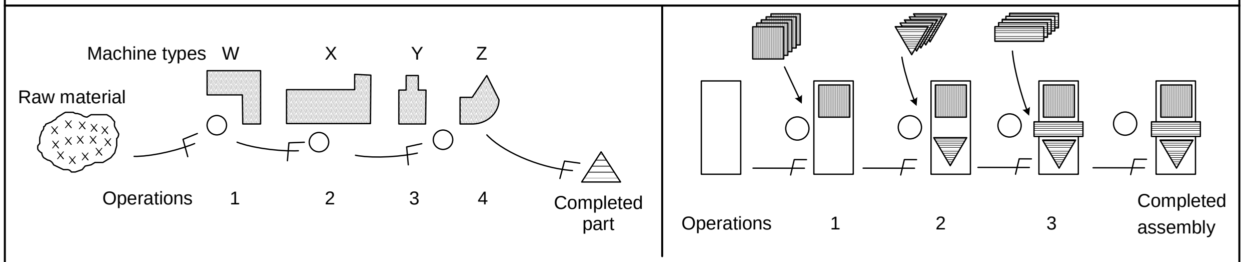


Layout by process (function). All operations (processes) of the same type are performed in the same area; like machines or similar assembly operations are grouped together. That is, move the material through process dept's. or areas.

– Examples –

Forming and treating – normal machine-shop work; most textile and cloth-making; job printing.

Assembling – sheet-metal assembly by spot welding, riveting, stapling. soldering.



Layout by product (line production). Machines or assembly work stations arranged in the sequence of operation, successive operations being performed immediately adjacent to each other. That is, move the material from one operation directly to the next.

– Examples –

Forming and treating – machining a motor block; quick car-washing line.

Assembling – automobile assembly line; assembling a tray of food in a cafeteria.

The left-hand sketches show the four forming or treating operations necessary to make a part △

The right-hand sketches show the three assembly operations necessary to assemble parts △, ▥, and ▭

to major component ▭

= Raw material ○ = Worker ▨ = Machinery —⺊ = Movement of material

Figure 3-2. The classical types of plant layouts. From R. Muther, *Practical Plant Layout* (New York: McGraw-Hill Company, 1955).

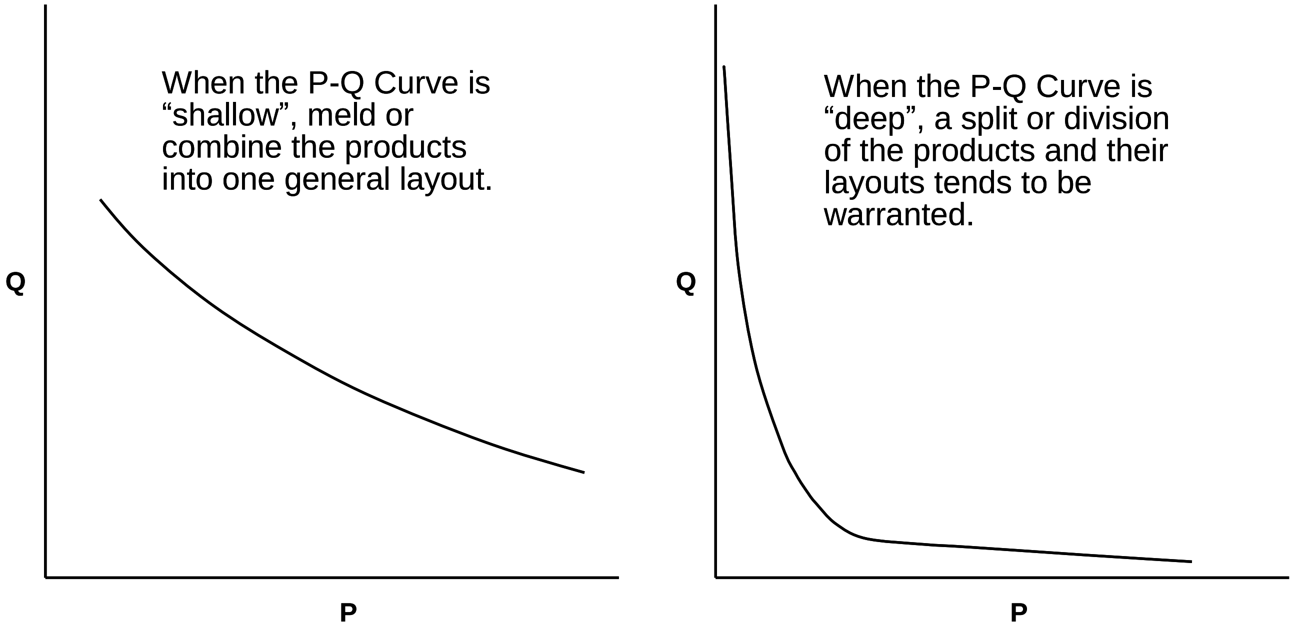


Figure 3-3. Significance of the P-Q Chart in layout planning is indicated here.

it is sometimes practical to make a three-division split of the items involved, as in the following example.

Examples of P-Q Application

One firm making lighting fixtures found its P-Q curve led to considerable change in layout. The plant originally was planned with one assembly department consisting of individual workplaces, that is, a series of fixed-position assembly workplaces with each person assembling the entire fixture.

On analysis, the plant manager found a typical P-Q curve. This encouraged him to rearrange his assembly department accordingly. In one area he set up assembly lines; in another, teams of two to four workers each; in a third area, individual assembly benches as before.

The division of the assembly area was approximately as follows:

1.	Production line	19 items	63% of volume
2.	Team assembly	35 items	28% of volume
3.	Individual bench	100 items	9% of volume

The result of this rearrangement alone led to an increase in output of 17 percent, for no other changes were involved.

Still another example of improved layout based on P-Q analysis is shown in

Figure 3-4. Here is a case where the layout was divided into fast and slow-moving items. This layout allowed efficiency at both ends of the P-Q curve. And, as might be supposed, there were other savings in delivery service and inventory-carrying charges.

Splits and Combines of Activities

Simply stated, an analysis of product and quantity frequently leads to splitting plant areas or departments into at least two logical areas:

(1) high-volume, low-variety "fast movers," and
(2) low-volume, high-variety "slow movers."

For the first, a high degree of mechanization, special-purpose equipment, and heavy investment in handling equipment are justified. Savings potential is greatest here. On the other hand, for the slow movers, changeovers are frequent, and savings on each piece do not accumulate too much. This condition calls for a high degree of hand work, general-purpose machinery, and low investment in handling equipment. Pricing potential is greatest here.

Within a grouping of more or less *similar* products, splits based on quantity are practical. In such cases, the planner is frequently better off to remove completely the jobbing work from the mass production areas. Besides differences in arrangement, these different types of layouts call for differences in equipment, in production control system, in skill of workers, in pre-production engineering, in supervisory outlook, and in many other factors.

We have emphasized P-Q analysis as a basis of dividing areas because it is so often overlooked. But the products involved in one layout project may be quite dissimilar. In such cases, there are other, more important, reasons for splitting or combining areas. We implied this when we said to divide or group products or items before making the P-Q analysis. Actually, the planner should not attempt to apply the P-Q chart when the products or processes are entirely different. If you must plan for the production of such diverse items as wooden sailboats and electronic components, you already know you would plan for separate plants because of the nature of the products themselves.

Actually, the decision to split or combine plant facilities can be based on one or a combination of several factors:

1. Size, weight, shape, or physical characteristics of the items
2. Basic material of the items
3. Processes, routing, or sequence of operations
4. Cycle or Takt times, if not already reflected in fast/slow mover split
5. Equipment involved or the type of building structure to house the equipment
6. Quality or workmanship required
7. Value or risk-of-loss of the item
8. Hazard or danger to personnel or property
9. Type of power, utilities, or auxiliary services

.

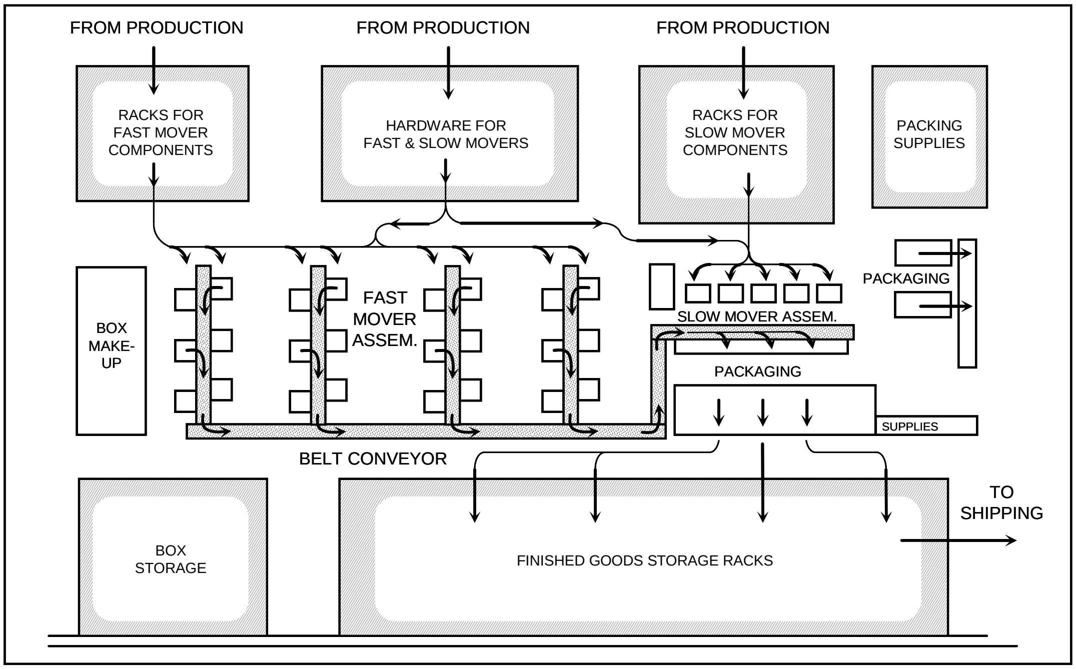


Figure 3-4. How P-Q analysis leads to layout effectiveness. The company involved here produces electrical connectors, primarily for the power utilities. Fabricating involves presses, screw machines, milling machines, threaders and tappers, and the like. Subsequently, all items move to storage before assembly. From here they are drawn out in generally the right proportions to make an assembly batch.

Before analysis, the pieces were assembled by workers at individual benches, packaged and/or master packed, stored as finished goods, order filled, and shipped. A P-Q analysis showed that 13% of the total catalog items accounted for 88% of the volume in finished pieces (80% of the sales dollars).

The assembly time is relatively small for all items, so any customer's order can usually be assembled and shipped within one day's time, if the order is not too large and if the parts are ready. However, many parts are used in several different end-products.

Based on these facts, the assembly and finished goods storage was laid out accordingly. The "fast-movers" were to be handled on one basis and the "slow-movers" split off and handled on a different basis. This was done as follows:

> *Fast-movers* – made to schedule by workers on incentive; taken away by conveyorized methods to packaging; stored in finished-goods inventory on pallet racks waiting for order filling.
>
> *Slow-movers* – made to order by workers with more diverse skill and knowledge not working on incentive; delivered to its own packaging area by hand or push cart; placed on shelves by customer order for immediate order filling.

10. Organizational structure of the company
11. External considerations (property resale, appearance, taxes, and the like)

Dissimilarities in these factors – especially dissimilarities in P, Q, R, S, and T – are commonly used throughout commerce and industry as a basis for splitting or dividing areas or facilities. The problem for the layout planner is to determine which factor(s) is dominant in the particular project. In part, one can do this by plotting a factor such as "product size" against P and noting the deepness of the resulting curve. If other factors are equal or unimportant – which they seldom are – the relative depth of the curve would indicate the degree of split.

The so-called classical splits in layout most often rely on the dominance of P, Q, or R.

> *Layout by fixed position*, as described in Figure 3-2 is generally adopted when the product is physically large; the quantity, very small; and when the process involves only hand tools.
>
> *Layout by process (function)* is adopted when the product is physically smaller though of several varieties; the quantity, large; and when the process or its equipment is large, costly, demanding special utilities or building.
>
> *Layout by product (line production)* is adopted when the product is special in some way; the quantity, very high; and the process, relatively simple.

Splits determined by several factors in the same project are common. For example, a pharmaceutical plant may divide its production packaging from its sample packaging because of the difference in end product (package) and shipping sequence. The same company may divide its sample packing from its packing of salespeople's samples or specially ordered samples because of difference in quantity. Typically, therefore, the most effective analysis lies in dividing areas by dominant factors and then applying the P-Q curve. Secondary factors may be similarly identified to reinforce or serve as a further basis for segregation or for subsequent split into sub-areas.

The influence of the product characteristics on layout reemphasizes the back-pressure which layout can put on product design. It is well known that the effectiveness with which diverse products can be designed to be produced with the same materials, equipment, operation sequence, and the like will in large measure control the degree to which line production and automation can be adopted.

When the best way to divide a total area or space for layout purposes is not obvious, or when there are significantly different ways to divide into activity-areas, the checklist in Figure 3-5 will be helpful. It presents the factors most commonly used to split or combine products, operations, equipment, areas and activities into the specific activity-areas that will appear in the layout. The factors listed apply to manufacturing, distribution and service facilities of all kinds. Some apply also to offices and institutional space. The two columns on the right-hand side of the checklist can be used to rate the relevance, significance, dominance and/or importance of factors to a specific decision of splitting or combining.

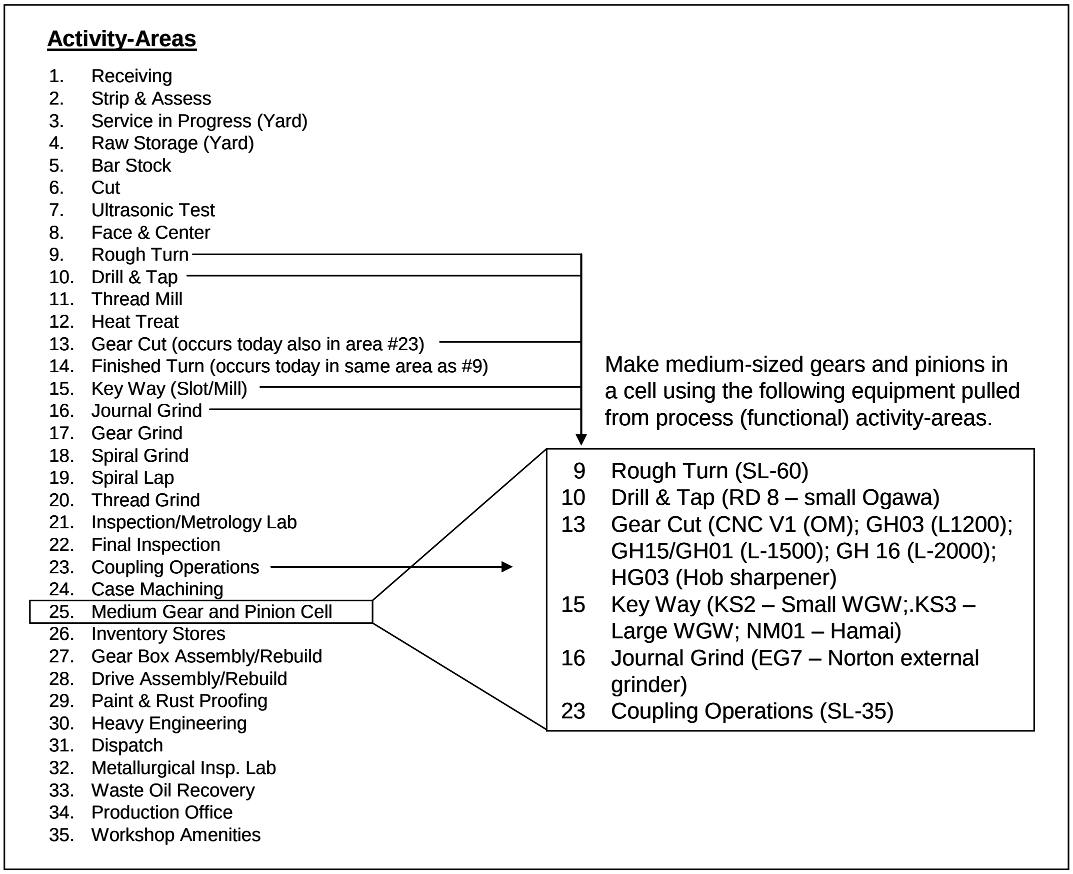
Basic Element	Factors: Split or Combine by	General Examples		
P - Products or Materials	Material type	Solid, liquid, gas; ferrous vs. non-ferrous; plastic, glass		
	Size	Large vs.small		
	Weight	Heavy vs. light; dense vs. soft or bulky		
	Shape	Conveyable vs. not conveyable; compact vs. irregular		
	Risk	Sturdy vs. fragile; safe, ordinary vs. hazardous, toxic		
	Condition	Clean vs. dirty; hot vs. cold, normal; stable vs. unstable		
	Value	High vs. low		
	Quality/tolerance	High vs. low; inspection required; specifications; workmanship		
	Product design	Type; standard vs. special or custom; family A vs. B; model A vs. B		
	Stage of life cycle	New vs. existing or mature; stable vs. phasing out		
	Pack or container	Bulk vs. contained; pallet vs. case; box, drum, bag, special		
Q - Quantities	Popularity	Hgh vs. low volume		
	Lot size	Large vs.small; long runs, tough changeover vs. short, easy		
	Order quantity	Large vs. small		
R - Routing or Process	Nature of process	Hot vs. cold; wet vs. dry; dirty vs. clean; high labor vs. high capital		
	Type of operation	Cut, form, treat, assemble, store, staging, receive, repair, support, office…		
	Sequence	Common sequence vs. different; common first, last or key operations		
	Equipment used	Automatic, high-tech vs. manual, low tech; special vs. general purpose; same vs. different		
	Operator type or skill	Normal vs. special; learning curve; level of supervision; contract or temp. vs. payroll		
S - Supporting Services	Scheduling	Make to stock vs. to order; pulled vs. pushed; run regularly vs. randomly, infrequently		
	Security	High security vs. normal security; restricted access		
	Support services	Needing central services vs. containing their own; maintenance, tooling, fixtures, testing		
	Personnel services	Level of personnel comfort, conveniences and amenities		
	Utility requirements	High-cost, special vs. conventional utilities and auxiliaries		
	Building requirements	High vs. low bay; floor strength, dust, temperature or humidity control; containment		
T Time-related	Takt or cycle time	Short cycle work vs. long cycle		
	Urgency	Immediate rush service vs. normal; emergency vs. routine		
	Seasonality	Level throughout the year vs. peak for summer, Christmas, harvest time…		
Other	Market and customer	Domestic vs. export; civilian vs. military; single vs. several or many; service level offered		
	Order go-togethers	Frequently ordered together; belong to or form a kit		
	Inventory	Owned vs. consigned or contract; customer-specific, active vs. service, pick vs. reserve		
	Regulation	Segregation required; special handling or controls; bonded		
	Organization	Report to same manager		

Figure 3-5. Checklist for splits-and-combines analysis. Consider these basic elements and factors when dividing a total space, area or facility into activity-areas for layout planning. Use the two blank columns on the right to identify which factors apply to a particular decision and to rate their relative importance or dominance. As a rule: Keep similar together; place dissimilar apart or in separate activity-areas.

Value Streams, Cells and Mixed-Model Production

The term “value stream” is sometimes used to describe a series of sequential operations (or processes) for a product or common to a product family. Value streams are typically identified using a combination of P-Q analysis and process flow or routing analysis. This latter technique is discussed in the next Chapter on Flow of Materials. “Layout by value stream” is a combination or hybrid of classical “layout by product” and “layout by process.”

Manufacturing cells devoted to one part or product are a special case of layout by product or line production. Most cells make a family of parts or products or a number of similar items that largely share a common sequence of operations and production equipment. [1] Such cells lead to group-production layouts – a combination of layout by product and by process. See Figure 3-6.



Activity-Areas

1. Receiving
2. Strip & Assess
3. Service in Progress (Yard)
4. Raw Storage (Yard)
5. Bar Stock
6. Cut
7. Ultrasonic Test
8. Face & Center
9. Rough Turn
10. Drill & Tap
11. Thread Mill
12. Heat Treat
13. Gear Cut (occurs today also in area #23)
14. Finished Turn (occurs today in same area as #9)
15. Key Way (Slot/Mill)
16. Journal Grind
17. Gear Grind
18. Spiral Grind
19. Spiral Lap
20. Thread Grind
21. Inspection/Metrology Lab
22. Final Inspection
23. Coupling Operations
24. Case Machining
25. Medium Gear and Pinion Cell
26. Inventory Stores
27. Gear Box Assembly/Rebuild
28. Drive Assembly/Rebuild
29. Paint & Rust Proofing
30. Heavy Engineering
31. Dispatch
32. Metallurgical Insp. Lab
33. Waste Oil Recovery
34. Production Office
35. Workshop Amenities

Make medium-sized gears and pinions in a cell using the following equipment pulled from process (functional) activity-areas.

9	Rough Turn (SL-60)
10	Drill & Tap (RD 8 – small Ogawa)
13	Gear Cut (CNC V1 (OM); GH03 (L1200); GH15/GH01 (L-1500); GH 16 (L-2000); HG03 (Hob sharpener)
15	Key Way (KS2 – Small WGW;.KS3 – Large WGW; NM01 – Hamai)
16	Journal Grind (EG7 – Norton external grinder)
23	Coupling Operations (SL-35)

Figure 3-6. List of activity-areas for a job-shop making gears. Note the manufacturing cell (Area 25) for a family of medium-sized gears and pinions. It will be formed by relocating equipment from 6 other areas. This list represents a hybrid layout – generally *by process* in areas 1 - 20, but also *by product* in Areas 24, 25, 27 and 28.

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[1] For a full discussion of cells and how to plan their operation, see the companion to this book: *Planning Manufacturing Cells*, by H. Lee Hales and Bruce Andersen, Society of Manufacturing Engineers, 2002.

The term “mixed-model production” describes a value stream, assembly or production line, or a manufacturing cell making two or more items in any quantity or sequence with minimal or no batching or physical reconfiguration. This is not quite the same meaning as making every product every day (EPED). EPED is a related scheduling practice – one that is enabled by effective and flexible organization of capacity and space.

Establishing mixed-model production requires the analysis of similarities and differences in P, Q, R, S and T described above. Most important are similarities in size, weight, tolerances and finish, processing times (to maintain line balance), tools and fixtures, handling equipment, complexity and operator skills…

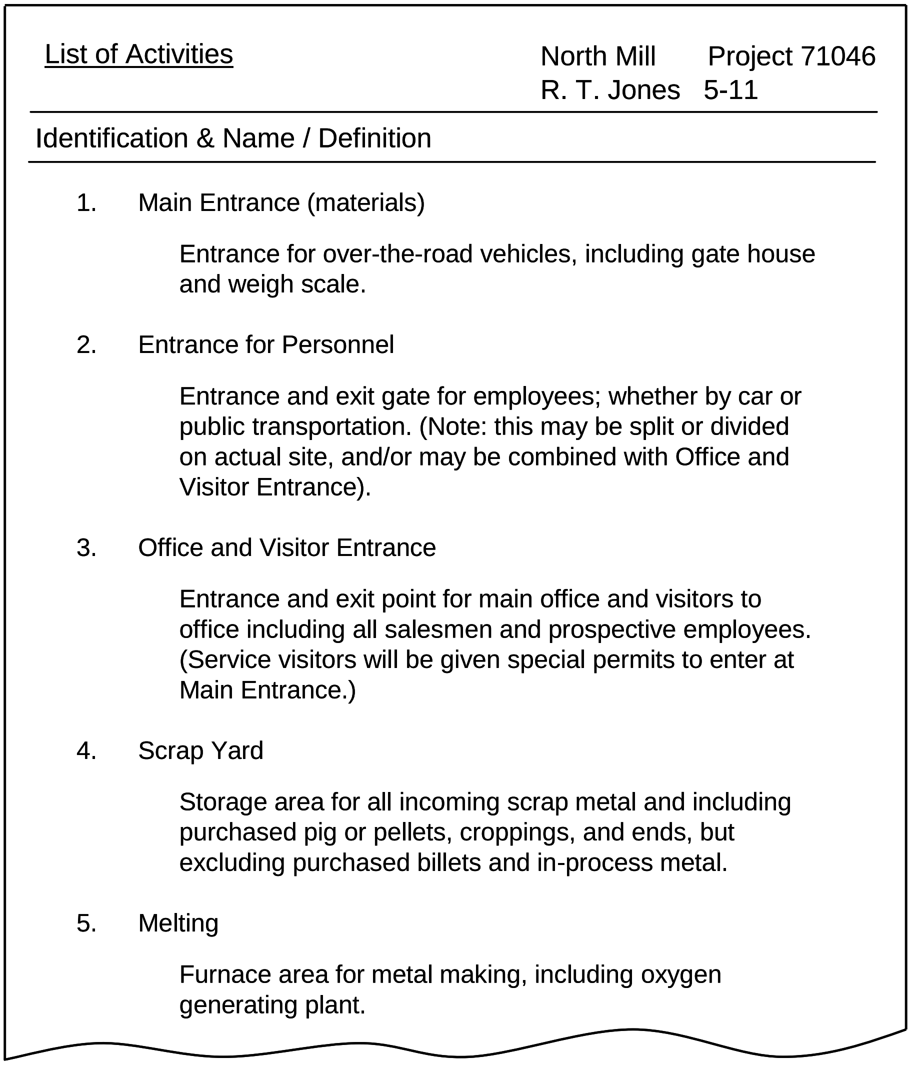
Identification of Activity-Areas

By the term *activity,* or *activity-area,* we mean the various areas or “things” to be included in the layout. An activity may be a building or the main site entrance; it may be a department within general offices; it may be a specific testing machine within a small laboratory layout – all depending on the phase or level of planning of the particular project. “Activity” is thus a generally usable term in any layout planning project.

Many layout planners take for granted the division of space into activity-areas. It is convenient to plan a new layout using current department names. But big improvements may be overlooked if the planner fails to challenge existing area identifications. Indeed, the possibility of a major cost breakthrough may be lost if new splits or combines of activity-areas are not considered. Good examples: The use of mixed-model assembly to combine historically separate lines. Or, introducing product-focused cells where job-shop layout by process has prevailed. Or, decentralizing batch processes for treating, cleaning, painting… and placing them in-line. Or, combining and eliminating separate machining areas with the use of an integrated, multi-function machining center.

Regardless of the depth and extent of activity-area division, or whether the project is for new, renovated, or existing space, the layout planner must specifically identify the activity-areas of the project. They not only define the scope of the total area, which is needed in Phase I, but from this point through all of the SLP pattern of procedures, all calculations and planning are done for the specific activities. For example, to consider Sales Office, when planning the relationships, as including the material-purchase requisitioning function, but to consider that function in Production Planning, when determining space requirements, can only lead to errors in the layout (or their costly correction during its adjustment into alternative plans). Similarly, to consider Receiving and Shipping as one combined activity automatically builds into the layout a U-shaped flow of materials, which may not be intended or at all desirable.

Therefore, clearly and consistently identifying all activities early in the project saves time later on in the planning. Preparing the list of activities is not complex in itself, but it is important, for it represents the result and culmination of the planner's analysis of input data.



List of Activities

North Mill Project 71046
R. T. Jones 5-11

Identification & Name / Definition

1. Main Entrance (materials)

   Entrance for over-the-road vehicles, including gate house and weigh scale.

2. Entrance for Personnel

   Entrance and exit gate for employees; whether by car or public transportation. (Note: this may be split or divided on actual site, and/or may be combined with Office and Visitor Entrance).

3. Office and Visitor Entrance

   Entrance and exit point for main office and visitors to office including all salesmen and prospective employees. (Service visitors will be given special permits to enter at Main Entrance.)

4. Scrap Yard

   Storage area for all incoming scrap metal and including purchased pig or pellets, croppings, and ends, but excluding purchased billets and in-process metal.

5. Melting

   Furnace area for metal making, including oxygen generating plant.

Figure 3-7. Partial listing of activities for a new steel mill.

Figure 3-7 shows part of a listing for the layout of a new steel mill. Note that it begins with various entrances to the process and the office and then follows the processing of materials. Support areas are not shown in this Figure but would appear at the bottom of the list. The general rule is to order and number your activity-areas in a natural and meaningful way. Often this will be achieved by grouping or clustering the areas by organization, or by type of activity, or by type of space. It is usually helpful to list production areas “in order of appearance” as the manufacturing process is described, adding service and support areas once all processing areas have been defined. (See also the example in Figure 3-6).

Most plants and industrial sites can be planned effectively with a list of 20 to 40 activity-areas. If you feel that more are needed, you are likely tackling too much detail in one pass and will find it much easier to aggregate areas and then break them out later in Phase III Detail Layout. Or, leave out some areas that are fixed and will not change in your project. Or, combine activities that will always stay adjacent.

Projections into Future

Obviously, in planning a layout for the future, the planner must base the work on projected input figures. This means that input data, to which the layout will be designed, must be projected for conditions which will exist beyond – or at least at the time – the layout is installed as suggested in Figure 3-8 below.

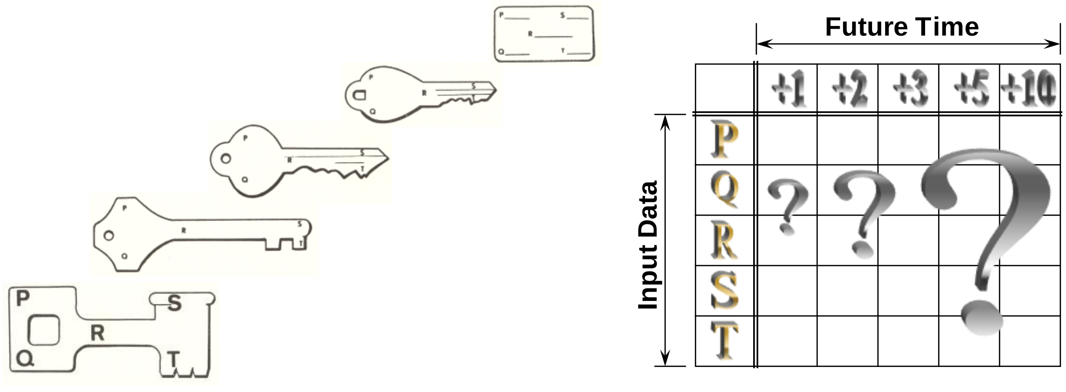


Figure 3-8. Projecting key inputs. The longer the horizon the more uncertain the projections.

The extent of the projections varies with the nature of the project. On a total, new facility involving several buildings, it is entirely practical to attempt projections extending over 25 or even 50 years, although precise forecasts can seldom be made so far into the future. When projecting many years ahead, the planner usually can use only policy statements regarding the company's basic direction. That is, you may have to substitute for specific figures an assumption such as:

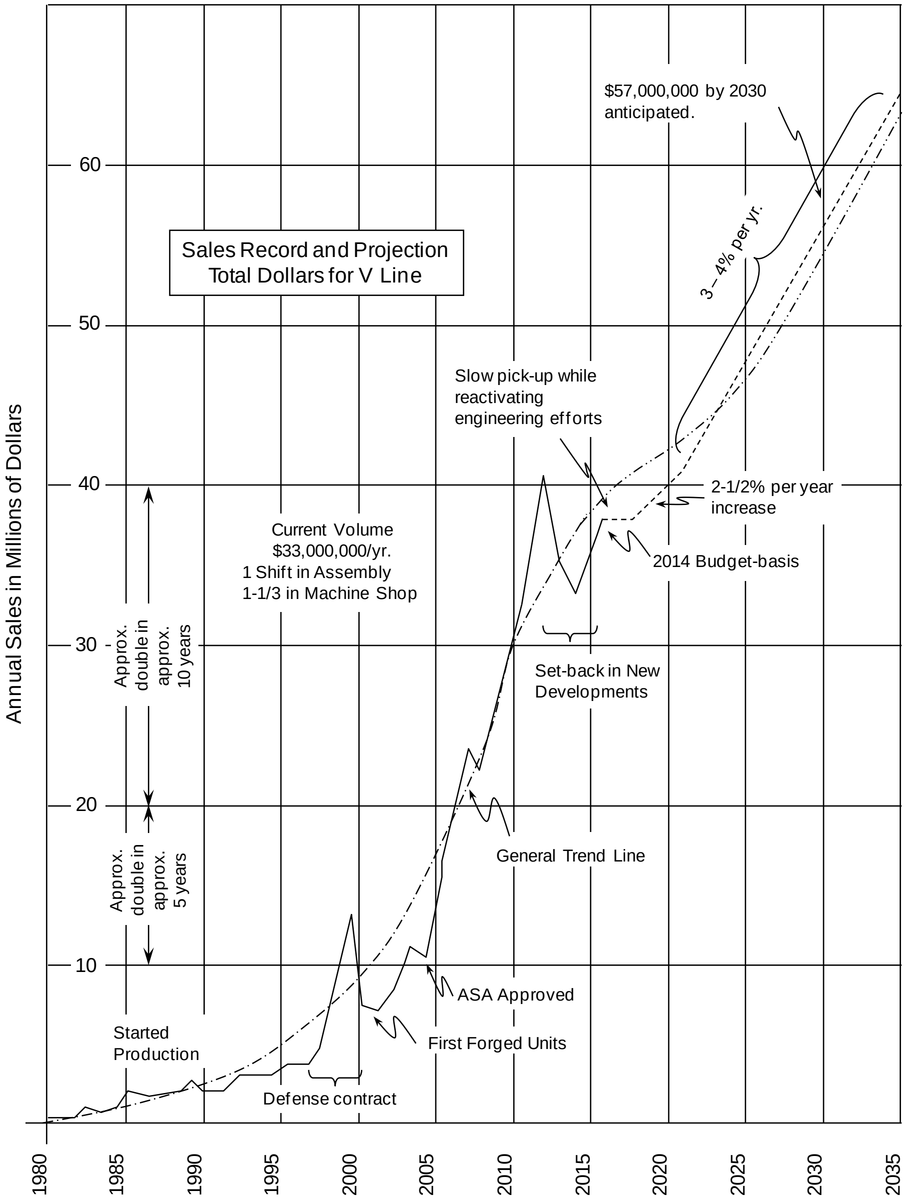
> "The company is dedicated to a steady growth – in the neighborhood of 15 percent per year in dollar sales. Its products will be general industrial chemicals produced through process equipment involving mixing, blending, refining, and the like. Filling or packaging operations will continue to be a highly significant aspect of the labor content and the area required. Engineering and test laboratories will undoubtedly be the backbone of product development and process control. Marketing and distribution is anticipated to take quite a different form in 20 or 30 years' time. Fresh air and an abundant supply of cooling water are anticipated as being major considerations for the plant during the next 50 years."

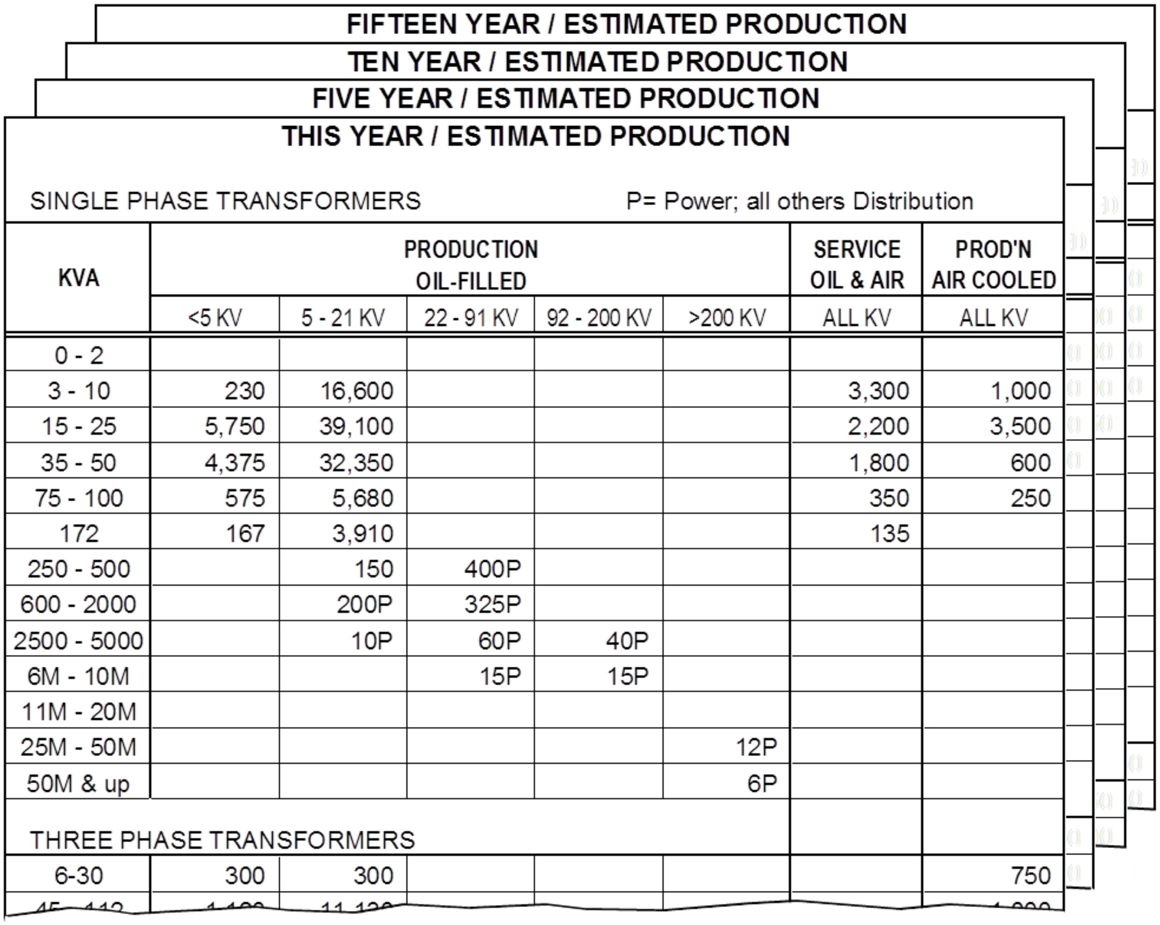
Most often, however, the planner is not concerned with such long-range projects. Rather, the concern is with what will happen in the next two, five, or ten years. And on short-range rearrangements, perhaps a three-to-six months' projection is all that is necessary.

In any event, the layout planner must be able to set forth basic assumptions of what is anticipated at some logical future time, in terms of product designs, marketable quantities, processes and their machinery, plant and personnel service, and timing considerations. This is where most layout projects begin. And why the SLP pattern begins with key inputs and their analysis – before the investigation of relationships and space.

In developing plans for the future, it is frequently practical to see what has been done in the past. The history of the total company or of specific items can be plotted in terms of quantities over past periods. A trend thus derived can help the planner project into the future. Figure 3-9 shows such a plot. (Sound market research is, to be sure, a far better basis for future projections.)

Whether or not the projection is broken down into product groups or remains one total figure, it is best to have both dollars and numerical figures (quantities). The table in Figure 3-10 breaks down the data which give the most aid to layout planners. That is, it contains a quantity break down by product type and gives further break downs, projecting these for several periods in the future.





FIFTEEN YEAR / ESTIMATED PRODUCTION

TEN YEAR / ESTIMATED PRODUCTION

FIVE YEAR / ESTIMATED PRODUCTION

THIS YEAR / ESTIMATED PRODUCTION

SINGLE PHASE TRANSFORMERS P= Power; all others Distribution

KVA	PRODUCTION OIL-FILLED					SERVICE OIL & AIR	PROD'N AIR COOLED
	<5 KV	5 - 21 KV	22 - 91 KV	92 - 200 KV	>200 KV	ALL KV	ALL KV
0 - 2							
3 - 10	230	16,600				3,300	1,000
15 - 25	5,750	39,100				2,200	3,500
35 - 50	4,375	32,350				1,800	600
75 - 100	575	5,680				350	250
172	167	3,910				135	
250 - 500		150	400P				
600 - 2000		200P	325P				
2500 - 5000		10P	60P	40P			
6M - 10M			15P	15P			
11M - 20M							
25M - 50M					12P		
50M & up					6P		

THREE PHASE TRANSFORMERS

6-30	300	300					750

Figure 3-10. Projection of future quantities as a basis for planning a new plant for electrical transformers. Future estimates are set forth for twenty years and the product and quantity data are broken down by phases, by type (P or D), by oil or air, by production or service requirements, by capacity (KVA), and by KV range.

Figure 3-9. Graphical record of past sales with projection into the future. This type of picture is very helpful in establishing the plan-for quantities – especially when a new site or major commitment on "location" is involved. Although the long historical and long future figures are needed for master planning or long-range layout, projections for a much shorter period would generally be used for smaller relayout projects. This kind of forecasting, when done for each product line and integrated into total company objectives, can serve as an aid – along with other more sophisticated techniques – to developing long-range requirements for space, equipment, and capital expenditures.

Note: A few years of sales history may be easy to get from current information systems. But going back more than 5 to 8 years typically requires research and approximate estimates by “old timers.” But the exercise provides helpful context when projecting 5 to 10 years into the future.

Note also that sales history will likely be in actual dollars, not adjusted for inflation. For clarity on the true rate of volume growth, planners should always adjust historical dollars and projections to constant – typically current year – monetary value.

Master Plans

It is usually helpful to develop an ultimate layout, or *master plan*, for the future and to work backwards into various increments of expansion, even though the time schedule may not be specific. There are various reasons for master planning: logical and systematic expansion to save the cost of utilities; utilization of real estate, lining up columns, building facings, and doorways to reduce maintenance and material handling costs and to improve the appearance of the facility; permitting of piecemeal expansion for growth within an overall plan so that capital investments are committed on a more conservative basis. A logical master plan into which expansions can be fitted when and if they come along affords many future savings – not the least of which is the engineering man-hours devoted to planning layouts and new facilities. Sound master plans also result in wise placement of the most-fixed facilities, providing ample room for their potential expansion or eventual replacement.

An overall master plan, such as that shown in Figure 3-11, is a basic ground plan into which subsequent growth can be fitted when it is called for.

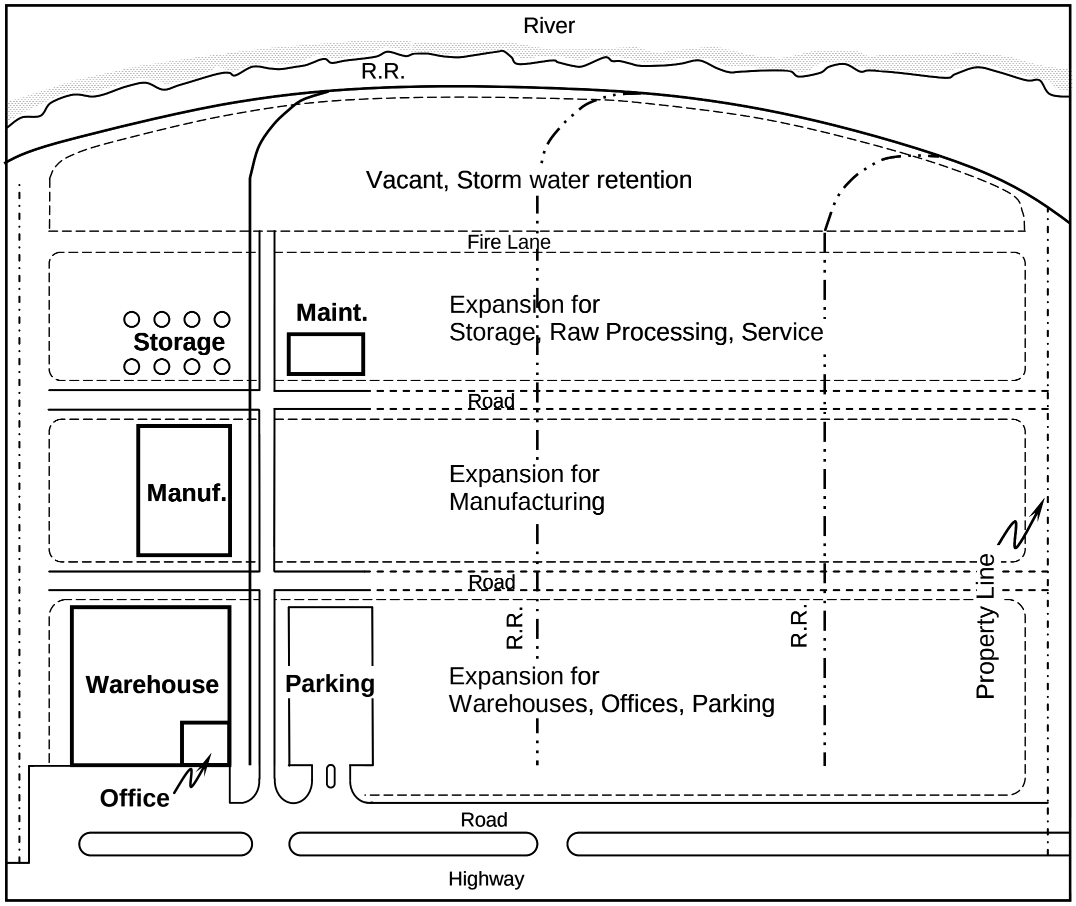


Figure 3-11. Master plan for long-range expansion of facilities. The current, "going in" arrangement of facilities – storage tanks, maintenance, manufacturing, warehouse, and office – are shown as solid lines. Areas reserved for future expansion are shown as dotted lines and are set aside on a planned basis by type of activity.

Product Changes

Changes in the inherent characteristics of products and materials must also be anticipated by the planner. Changes in product design can defeat the best layout planning. One layout, for example, voted the finest in its industry, became obsolete within 10 years and was completely abandoned, primarily because of a change in size of the product. It is well worthwhile, therefore, to check past trends in nature or characteristics of the products or materials involved in a layout plan. An example of how this can be done simply, and in a meaningful way, is shown in Figure 3-12 – though it represents but one way of helping anticipate changes in products or materials. In any event, the product-planning or design-engineering group (speaking for P) and the sales or distribution group (speaking for Q) should provide figures projected over a logical period, approved by top management, broken down sufficiently to serve the layout planner as a specification for planning the facility.

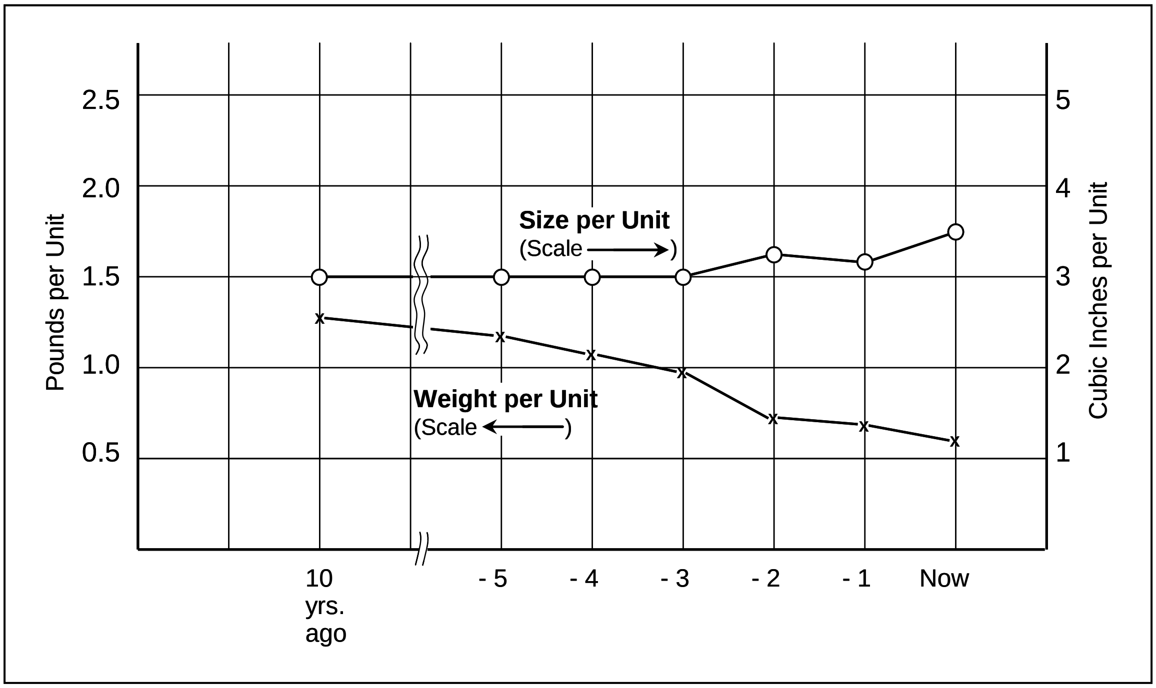


Figure 3-12. Trends in products' size and weight. Trends in the nature or the characteristics of the products being produced can seriously affect a layout – especially when sudden or major changes occur. Here a plot of the trends in size and weight of this company's product shows little appreciable increase in the size but a rather significant decrease in the weight per unit. Will these trends stabilize, continue, or change abruptly? And what effect will such changes have on storage facilities, handling container, and clearance or set-down area around machines? These questions should be answered – to the best of the company's ability – before the layout project moves ahead very far.

Trends in process machinery or equipment and in the ratio of production to non-production areas and man-power similarly should be appraised. Trends in product diversification or simplification will normally show up in the P-Q analysis discussed in earlier pages of this chapter.

The Danger of Getting Too Specific

One warning should be made – the tendency to get too specific. Layout planners must have data to plan their layouts; this has been emphasized. However, even though a company's management or product-planning group has set such figures down in writing, they cannot be considered as either unchangeable or precise. In fact, if any projection figures come out exactly as set down, it is a coincidence – except perhaps where contractual customers are involved

Usually, the set of plan-for input data must include some kind of cushion, or safety factor, or it must be recognized that overtime or a second or third shift will be used to pick up peak conditions. This should be understood by everyone before specific plan-for figures are agreed upon.

Similarly, once the figures are agreed upon, the layout planner must recognize that these figures are, at best, estimates and that some condition may occur which will change completely the nature of the design criteria – the projected input data. Changes to meet a competitor's product design, to take advantage of a new process, to conform to new sanitation or labor-union provisions are bound to occur. The rapidity of such changes is becoming more important each year. If the layout planner relies too literally on the plan-for figures, the layout will be too inflexible or too costly to adapt to the inevitable minor changes.

Summary

Based on the above discussion, we conclude that the layout planner must take a step before the planning of relationships, space, and adjustment. That first step involves gathering and analyzing data to which the layout will be planned. It generally includes the following sequence:

1. Identify specific elements of input data needed as design criteria for the project at hand.
2. Project these data into the future. (Note that this will undoubtedly involve the layout planner's restructuring information that is available from or supplied by others in the organization.)
3. Document basic assumptions about existing and future conditions and inputs.
4. Seek general approval and top-management endorsement of the input data and the basic assumptions.
5. Examine the data for distinctive dissimilarities, using P-Q chart and variations thereof to arrive at basic types of layout and/or definitive bases for dividing (splitting or combining) activity-areas.
6. Identify and define the activities (or activity-areas) to be used in the subsequent planning and order them in a logical way.

Chapter 4

Flow of Materials

The third letter of our Key to unlocking layout planning problems (see Figure 1-1) is R (Routing). Routing means how an item is made – its process. The process is established essentially by selecting the operations and sequences that will best produce P and Q wanted in the optimum operating T – although many other considerations may be involved in the determination.

The routing yields the basic data for analyzing the flow of materials. But before utilizing the routing data obtained, the planner should recall the meaningful little word "why," the business end of our key. The routing should be examined and proved reasonably right; it should be restudied when the planner feels it can be improved.

The standard work-simplification check originally developed by Allan H. Mogensen in the 1930s – and discussed in all industrial engineering texts or handbooks – is especially applicable.[1] Mogensen's check challenges each step in the process routing with these words and questions:

1. *Eliminate* – Is the operation necessary, or can it be eliminated?
2. *Combine* – Can it be combined with some other operation or action?
3. *Change sequence, place, or person* – Can these be changed or rearranged?
4. *Improve details* – Can the method of performing the operation or action or its equipment be improved?

Determining the process routing occurs in Section 1 of the SLP pattern. Once finalized, the planner can begin flow-of-materials analysis. This occurs in Section 2.

Flow of Materials – Heart of Many Layouts

The analysis of materials flow involves determining the most effective *sequence(s)* of moving materials through the necessary steps of the process(es) involved and the *intensity* or magnitude of these moves. An effective flow means that materials move progressively through the process, always advancing toward completion and without excessive detours or back-tracking (counterflow).

Flow-of-materials analysis is performed in Section 2 of the SLP Pattern. It is the heart of layout planning wherever movement of materials is a major portion of the process. This is especially true when materials are large, heavy, or many in quantity or when transport or handling costs are high compared with costs of operation, storage, or inspection. In extreme cases of this kind, the desired flow is developed and then diagrammed directly. The space requirements are hung on the flow diagram. Little investigation of supporting services is made, and no activity relationship chart is

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[1] Mogensen's phrase "Work smarter, not harder" was central to his *Work Simplification, A Program of Continuous Improvement* – 50 years before the popularity of Kaizen and Lean Thinking.

constructed. The services and other-than-flow relationships are simply picked up as part of the Modifications and Limitations (in Section 4 of the SLP Pattern).

Analyzing materials flow, therefore, is one of the primary steps every layout planner should understand and know how to do.

Determining Method of Flow Analysis

There are several different methods of analyzing flow of materials. Part of the problem of course is knowing which method to use for a given project. The P-Q chart can be used as a guide, for the method of flow analysis varies with the volume and variety (quantity and number of types) of the items being produced. See Figure 4-1.

1. For one or a few standardized products or items, use an *operation process chart* or some similar flow chart.
2. For several products or items, use a *multi-product process chart*, if assembly and disassembly are not involved.
3. For many products or items,
   a. *Combine* them into logical groups and analyze as 1 or 2 above; or
   b. *select* or sample products or items and apply 1 or 2 above.
4. For very many diversified products or items, use the from-to chart.

Each of these flow-analysis techniques are discussed further in this chapter. The chief point here is that different methods of flow analysis should be used for different product volume and variety conditions and that the P-Q curve can show which type of analysis should be made.

The Operation Process Chart

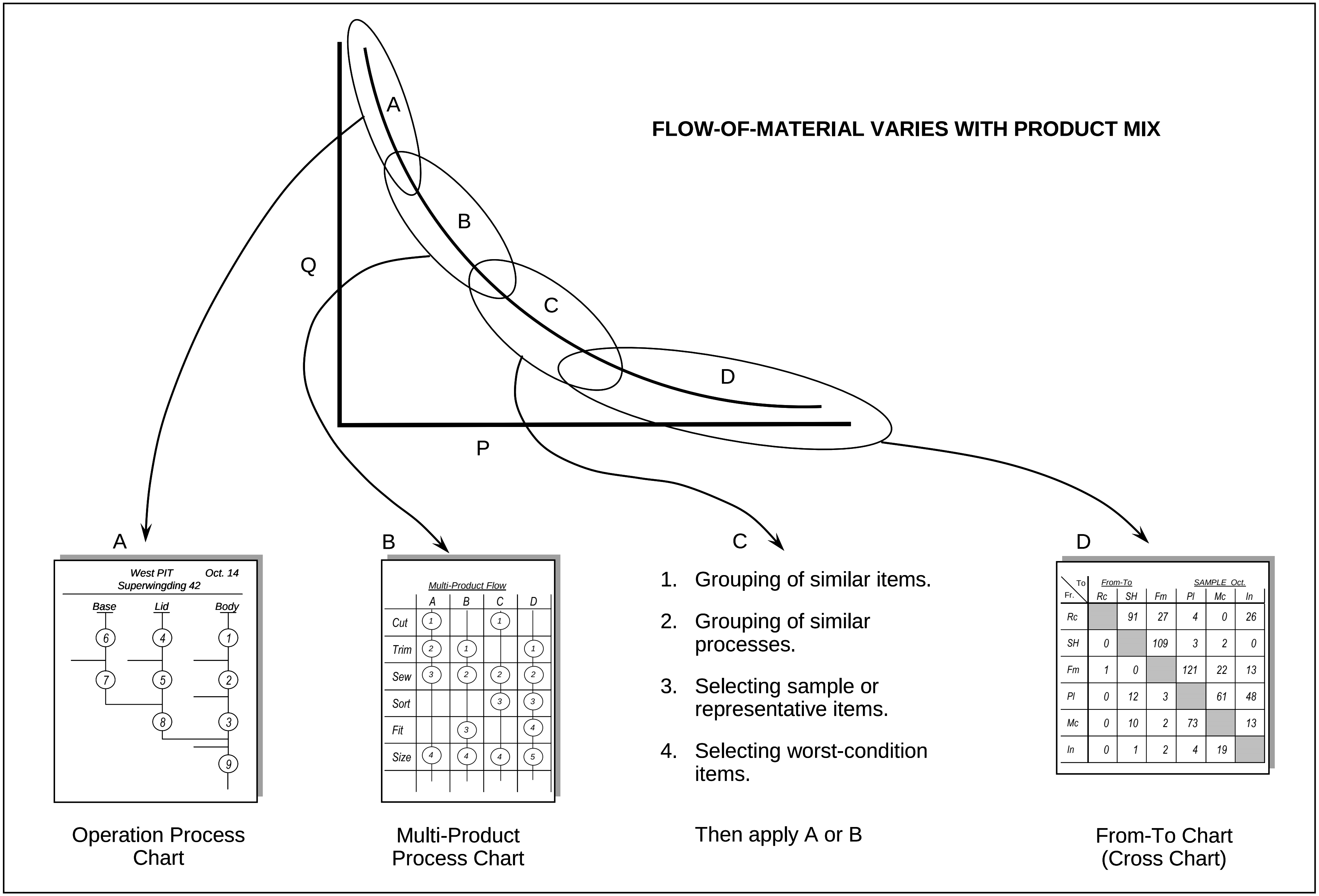
If the planner can picture the materials flow – can see it – the layout can be planned. That is why the visual aspects of analysis are continually emphasized in this book. In fact, this necessity to "see the picture" is perhaps the underlying reason that SLP has developed into its present form.

Figure 4-1. Guide to analysis of flow. Besides being a direct aid in planning a layout, the P-Q Chart is a guide to the type of flow analysis to use.

A plant having only a few high-volume items (A) will analyze its flow by the Operation Process Chart. When several such charts are necessary for a given project, it becomes difficult to integrate these charts. Therefore, for several high-volume items (B), a Multi-Product Process Chart is a better technique for flow analysis.

When many items are involved (C), we follow still another course of analysis – selecting or grouping. Either we group the items – usually by like products or like equipment characteristics – or we select representative, sample, or "worst-condition" items, and then apply one or the other of the two techniques above. Finally, if the project involves a great many diversified items of relatively small volume each (D), we use the From-To Chart or Cross Chart.

FLOW-OF-MATERIAL VARIES WITH PRODUCT MIX



Operation Process Chart

Multi-Product Flow

	A	B	C	D
Cut	1		1	
Trim	2	1		1
Sew	3	2	2	2
Sort			3	3
Fit		3		4
Size	4	4	4	5

Multi-Product Process Chart

1. Grouping of similar items.
2. Grouping of similar processes.
3. Selecting sample or representative items.
4. Selecting worst-condition items.

Then apply A or B

From-To SAMPLE Oct.

Fr. \ To	Rc	SH	Fm	Pl	Mc	In
Rc	▨	91	27	4	0	26
SH	0	▨	109	3	2	0
Fm	1	0	▨	121	22	13
Pl	0	12	3	▨	61	48
Mc	0	10	2	73	▨	13
In	0	1	2	4	19	▨

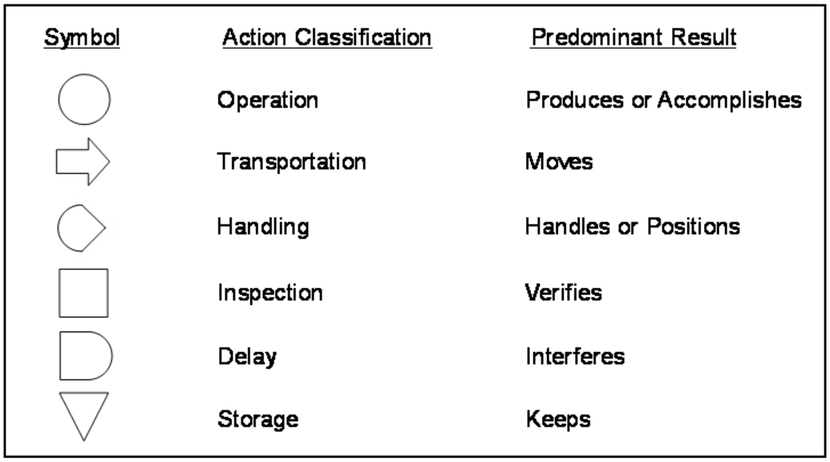
From-To Chart (Cross Chart)

To help the planner see, a system of sign language is used – equivalent to those used by the mathematician, the chemical engineer, or the procedures analyst. The sign language of process charting is well-known to trained industrial engineers. It was originally developed by Frank and Lillian Gilbreth in the 1920s. Subsequently, two different committees sponsored by the American Society of Mechanical Engineers modified it to the form given in Figures 4-2 and 4-3.

Essentially, only six things can happen to material as it moves through a process:

1. It can be formed, treated, or be assembled or disassembled with other items or materials.
2. It can be moved or transported.
3. It can be handled – arranged, picked up, set down, re-oriented.
4. It can be counted, tested, checked or inspected.
5. It can wait for some other action or for the rest of its batch.
6. It can be stored.

By using a symbol for each of these six actions and connecting the symbols with lines, the movement and process sequence of any product or material can be charted. The conventions for making an operation-process chart are given in Figure 4-3. A sample chart is illustrated in Figure 4-4.



Symbol	Action Classification	Predominant Result
○	Operation	Produces or Accomplishes
⇨	Transportation	Moves
⬠	Handling	Handles or Positions
□	Inspection	Verifies
D	Delay	Interferes
▽	Storage	Keeps

Figure 4-2. Symbols, action classification, and predominant result of the "sign language" used for process charting. Extracted from ANSI Y15.3M – 1979. While the industrial engineering profession allowed this standard to lapse, the symbols remain widely used and are available in Microsoft Visio ® as TQM stencils. They are easy to create in electronic form, and for paper and pencil applications a plastic stencil is provided in the Working Forms section of this book.

Some clarification is in order here. While we are dealing in Part Two with Phase II planning: General Overall Layout, and are considering Phase II techniques for flow-of-materials analysis, most of the same techniques are used in Phase III, Detailed Layout Planning, usually showing greater detail. Also, in traditional *operation* process charts, only the operations and inspections are shown. When all six symbols are used, the result is a *flow* process chart, showing every action in which the material becomes involved. In overall layout (Phase II), the operation process chart is used to define the manufacturing process and its operational steps. It may be expanded into a flow process chart to show movement of material between major operations and areas; pick-up and set-down points.

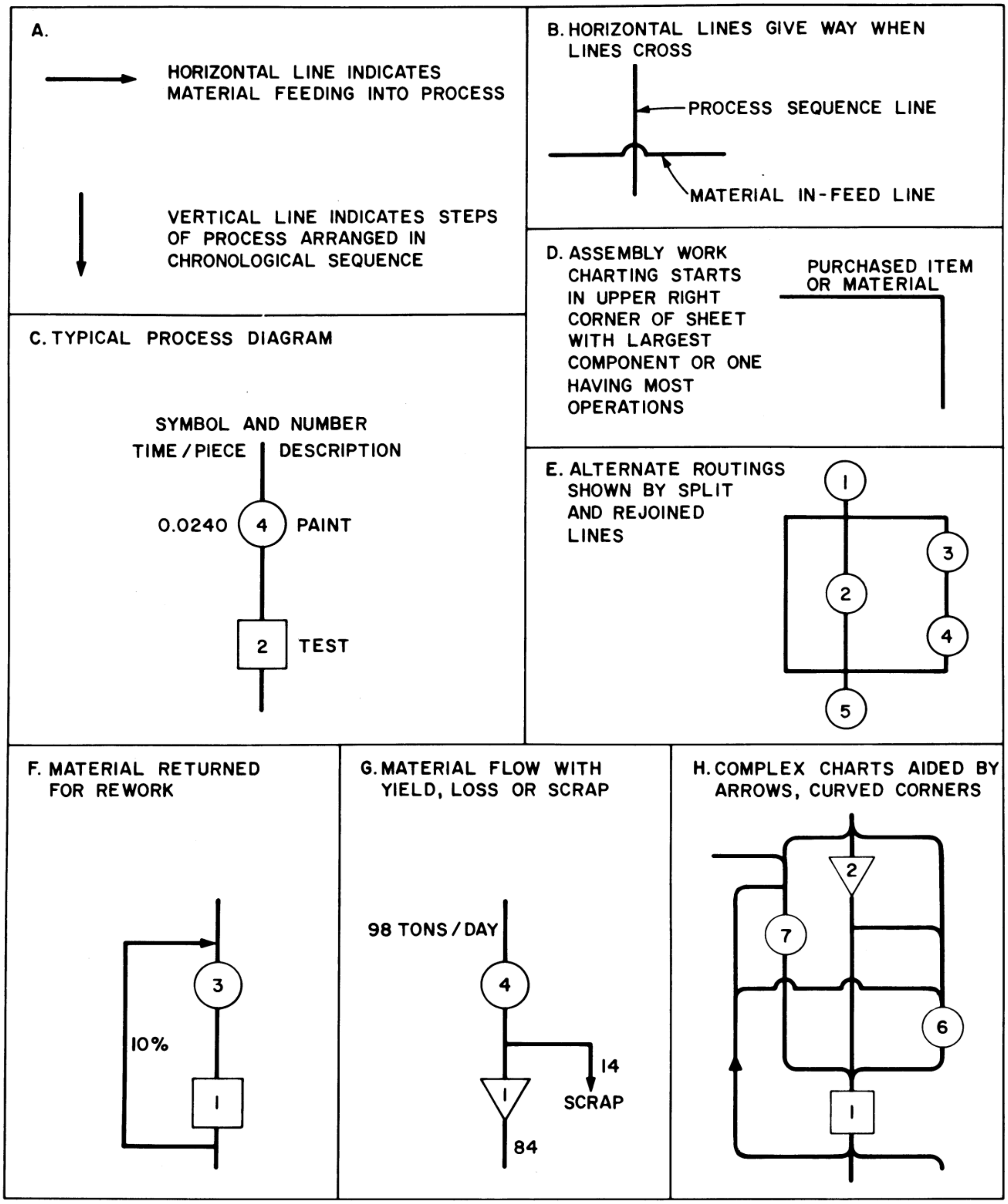


Figure 4-3. Conventions and modifications in making process charts. Extracted from American National Standard ANSI Y15.3M – 1979 on Process Charts. (Formerly ASME Standard 101, Operation and Flow Process Charts).

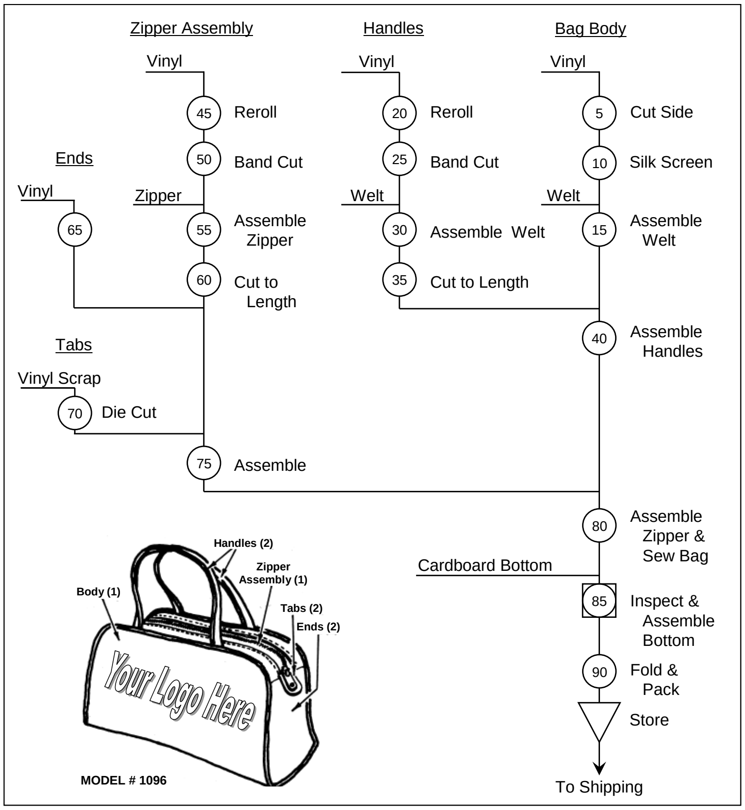


Figure 4-4. Operation Process Chart showing the chronological sequence of operations and how and where the components go together. With the exception of the final storage, only operations and inspection are shown. Intermediate delays, transports, handlings or storages do not appear.

To assist in making the operation process chart, especially where complex assembly is involved, it is frequently helpful first to rough out how the materials go together. By taking a completed product and disassembling it, piece by piece, in this way learning how it should be assembled, one can draw a rough chart of the assembly sequence, and then prepare an operation-process chart for flow-of-materials analysis.

Various modifications of the conventions and charting practice can be made. Sometimes there isn't time to include all the information; other times a different form will be more meaningful. Most people agree on sticking to the standard conventions, but they modify or adjust the chart to get the clearest picture possible of the project at hand.

Nested Process Charts

To manage detail in large plant-wide layout projects, it is often useful to draw a “high-level” or “master” process chart identifying major items, products or “value streams” with numbered symbols. Then each numbered item can be further detailed or “exploded” on a separate process chart. The high-level chart is essential for planning the general overall layout in Phase II. The detailed charts are used in both Phase II and Phase III. An illustration appears in Figure 4-5.

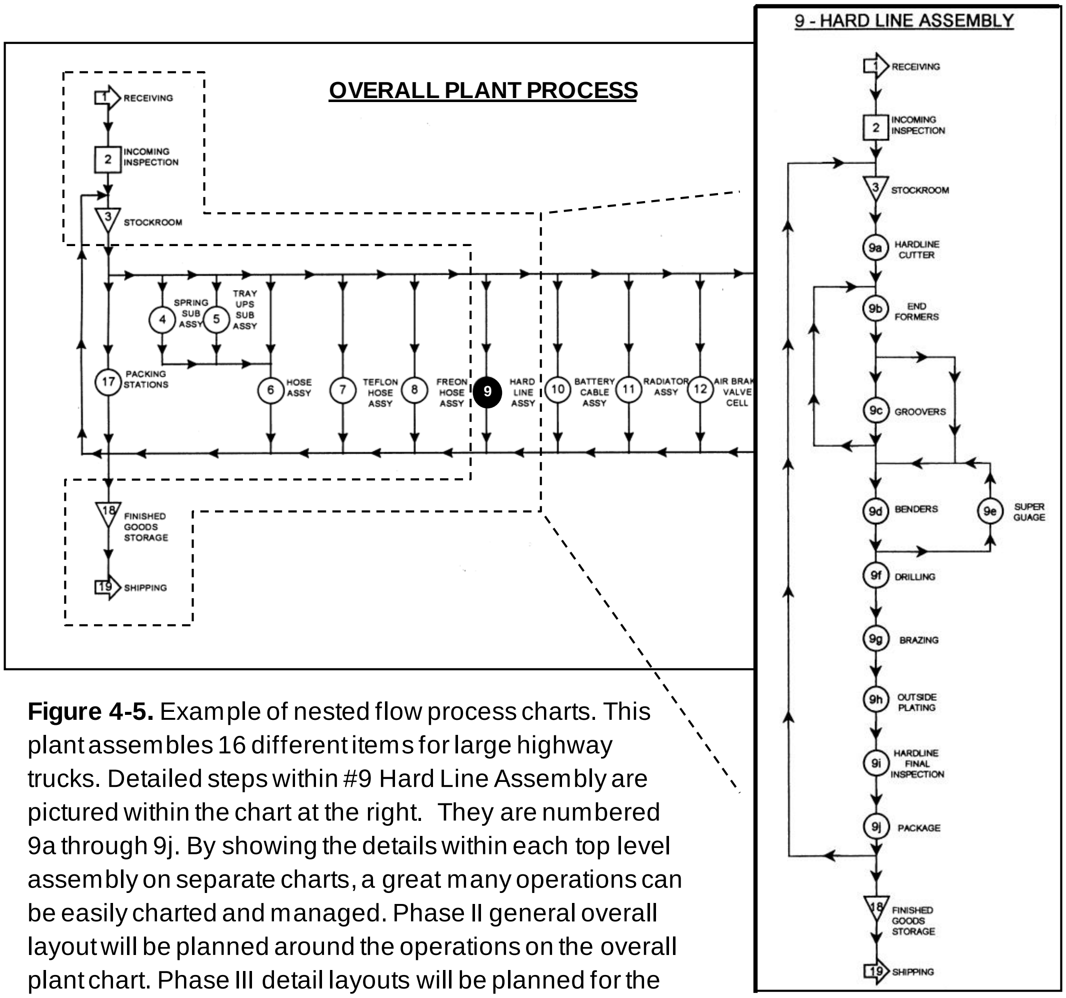
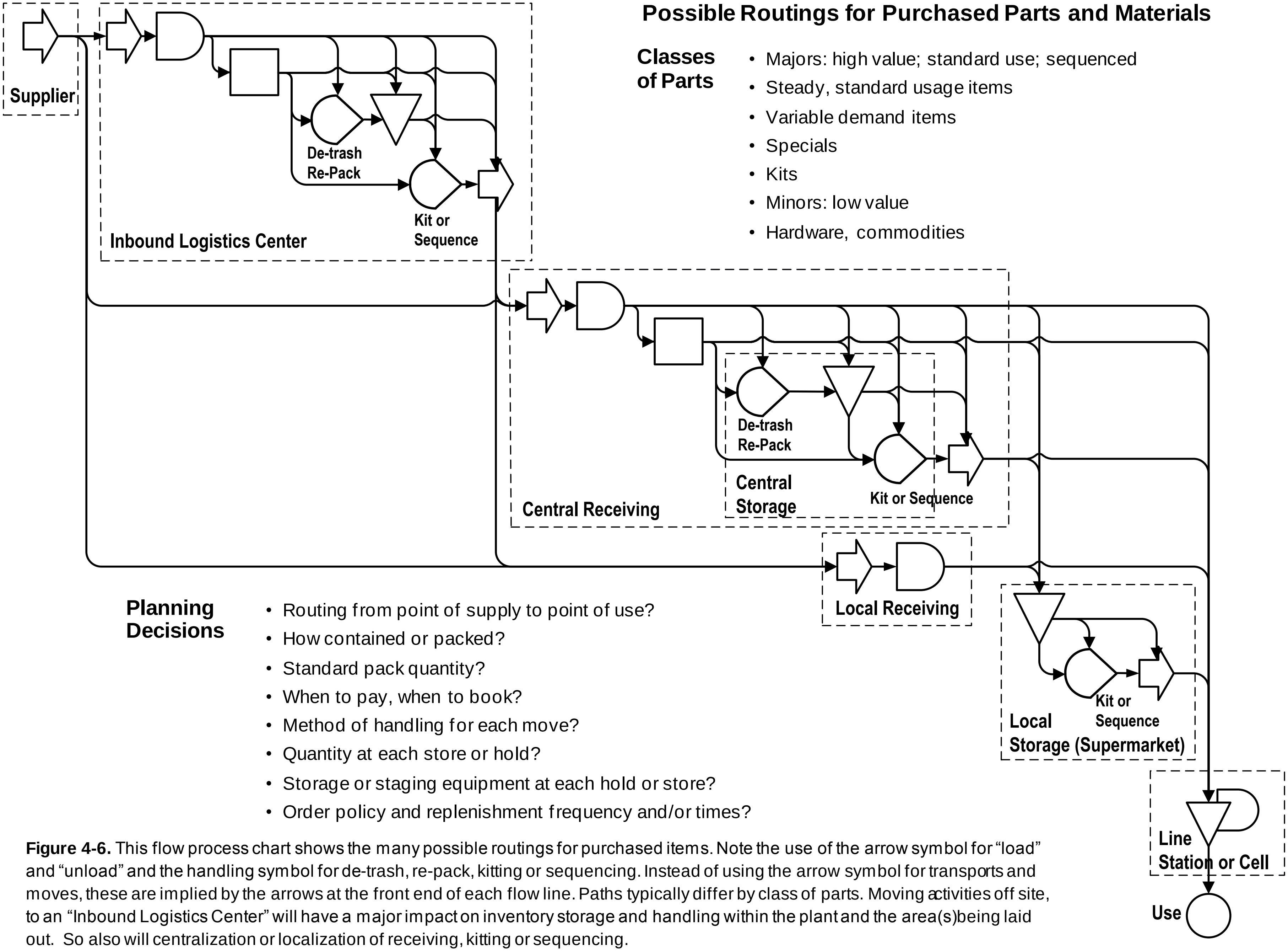


Figure 4-5. Example of nested flow process charts. This plant assembles 16 different items for large highway trucks. Detailed steps within #9 Hard Line Assembly are pictured within the chart at the right. They are numbered 9a through 9j. By showing the details within each top level assembly on separate charts, a great many operations can be easily charted and managed. Phase II general overall layout will be planned around the operations on the overall plant chart. Phase III detail layouts will be planned for the operations on each detailed chart.

Process Charting for Materials Management Operations

Operation and flow process charts are most often used to document progressive forming, fabrication and assembly. But they are also excellent for understanding the routing of purchased parts and materials as they move from outside suppliers to points of use in the layout. An illustration appears in Figure 4-6. Note the use of the handling symbol to identify kitting and sequencing operations.

The materials management policies governing these movements have a significant impact on receiving, storage and material handling activities, locations, methods, equipment and space. The greater the use of purchased parts and sub-assemblies, the greater is the impact. In final assembly plants, the replenishment process is a close second to assembly itself in determining the layout. For these reasons, the planner should challenge the materials management policies and practices early – before finalizing activity-areas and beginning a flow analysis. The most fundamental challenges and potential changes involve:



Possible Routings for Purchased Parts and Materials

Classes of Parts

- Majors: high value; standard use; sequenced
- Steady, standard usage items
- Variable demand items
- Specials
- Kits
- Minors: low value
- Hardware, commodities

Planning Decisions

- Routing from point of supply to point of use?
- How contained or packed?
- Standard pack quantity?
- When to pay, when to book?
- Method of handling for each move?
- Quantity at each store or hold?
- Storage or staging equipment at each hold or store?
- Order policy and replenishment frequency and/or times?

Figure 4-6. This flow process chart shows the many possible routings for purchased items. Note the use of the arrow symbol for “load” and “unload” and the handling symbol for de-trash, re-pack, kitting or sequencing. Instead of using the arrow symbol for transports and moves, these are implied by the arrows at the front end of each flow line. Paths typically differ by class of parts. Moving activities off site, to an “Inbound Logistics Center” will have a major impact on inventory storage and handling within the plant and the area(s) being laid out. So also will centralization or localization of receiving, kitting or sequencing.

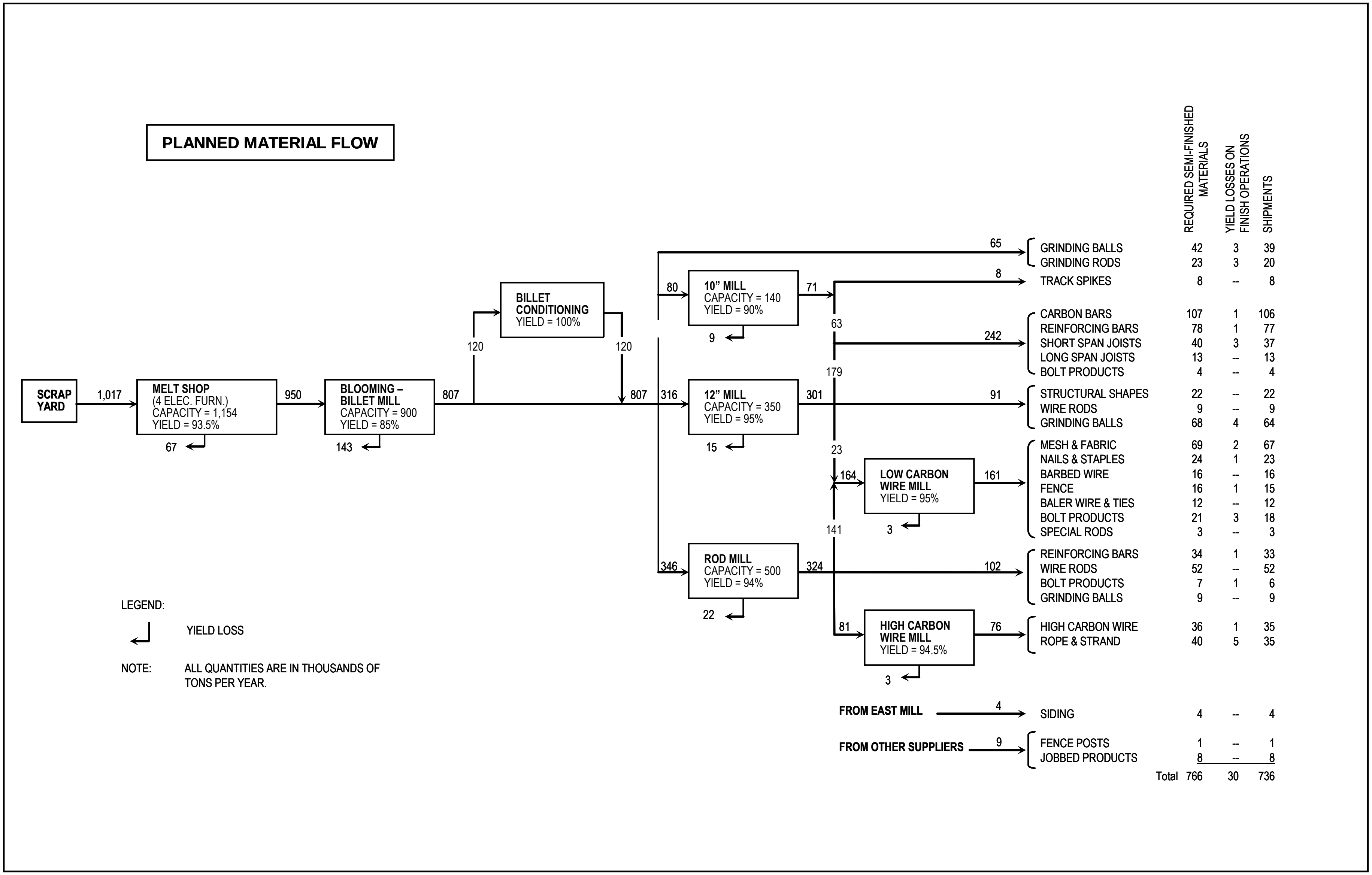
1. Sourcing – including terms and conditions – affecting minimum order quantities, lead times, transport costs, and ultimately inventories and storage space needed
2. Inbound transportation modes and methods affecting delivery frequencies, lead times, and their variability. These in turn affect inventories and space for receiving and storage
3. Sequencing of items relative to planned usage
4. Handling of order-specific and special build items
5. Kitting and delivery of multiple parts instead of individually
6. Certification and need for inspection
7. Pack quantities – standard (always the same) – or not
8. Forms of packaging and associated waste flows
9. Use of returnable containers, frequency and methods of return
10. Unloading, receiving, inspecting and storage within the layout: centralized or distributed (supermarkets) and/or at points of use
11. Role of the supplier or a third-party in holding inventory off site (outside the layout) and delivering just-in-time; Also performing consolidation, pre-receiving, sequencing, de-trashing, re-packing, kitting… to reduce the materials management footprint in the layout
12. Any use of off-site services or space that will affect the layout in a significant way

The policies and practices above will have their first and likely greatest impact in Phase II overall layout planning. For this reason, we will discuss them in more detail in Chapter 7 when determining space requirements, and in Chapter 9 when incorporating the impact of handling and storage methods on overall layout. Materials management practices also affect detail area and workplace layouts where significant percentages of the space involve storage or presentation of parts and materials. For this reason we will revisit them again in Chapters 11 and 12.

Intensity of Flow

Recall from our earlier definition that flow-of-materials analysis includes both the sequence (R) and the intensity or magnitude of materials movement (for P and Q). If the flow analysis is made in order to arrange operations or activities in the correct relationship to one another, the magnitude of movement (or intensity of flow) over the various routings or paths is the basic measure of relative importance of each route – and therefore of relative closeness of operations to one another. The best layout from a flow-of-materials perspective will be the one that minimizes route distances times their intensities. Figure 4-7 shows this intensity of flow as a number beside each flow line and as annual tonnages of end product at the right. This is a different form of process analysis, horizontal and without symbols. Also, it picks up the problem of yield losses, which is discussed in the following paragraph.

Outflow of waste can be a major part of a layout handling problem. In a sheet-metal shop, for example, not infrequently, trim amounts to twenty or thirty percent of the tonnage involved. This waste material is often awkward to handle. The materials are likely to be dirty, or sharp, unduly bulky, or dangerous, requiring quite a different handling method than that used for the in-feeding of materials or components. To overlook this outflow in layout planning can be disastrous. Figure 4-8 shows the conventions used for including these features in the operation process chart.



	REQUIRED SEMI-FINISHED MATERIALS	YIELD LOSSES ON FINISH OPERATIONS	SHIPMENTS
GRINDING BALLS	42	3	39
GRINDING RODS	23	3	20
TRACK SPIKES	8	--	8
CARBON BARS	107	1	106
REINFORCING BARS	78	1	77
SHORT SPAN JOISTS	40	3	37
LONG SPAN JOISTS	13	--	13
BOLT PRODUCTS	4	--	4
STRUCTURAL SHAPES	22	--	22
WIRE RODS	9	--	9
GRINDING BALLS	68	4	64
MESH & FABRIC	69	2	67
NAILS & STAPLES	24	1	23
BARBED WIRE	16	--	16
FENCE	16	1	15
BALER WIRE & TIES	12	--	12
BOLT PRODUCTS	21	3	18
SPECIAL RODS	3	--	3
REINFORCING BARS	34	1	33
WIRE RODS	52	--	52
BOLT PRODUCTS	7	1	6
GRINDING BALLS	9	--	9
HIGH CARBON WIRE	36	1	35
ROPE & STRAND	40	5	35
SIDING	4	--	4
FENCE POSTS	1	--	1
JOBBED PRODUCTS	8	--	8
Total	766	30	736

Figure 4-7. A form of process chart used in planning major expansion of a steel mill complex. Here each rectangle represents a major activity-area; numbers beside each flow line represent thousands of tons per year; and yield loss is shown by the back-flow arrow. This shows the break-down of basic material into various derivative products, rather than the build-up into an assembled product as in Figure 4-4.

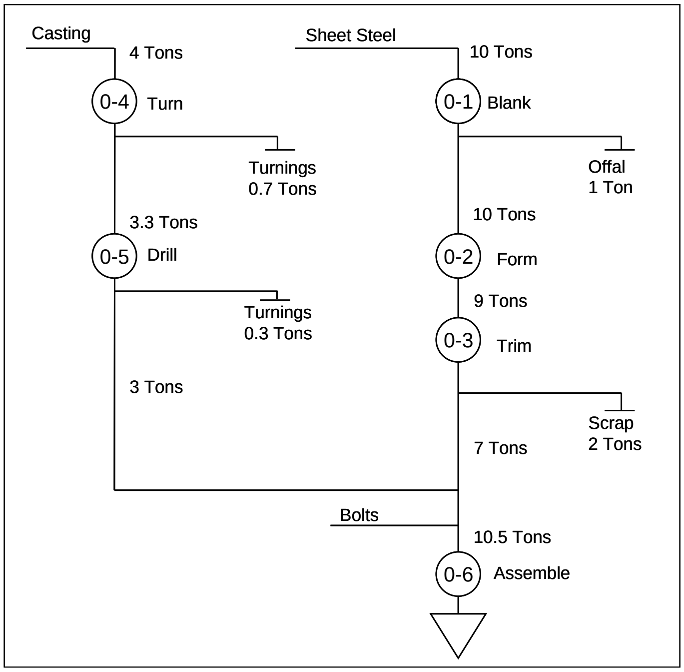


Figure 4-8. Operation Process Chart with intensity of material flow and the out-flow of chips and scrap.

Measures of Intensity

Where materials are similar or more or less homogeneous, then units like pounds or tons, gallons or other cubic volume, or pallet-loads or tote-boxes are satisfactory measures of the magnitude or intensity of movement. The common calculation is the number of pieces moved per period times the unit of measure per piece. However, when it is necessary to convert from one unit of measure to another, when materials are quite diverse in nature and characteristics, or when there is no common container or handling unit, measurement of flow intensity is more difficult. To help solve this problem the "Mag Count" was developed. Mag Count, the transportability of any item in any condition, is quite a valuable measure, for the conditions of materials change at various stages in the process. (A complete description with tables of values for using the Mag Count is described in Appendix I.)

Mag Count may be a more sophisticated method of measuring flow intensity than is needed, but it – or a simplification of it – is very convenient on many layout planning projects, especially where there is no other readily usable unit of measure.

Gathering data on flow intensities is often a challenge. Typically the layout planner must piece together data from several production information systems and be ready to apply judgment and rough estimates when data is limited or unavailable. Appendix II discusses data sources for flow analysis in some detail.

If the project involves any possible change in methods for transporting materials, and especially if the planner expects to apply some organized analysis of materials handling problem(s), the products and materials should be classified according to their physical characteristics, quantity, timing, or special control. Then the flow-of-materials analysis for layout planning can be combined with analysis-of-moves for transport planning. This classification of materials is discussed in detail in a companion book, *Systematic Handling Analysis (SHA)*, a condensation of which appears in Appendix X.

When some moves are more difficult or costly than others, this should be reflected in the flow-of-materials analysis. If the handling methods are given or known, it may be relatively straightforward to “factor” the material flow on each route by taking into account the ease or difficulty associated with each class or type of material and each type of handling device. Typical considerations include: speed, safety, risk, number of people required to make the move, disruption to production… The most common type of move can be given a value of 1.0 whenever it is made. Other types of moves can be factored relative to 1.0, to account for their relative effort and cost. See Figure 4-9.

Load Size Type of Equipment	Oversized	Long & heavy	Pallet size	Carton/Tote
Over the Road Vehicle	2.5	2.5	2.0	1.5
Yard Crane or Tractor & Cart	5.0	3.5	NA	NA
Bridge Crane	4.0	2.5	NA	NA
Fork Truck - Outdoors / Yard	5.0	4.0	2.0	2.0
Fork Truck - Indoors only	NA	NA	1.0	NA
Man and Cart	NA	NA	NA	0.5

Figure 4-9. Equivalent move factors for a machining and fabrication shop making a wide range of valves, pressure regulators, and assembled package plants for natural gas distribution. Moves range from small pans and totes moved by cart to completed assemblies over 100 cubic meters in size and moved by tractor-trailer. The most common move – forklift and pallet – has a value of 1.0.

Equivalent Movement Factors by Class of Material

	Material Classes 	Count per unit	Equivalent Value Per Move considering: Payload, Time & speed, Effort, Risk		
			Model A	Model B	Chassis A & B
a	Sheet steel and plates	20	0.20	0.20	0.20
b	Purchased parts	30	0.20	0.20	
c	Body fabrications unpainted	6	1.00	1.00	
d	Chassis unpainted	1			0.50
e	Body fabrications prime painted	6	1.20	1.20	
f	Chassis prime painted	1			0.70
g	Sub assemblies unpainted	8	0.20	0.20	
h	Sub assemblies painted	8	0.30	0.30	
i	Final assemblies before final paint	1	0.33	0.33	
j	Final assemblies after paint	1	0.50	0.50	

Figure 4-10. Equivalent movement factors in production of off-highway trucks. Each move of an unpainted dumper body fabrication counts as 1.00. Moves for the other material classes are factored relative to 1.00, considering payload (size and weight), time and speed, effort (labor) and risk of injury and damage to people, materials, and surroundings. Here, the moves will be made by such devices as yard cranes, overhead cranes, forklifts, and the trucks themselves, once assembled and fueled. Given the count per unit of each class and a forecast for Models A & B, this table can be used to estimate the equivalent intensities of flow for an hour, shift, day or year.

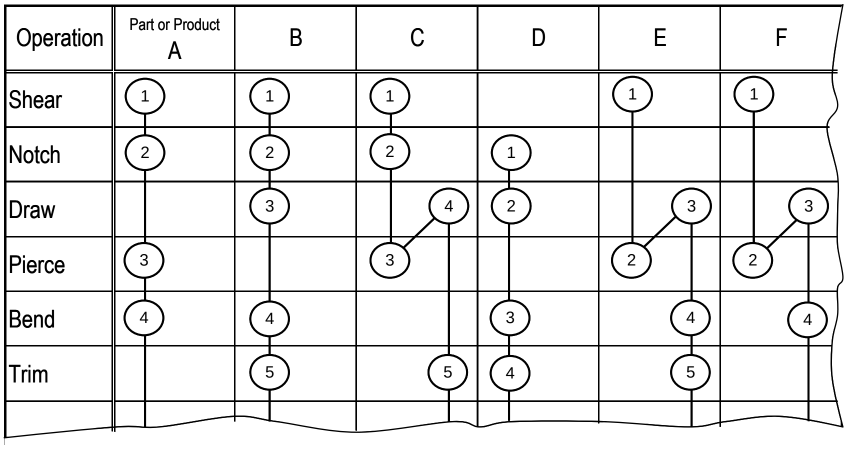
Figure 4-10 shows equivalent move factors for ten diverse material classes involved in off-highway truck fabrication and assembly. Here, the handling equipment is not shown in the table but its characteristics were considered in arriving at the move values.

Both examples in Figures 4-9 and 4-10 are more approximate and judgmental than Mag Count. But they were quick to establish and apply, captured the relative differences in material handling effort and were sufficient for the layout task at hand. Remember that it can be costly to get too intrigued with the details of the procedure or analysis being made. Doing so often means that decisions are based on figures far more finite than the future life of the layout warrants or more accurate than the P and Q information itself. Being "precisely wrong" is all too common in the calculation of flow.

Multi-Product Process Chart

When there are three or four items to be charted, it is best to make an operation-process chart for each one. But when the number of charts becomes many – say six to ten, depending on the nature of the products – it is better to use the multi-product process chart, especially if there is no assembly work.

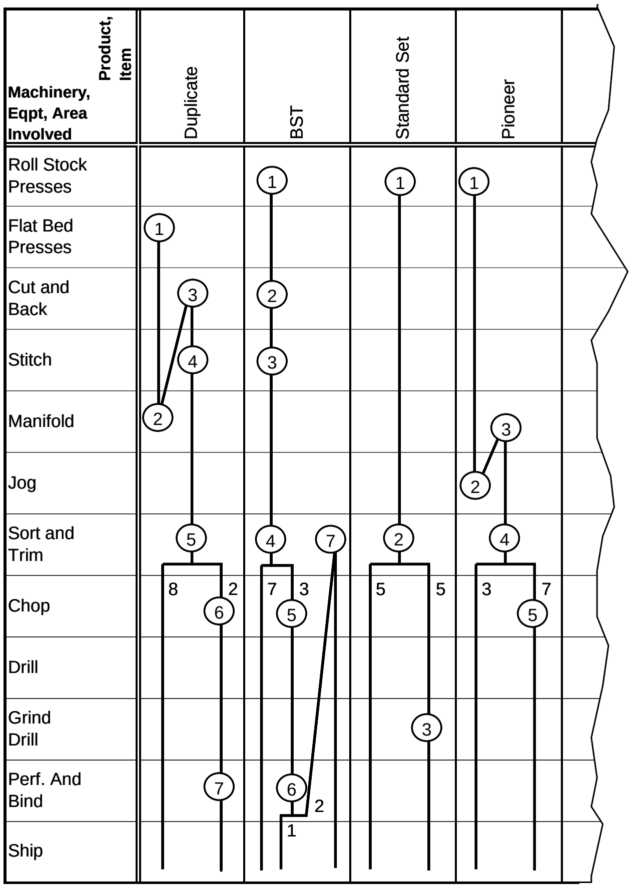
The multi-product process chart brings all items together in one document so they can be pictured easily. It lists, down the left side, all the *operations* through which all of the items may pass. Across the top, side by side and each in a separate column, are listed the various *products* or items involved. The routing of each item is then traced – in its column – through the pre-identified operations. Examples appear in Figures 4-11 and 4-12.



Operation	Part or Product A	B	C	D	E	F
Shear	1	1	1		1	1
Notch	2	2	2	1		
Draw		3	4	2	3	3
Pierce	3		3		2	2
Bend	4	4		3	4	4
Trim		5	5	4	5	

Figure 4-11. Multi-Product (Multiple Product or Part) Process Chart. From a layout perspective, Draw should come after Pierce. But drawing a pierced hole in sheet metal distorts the hole and its location. This chart helps to see where process sequences may need to differ from physical sequences or “line-ups” in the layout – and why process engineering should be involved in the layout planning.

By charting the part routings side by side, the planner can compare the flow paths for each. The layout objective is to have a progressive flow with a minimum of back-tracking and to place closest together those operations which have the greatest intensity of flow between them. This means interchanging the horizontal operation lines of the chart until the optimum sequence is obtained.



a

Product, Item / Machinery, Eqpt, Area Involved	D-1	D-2	D-3	D-4	E-1	G-1	S-1	
Q per Year	19,000	5,700	4,900	4,700	11,000	9,100	3,100	
Steel Strip Storage				1			1	
Raw (In) Storage	1	1	1		1			
Extrusion Storage						1		1
In Process Storage	4			3			3	
Straighten	2	2						
Punch				2 4		2	2	
Drill		3	2		2			
Counter-sink		5					4	
Tap					2			
Grind Drill	3							
Polish, Belt Sand	5	4				5		
Thread	6							
Solvent Clean	7							
Storage for Assy	8	6	3	5	3			
Assembly	9	7	4	6	4	3/4 6	5	

b

Figure 4-12 a & b. Modifications of the Multi-Product Process Chart. At left (a) is an example of routings split into alternative paths of flow. The percentage of material flowing over each route is shown by a one-to-ten index number. Percentage or actual intensity figures would be more accurate.

At right (b) routings are charted on a simple table or worksheet without the formality of circles and connecting lines. Flow is indicated by recording numbers in sequence opposite the appropriate operations. Note the double routing through "Punch" for item D-4, the alternate routing for Op. 2 for item E-1, and the double assembly operations (3 and 4) and the return for Op. 6 for item G-1. This is a quick way to record routings when no formal operations, process, or routing sheets are available. Connecting lines can be added later according to the actual numerical intensity of flow for each item – by applying the Q data at top of each column and a size, weight, or Mag-Count measure for each item.

A simple way to find the best sequence and eventual layout arrangement is to score the extent of back-tracking. For example, in Figure 4-12b, a value of two can be assigned for each incidence of back-tracking and a value of one for each operation by-passed in the counter-flow. Thus, D-1 scores 2+5 or 7. The total score for the sequence shown is 22. Other sequences can be scored and compared to this one. Additional scoring might assign +2 for each case where one operation feeds directly to the next, but only +1 when an operation is by-passed during forward movement. Such scores are made more meaningful by incorporating a measure of the intensity of flow. For example, D-2's score of 4 x 5,700 units becomes 22,800 vs. 45,500 for G-1. More sophisticated mathematical techniques may also be applied. This exercise identifies potential process improvements independent of the layout plan – for example, the need for D-1, D-4 and S-1 to pass through in-process storage. However, be sure not to overlook the benefits of a circular or U-shaped arrangement when laying out multi-product process operations. These may shorten the distances and impact of unavoidable back-tracking.

Note that the multi-product process chart does not show an assembly breakdown of components. Its use is therefore limited to major items and generally to routings listing only two or three lines on the chart for assembly and subassembly.

Grouping or Selecting

When the number of items involved reaches somewhere around thirty to fifty, some form of grouping or selecting becomes practical. By combining all or certain items which are *alike in design,* the planner may have a group with a common or reasonably distinct routing sequence. Items which are *alike in process* equipment frequently follow the same routing. Seek out these groups by classifying like designs in the former case (similarities in dimension, shape, chemical, or other characteristics), and, in the latter case, by looking for items which begin or end at the same operation or which pass through certain key operations.

It may then be possible to go back and apply the techniques of the operation process chart or multi-product process chart to the flow problem for the group.

Analyses of this kind lead to group-production layouts. Group production is neither line production nor layout by process, but a combination of the two, which retains the advantages of reduced handling and production supervision and control, yet does not cause too much loss of equipment utilization. See Figure 4-13.

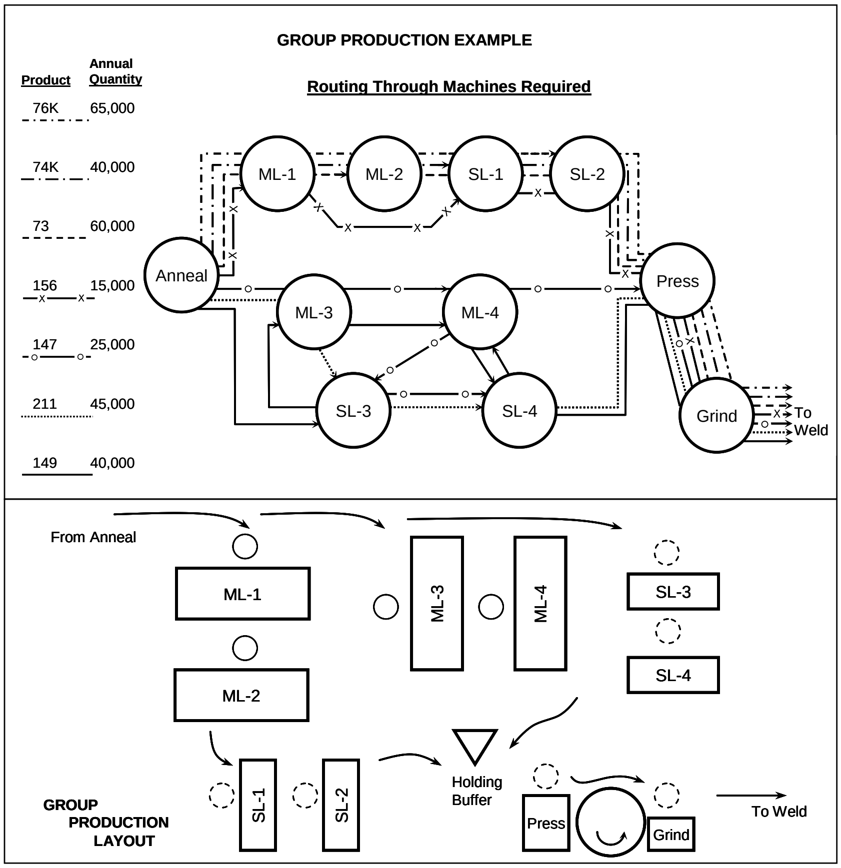


Figure 4-13. Group production based on combining certain similar items. This plant makes enamel-ware utensils for household and institutional use. Of some 300 catalog items, the layout planners combined seven reasonably similar teapots and coffee kettles into a group. The flow chart (top) shows the routing and operating equipment. The actual layout, with the general pattern of flow roughly marked by arrows, is shown below the flow chart.

If grouping is impossible, the planner can *select or sample* representative items. Every hundredth part number, every fifth formula, items ordered on various mixes of order number, day, week, and month can be the bases for selecting typical items. A random sampling based on statistical analysis is also valid.

Because there is a chance for error in a small sample, it is often better to select "worst-condition" items. Such a selection rests on the precept that if a layout can handle the worst items, it can handle them all. Therefore, select three to five of the items which rate worst in each or several (not necessarily all) of the following characteristics:

Heaviest
Largest
Bulkiest
Most fragile
Most hazardous
Costliest
Most awkward to handle
Items with most operations
Greatest quantity
Worst quality problems
Most customer complaints
Worst scrap or spoilage record

Selecting items this way oversimplifies the analysis since only a few rather than all the items are considered. Still, it is sometimes highly practical. See Figure 4-14.

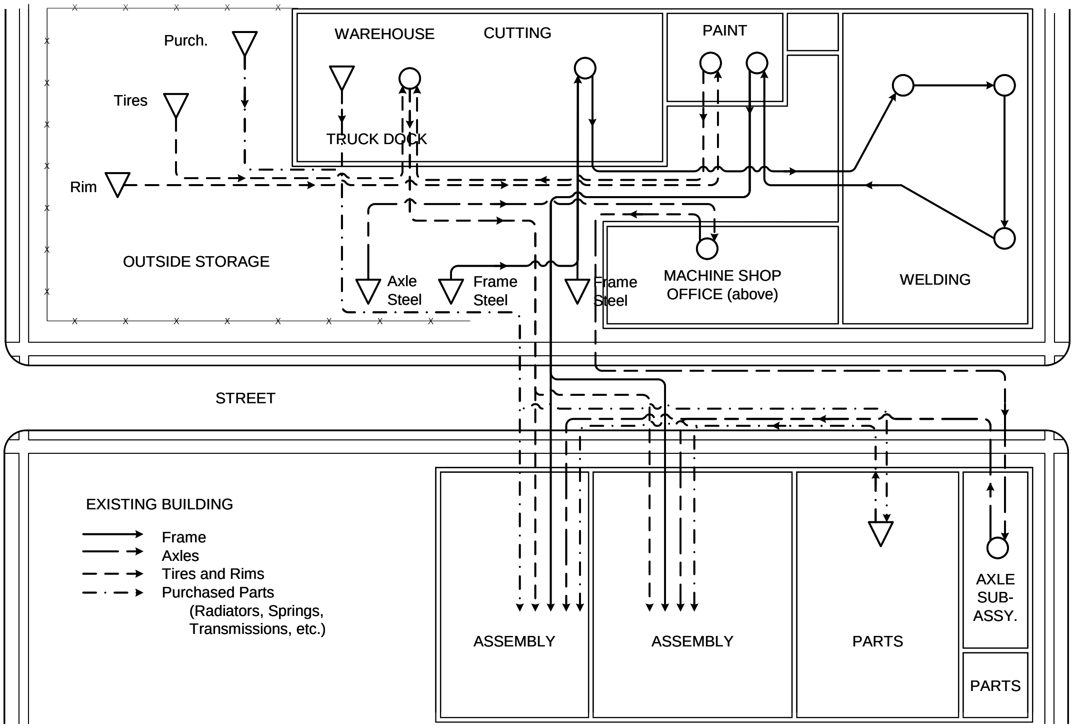


Figure 4-14. Flow diagram of an existing layout, showing the four items involving the greatest handling problems. This plant – divided in the middle by a street – had no process sheets to aid in determining its routings. Because of the need for a quick solution, the production manager selected two items each of the largest, heaviest, greatest quantity, most costly, and most awkward. These reduced to the four items with the worst materials handling problems. The manager diagramed their flow on the existing layout as shown. The necessity for these particular routings was challenged. Then the diagram was used as a basis for the proposed flow of material in the overall layout for a new plant.

The From-To Chart

Grouping or selecting gives way to the from-to chart when the products, parts, or materials under study are very numerous. The from-to chart is sometimes called a cross chart, and when distance is added to the values, it is termed a travel chart.

Figure 4-15 explains the from-to chart's structure. Listed on the rows and columns – in the same sequence – are all operations or work centers for all operations of the items being charted. Flows can be recorded in several ways, depending upon the purpose of the chart, the data and time available for analysis, and whether it is being completed with paper and pencil or in electronic form. In Figure 4-15, letters identify part movements. The numbers indicate the total count of part numbers (letters). An even simpler representation would be a strike mark for each part without letter identification. As noted earlier, if the parts are uniform and made in similar quantities and lots sizes, then the count of part numbers also represents intensity.

TO FROM	*Shear* 1	*Notch* 2	*Draw* 3	*Pierce* 4	*Bend* 5	*Trim* 6
Shear 1	--	*ABC* *3*	--	*EF* *2*	--	--
Notch 2	--	--	*BD* *2*	*AC* *2*	--	--
Draw 3	--	--	--	--	*BCD* *F 4*	*C* *1*
Pierce 4	--	--	*CEF* *3*	--	*A* *1*	--
Bend 5	--	--	--	--	--	*BDE* *3*
Trim 6	--	--	--	--	--	--

Figure 4-15. Making the From-To Chart. The from-to chart is made by listing the operations (or work centers) both down the side and across the top of the chart. Each intersecting box is used to record the movement *from* one operation *to* another. The routing of each product is traced by recording for each move it makes where it comes from and where it moves to. For example, if we take the same information shown on the multi-product process chart of Figure 4-11, we can post the movement as shown in this figure. Product A moves from Shear to Notch. We can record this by an "A" in the proper square. The material next moves from Notch to Pierce and again we note it on the chart by recording "A." This is done for each movement of the part. Similarly, each part is recorded. After all items have been recorded, the letters or quantities in each box are totaled and the total recorded there. This total, then, represents the degree of traffic flow between each pair of operations or work centers. This example is complete only for the routings shown in Figure 4-11.

Letters or part numbers or strike marks are impractical when summarizing the flows for dozens, hundreds or even thousands of parts or items. If sufficiently accurate and detailed part routings can be obtained in electronic form, the counts of parts moving between pairs of operations can possibly be extracted to populate the chart. If lot sizes and a production forecast (or history) are also available, counts can be extended to reflect work orders, jobs and perhaps estimated "moves" between pairs. Using Mag Count or similar factoring can refine the chart still further. This effort is often called production flow analysis (PFA). An example appears in Appendix III. A completed from-to chart appears in Figure 4-16.

FROM-TO-CHART

Item(s) Charted: *45 Representative Molded Parts*

Basis of Values: *(Q x Size x Care) / 1000*

Plant *South (Plastics Division)*
By *R.C.V.*
Date *8/10*

Project *15697*
With *M.R.J.*
Page *2* of *5*

Activity or Operation **TO** Activity or Operation **FROM**	*Mold* 1	*Normalize* 2	*Machine* 3	*Assembly* 4	*Spray* 5	*Machine Spray* 6	*Plate* 7	*Coat* 8	*Buff* 9	*Wash or Dip* 10	*Tumble* 11	*Stamp* 12	*Fill and/or Wipe* 13	*Pack* 14	*Ship* 15	16	**TOTAL**
1 *Mold*	--	*3 / 36*	*3 / 160*	*6 / 232*	*1 / 2*	*5 / 631*	*1 / 884*	--	--	--	*2 / 400*	*10 / 468*	--	--	*15 / 2222*		ⓐ *46 / 5025*
2 *Normalize*	--	--	--	--	*7 / 262*	--	*5 / 376*	--	--	*1 / 10*	--	*1 / 180*	*1 / 2*	*3 / 129*	*1 / 120*	--	*19 / 1079*
3 *Machine*	--	--	--	--	--	--	--	--	--	--	*2 / 152*	--	--	--	*1 / 8*	--	*3 / 160*
4 *Assembly*	--	--	--	*1 / 20*	--	--	--	--	--	--	--	--	--	--	*6 / 884*	--	*7 / 904*
5 *Spray*	--	*1 / 2*	--	--	*7 / 414*	--	*5 / 22*	--	*1/ 12*	--	--	*1 / 8*	*2 /168*	*1 / 76*	--	--	*18 /702*
6 *Machine Spray*	--	*9 /752*	--	--	--	--	--	--	--	--	--	--	--	--	*4 / 348*	--	*13 / 1100*
7 *Plate*	--	--	--	--	*1 / 8*	*5 / 376*	--	*6 / 910*	--	--	--	--	--	--	--	--	*12 / 1294*
8 *Coat*	--	--	--	--	*1/2*	--	--	--	*3 / 12*	--	--	--	--	*2 / 888*	--	--	*6 / 910*
9 *Buff*	--	--	--	--	--	--	--	--	--	--	--	--	--	*3 / 22*	*2 / 10*	--	*5 / 32*
10 *Wash or Dip*	--	--	--	--	--	--	--	--	--	--	--	--	--	*1 / 10*	--	--	*1/ 10*
11 *Tumble*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*4 / 552*	--	*4/552*
12 *Stamp*	--	*6 / 296*	--	*1 / 92*	--	*3 / 80*	--	--	*1 / 8*	--	--	*2 / 192*	--	*1 / 180*	--	--	*14 / 848*
13 *Fill and/or Wipe*	--	--	--	--	*1 / 2*	--	*1 / 12*	--	--	--	--	--	--	*1 / 156*	--	--	*3 / 170*
14 *Pack*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*12 / 1320*	--	*12 / 1320*
15 *Ship*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
18	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	*0*
TOTALS	*0*	*19 / 1076*	*3 / 160*	ⓐ *8 / 344*	*18 / 700*	*13 /1087*	*12 / 1294*	*6 / 910*	*5 / 32*	*1 / 10*	*4 / 552*	*14 / 848*	*3 / 170*	*12 / 1459*	ⓐ *45 / 5464*	*0*	*163/14,106*

NOTES:

ⓐ *45 parts (jobs) studied but 46 parts actually involved because one finished item involves two detail parts which are assembled together.*

In practice, it is difficult to use electronic routing data for several reasons. The work centers in the routing file must first be mapped to the planner's activity-areas. They may not reflect the latest operating changes. They may not show movement of scrap, re-work, and auxiliary materials and supplies; or stops at in-process storage, customer-returned goods, ends or leftovers sent back to storage, empty containers, and packing materials. These moves influence relationships, but are typically not found on route sheets or in electronic files. This means that using official company routings and electronic data more often than not fails to give a complete flow-of-materials analysis.

Warehouse or material handling control systems may be a better source if pick-up and delivery transactions can be obtained for a representative period. These "move tickets" will typically contain a "time stamp" and the part number that was moved. In this way, they represent actual routings. But if used to count "trips" you may unwittingly project the current material handling methods and practices into the flow analysis. It is generally better to measure the flow of materials themselves, or at least the containers or their cube, instead of trips or moves. Even when move data is readily available, it is useful to make at least some observations of moves actually made, provided existing operations are available. This can help to validate and calibrate electronic records. These and other issues relating to electronic data are discussed more fully in Appendix II.

Figure 4-16. Completed From-To Chart for a plant making a variety of decorated plastic products on a customer-order basis. Two figures have been posted (by hand) in each "box" (intersection) where flow of material is involved. The figure to the left of the slant line represents the number of parts (part numbers) making that particular move. The figure to the right of the slant line represents the actual intensity of flow. The intensity was established in this case by multiplying the annual quantity by the size of each item and the handling care required. Arbitrary scales were used to measure both size and care – similar to those values shown in Figure 4-9 and used in the Mag Count (see Appendix I).

Receiving and Incoming Stores are not shown, inasmuch as all materials start their first operation in Molding. Also, a selection of items, rather than all items, was made and applied to this chart.

This chart indicates that it is most important to have Molding close to Shipping (2222 units of flow intensity). Next most important is Pack to Ship (1320). Note that while this indicates direction of the flow, the total intensity of movement between any two operations results from going to and coming back. For example, Normalize to Stamp is 1/180 and Stamp to Normalize is 6/296 – and therefore the total intensity is 476.

In piece-part processing, the number of *parts* going to an operation should equal the number coming from that operation, but the *intensity* figures to and from a given operation will not be equal if processing changes the form or shape of the items or their handling care. Also small, non-molded parts are excluded from this example, yet they go to Assembly where they are added to the molded products. This further contributes to an intensity difference of 344 *to* and 904 *from* Assembly. As recorded in the chart notes, eight parts go *to* Assembly and seven come *from* Assembly. This is because two molded parts are joined there. As a result, even the number of items differ going *to* and coming *from*.

Boxes 4-4, 5-5 and 12-12 indicate duplicate operations within the same activity-area. These could just as easily be omitted without harm to the flow analysis and overall layout plan.

Note again that each figure in the text having a form number in the lower left corner (as this Figure 4-16 has a form number 136) will be found in the Working Forms section at the back of this book and in electronic form at www.RichardMuther.com

When time is short or electronic data is not readily available for large-scale analysis, planners may simply estimate and enter flow values, based on their knowledge of routings, material movements, and expected volumes. For more precision, estimates can be made by class of material or type of part, or by value stream, or by type of move – each perhaps on its own from-to chart – and then totaled. When estimating, be sure to involve the people closest to and making the moves – handling engineers, materials management personnel and material handlers themselves. Have them help you make and/or confirm flow estimates.

The From-To Chart in SLP

The from-to chart is a time-honored and flexible tool of flow analysis. As noted, it should be used when there are too many items and flows for process charting. It can record flows between stations or machines, work centers, departments, to and from docks, or other areas of interest. Technically, it is not mandatory that the rows and columns match. However, when using the chart in SLP, always be sure that operations listed on rows and columns match and correspond to the list of activity-areas defined in Section 1 of the SLP Pattern. Do not skip, omit, combine or break out.

Recognize that the chart shows exactly what it says – flow *from* each activity-area *to* every other. Flows are stated in terms of direction "from – to." In progressive manufacturing, most pairs will have flow in one direction only. Some will have flow in both directions. If the activities were listed in an effective order, flow values that are above a diagonal from upper left to lower right corners of the chart represent moves toward completion. Flows in boxes below the diagonal show counter-flow.

Good layout minimizes counter-flow and the distance between those activity-areas with the highest flow *between* them. As shown in Figure 4-17, this requires the layout planner to find and add the flows *in both directions* between each pair of operations.

	TO:	1	2	3	4	5	6
No.	**Activity-Area** **FROM:**	Logistics Area	Soft Housing - Pump	ECM Areas HH soft & hard; Hou	Heat Treat	Hard Housing - Pump	Drive Shaft - Soft Pump
		1	2	3	4	5	6
1	Logistics Area		4	3	0	0	2
2	Soft Housing - Pump	3		4	0	0	0
3	ECM Areas HH soft & hard; Housing	2	0		4	0	0
4	Heat Treat	0	0	3		4	0
5	Hard Housing - Pump	0	0	0	0		0
6	Drive Shaft - Soft Pump	1	0	0	2	0	
7	Drive Shaft - Hard Pump	0	0	0	0	0	0

			Flow Between		
No.	**Activity-Pair**		**From - To**	**To - From**	**Two-Way Flow**
1	1	2	4	3	7
2	1	3	3	2	5
3	1	6	2	1	3

Figure 4-17. Combining two-way flows. Flows in each direction are found by inspection and added. This adding and posting can be automated in an electronic spreadsheet.

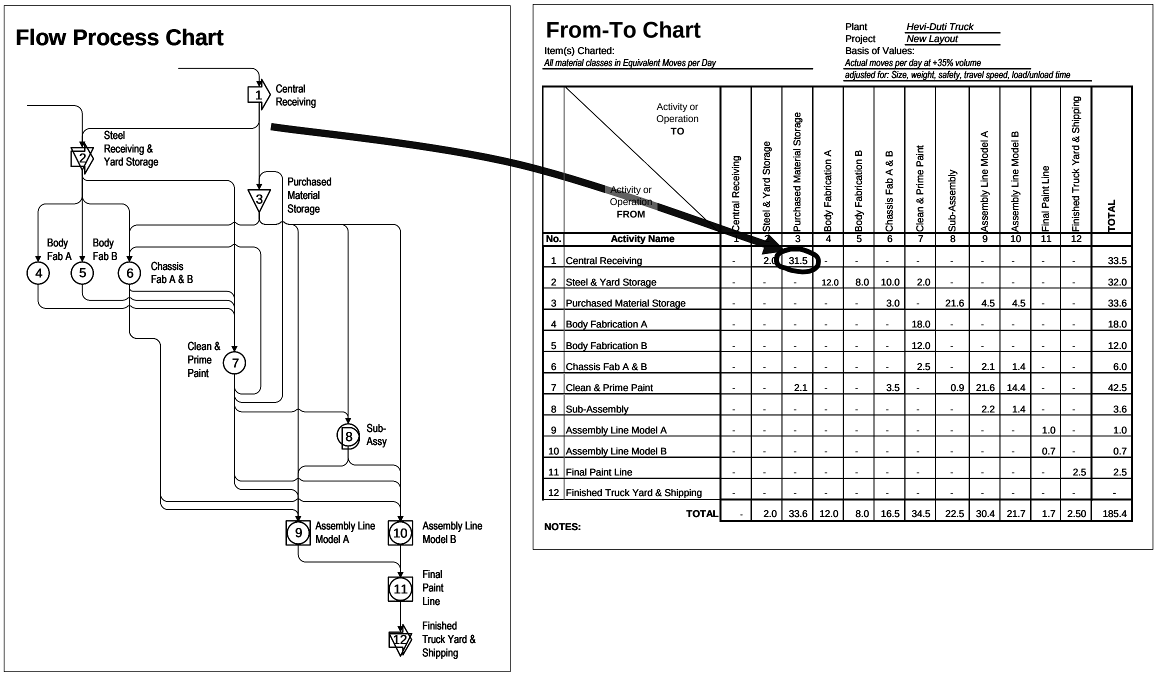
Always keep in mind that each total *two-way* flow (from-to plus to-from) represents a relationship, or relative closeness desired, between the particular pair of operations or activity-areas. The from-to chart thus establishes which activity-areas should be closest together for reason of material flow.

Using the From-To Chart to Summarize a Flow Analysis

In SLP, the from-to chart is often used as a summary document, with flows posted from operation process charts and multi-product process charts. Route charts and flow-in/flow-out charts illustrated in Figures 4 and 5 of Appendix II may also be useful.

If a process chart has been constructed to show flow between activity-areas – meaning its symbols correspond to the numbered list of activity-areas – then each connecting line on the process chart will correspond to a box in the from-to chart. See Figure 4-18. This discipline prevents oversights. There should be no "orphans" on the process chart (lines without a flow value on the from-to) and none on the from-to (flow values without a connecting line in the process chart). If desired, flow values on the from-to chart can be written next to the flow lines on the process chart.

Recall our earlier discussion on intensity of flow. For best results in SLP, the summary from-to chart should use an appropriate unit of measure – one that captures relative differences in the size, weight, shape, risk, and condition of items being moved, and their impact on material handling effort and cost. With such a relative-value chart, the planner can see more clearly which activities should be close to one another and how they should be arranged for optimum flow.



From-To Chart

Item(s) Charted:
All material classes in Equivalent Moves per Day

Plant *Hevi-Duti Truck*
Project *New Layout*
Basis of Values:
Actual moves per day at +35% volume
adjusted for: Size, weight, safety, travel speed, load/unload time

No.	Activity Name (Activity or Operation FROM / Activity or Operation TO)	Central Receiving 1	Steel & Yard Storage 2	Purchased Material Storage 3	Body Fabrication A 4	Body Fabrication B 5	Chassis Fab A & B 6	Clean & Prime Paint 7	Sub-Assembly 8	Assembly Line Model A 9	Assembly Line Model B 10	Final Paint Line 11	Finished Truck Yard & Shipping 12	TOTAL
1	Central Receiving	-	2.0	31.5	-	-	-	-	-	-	-	-	-	33.5
2	Steel & Yard Storage	-	-	-	12.0	8.0	10.0	2.0	-	-	-	-	-	32.0
3	Purchased Material Storage	-	-	-	-	-	3.0	-	21.6	4.5	4.5	-	-	33.6
4	Body Fabrication A	-	-	-	-	-	-	18.0	-	-	-	-	-	18.0
5	Body Fabrication B	-	-	-	-	-	-	12.0	-	-	-	-	-	12.0
6	Chassis Fab A & B	-	-	-	-	-	-	2.5	-	2.1	1.4	-	-	6.0
7	Clean & Prime Paint	-	-	2.1	-	-	3.5	-	0.9	21.6	14.4	-	-	42.5
8	Sub-Assembly	-	-	-	-	-	-	-	-	2.2	1.4	-	-	3.6
9	Assembly Line Model A	-	-	-	-	-	-	-	-	-	-	1.0	-	1.0
10	Assembly Line Model B	-	-	-	-	-	-	-	-	-	-	0.7	-	0.7
11	Final Paint Line	-	-	-	-	-	-	-	-	-	-	-	2.5	2.5
12	Finished Truck Yard & Shipping	-	-	-	-	-	-	-	-	-	-	-	-	-
	TOTAL	-	2.0	33.6	12.0	8.0	16.5	34.5	22.5	30.4	21.7	1.7	2.50	185.4

NOTES:

Figure 4-18. In this example, the From-To Chart is being used as a convenient way to the record flow intensity for each route defined on the Flow Process Chart. This is an optional use of the From-To Chart. Intensities could simply be added to the flow lines on the Flow Process chart.

Populating a from-to chart can be tedious. It is easy to get bogged down on minor flows and insignificant differences in relative flow. Shop floor people will be inclined to identify every flow that they can think of, including occasional and unusual exceptions to normal flow. This wastes time, wears everyone out and results in charts with unnecessary and cumbersome detail. They may even obscure the important relationships. In this regard, “data dumps” from a routing file into a spreadsheet may be even worse. The flow analyst must be prepared to exercise judgment and limit unnecessary or extraneous detail.

A practical, time-saving tactic is to “interpolate” flows once a few, key routes have been carefully measured or estimated – ideally some with high flow, some medium, and some low. Remaining routes can be quickly rated “about the same as…” or “about twice” or “about half as much as”. Here, the involvement of those making the moves is invaluable. Remember that in layout planning we are seeking relative flow and relative closeness desired. Differentiation of “abnormally high” from “important” or “ordinary” is more valuable than a precise estimate of the actual flow.

Recognize that the sums of flows to and from each activity-area can be confusing. They will balance when the physical form or handling difficulty of the material is unchanged by the process, so that what leaves is more or less the same in mass and handling effort as what goes in. Stock room flows exhibit balance unless the stockroom performs significant kitting, re-pack or order-picking. But in the case of progressive forming operations or disassembly, more may come out than goes in. And in assembly areas, more may enter than leaves. In areas such as treating or painting, the mass may balance but the “equivalent” flow in and out may differ based on change in condition, risk and handling effort.

There are various aids to interpreting the from-to chart, once it is made and the two-way total flows established. The pairs of activity-areas are ranked, based on the intensity of flow, starting with the largest and proceeding to the smallest flow. These ranked pairs indicate the order of the most important relationships. Another aid is calculating and recording the percentage-of-total flow intensity that each pair accounts for, which yields a measure of the relative importance of the flow between each pair. SLP takes this a step further with the use of a vowel-letter rating convention described below.

Converting Flow of Materials to Simple Convention

Because of the difficulty and time required to compare and visualize a great many numerical values, SLP converts its flow-of-materials intensities into a common rating system. The rating conventions are:

A	*A*bnormally high intensity of flow
E	*E*specially high intensity of flow
I	*I*mportant intensity of flow
O	*O*rdinary intensity of flow
U	*U*nimportant moves of negligible intensity

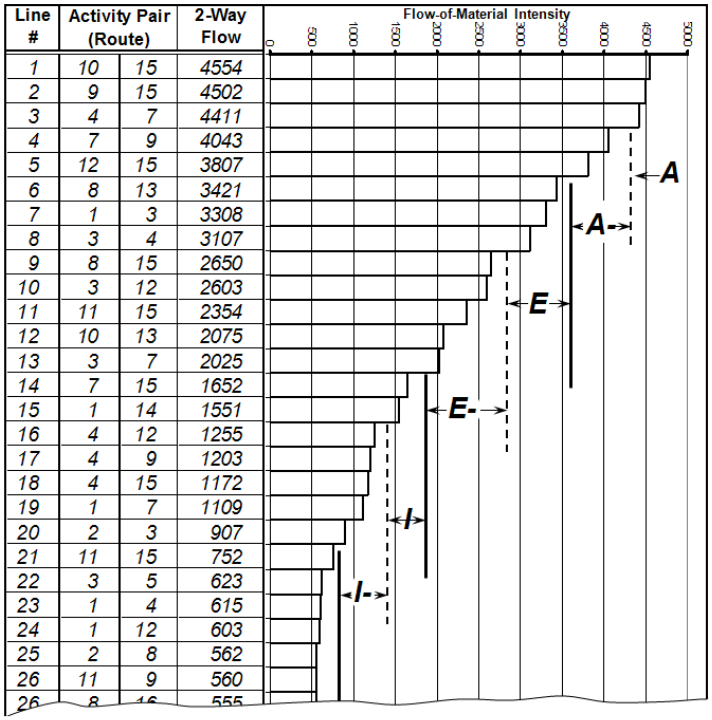
By grouping the quantified flow-of-materials intensities into this vowel-letter scale of values – and its cross-indexed number-of-lines convention, described in Chapter 6 – the planner can more readily find and work with the flow data. To give more precision in half degrees of flow intensity, add a minus sign to each vowel letter (A, A-, E, E-, I, I-, O, O-).

Mathematically, this gives a range of accuracy of plus-or-minus six-and-a-quarter percent (± 6¼%), which is usually well within the accuracy of the method or unit of measurement of the materials being moved or of the forecast quantities on which the flow-of-materials intensity numbers are calculated (that is, on the P and Q input data).

Converting to the vowel-letter convention is a fairly simple problem of calibrating (see Figure 4-19).

1. Identify each route by activity-areas serving as the origin and destination of the move (always keeping lowest number at left).
2. Complete a common-denominator measurement for the total flow of material (all products or materials in both directions) for each route (or pair of activity-areas).
3. Rank, in descending order of magnitude, the flow intensity for each route.
4. Plot the intensity of each route on a bar chart or graph.
5. Divide the bars at logical break points, recognizing that the A's may bracket perhaps only 10% of the highest routes (but the top 40% of intensity values) and that the O's may bracket intensity values of perhaps only 10% of the largest value (but the lowest 40% of the routes).
6. Draw division lines to indicate the range of vowel-letter ratings, using minus-sign ratings for degrees of flow intensity in between full vowel letters if appropriate.

With these five ranges (or classes), A, E, I, O, U, of flow intensity – nine if half degrees (minus-sign ratings) are used – each route is put into a simple, realistic, order-of-magnitude relationship, ready for subsequent use in comparing closeness desired among the various activity-areas.

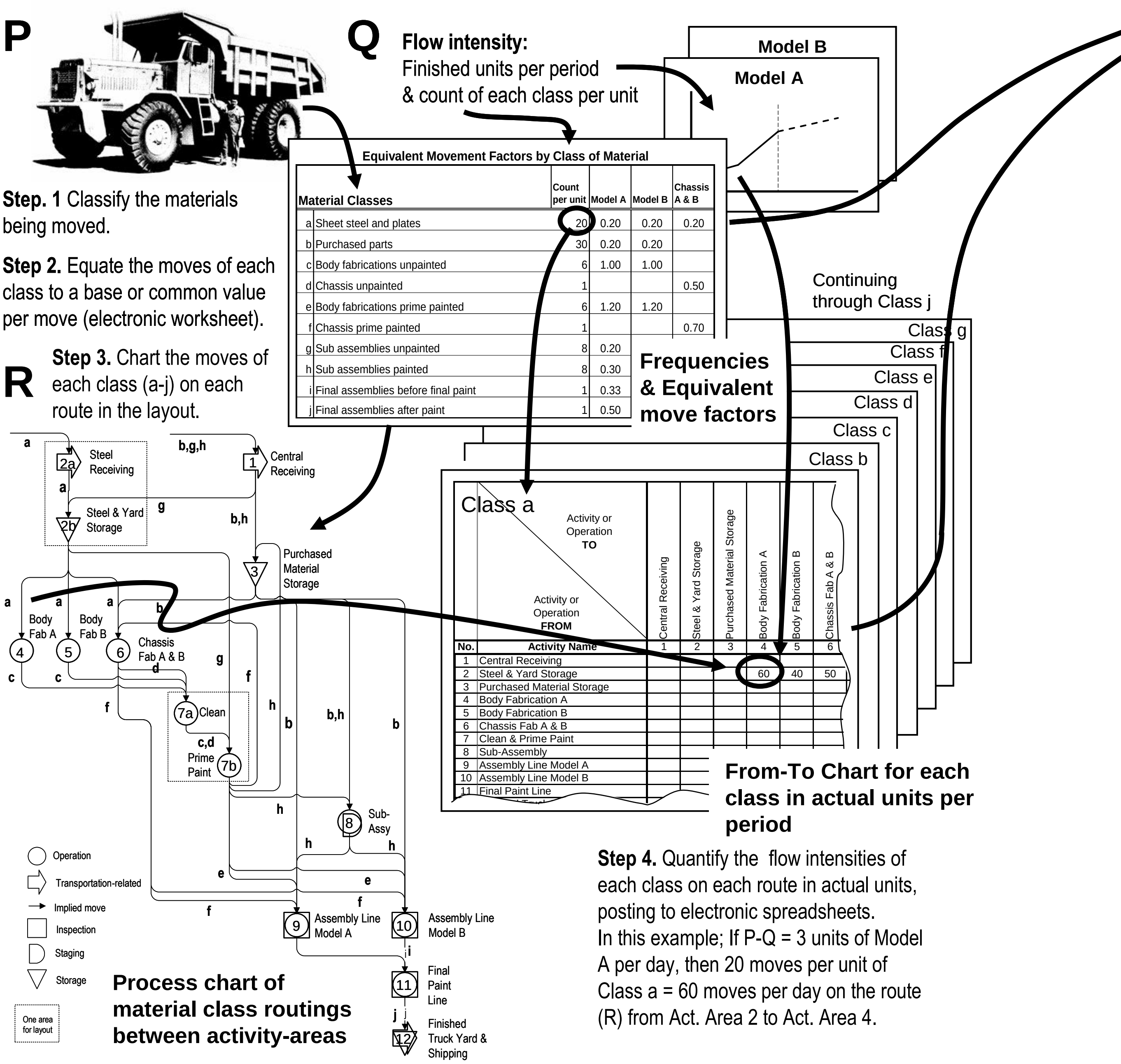


Line #	Activity Pair (Route)		2-Way Flow
1	10	15	4554
2	9	15	4502
3	4	7	4411
4	7	9	4043
5	12	15	3807
6	8	13	3421
7	1	3	3308
8	3	4	3107
9	8	15	2650
10	3	12	2603
11	11	15	2354
12	10	13	2075
13	3	7	2025
14	7	15	1652
15	1	14	1551
16	4	12	1255
17	4	9	1203
18	4	15	1172
19	1	7	1109
20	2	3	907
21	11	15	752
22	3	5	623
23	1	4	615
24	1	12	603
25	2	8	562
26	11	9	560
26	8	16	555

Figure 4-19. Calibrating or converting flow-of-material intensities against the vowel-letter rating scale.

Electronic Spreadsheets in Flow of Materials Analysis

Electronic spreadsheets can be useful when the flow analysis involves diverse classes of material. The equivalent movement factors for each material class are recorded in a worksheet. Actual moves are recorded on separate from-to charts (worksheets) – one for each class. In the cells of a summary worksheet, each actual move on each class worksheet is multiplied by its appropriate value on the equivalent factor worksheet and then summed. The result is a from-to chart of equivalent flows. An illustration appears here in Figure 4-20, including subsequent calibration of equivalent two-way flows. Step numbers refer to the procedure in Figure 4-21.



Flow intensity: Finished units per period & count of each class per unit

Step. 1 Classify the materials being moved.

Step 2. Equate the moves of each class to a base or common value per move (electronic worksheet).

Step 3. Chart the moves of each class (a-j) on each route in the layout.

Equivalent Movement Factors by Class of Material

	Material Classes	Count per unit	Model A	Model B	Chassis A & B
a	Sheet steel and plates	20	0.20	0.20	0.20
b	Purchased parts	30	0.20	0.20	
c	Body fabrications unpainted	6	1.00	1.00	
d	Chassis unpainted	1			0.50
e	Body fabrications prime painted	6	1.20	1.20	
f	Chassis prime painted	1			0.70
g	Sub assemblies unpainted	8	0.20		
h	Sub assemblies painted	8	0.30		
i	Final assemblies before final paint	1	0.33		
j	Final assemblies after paint	1	0.50		

Frequencies & Equivalent move factors

Class a

Activity or Operation TO

Activity or Operation FROM

No.	Activity Name	Central Receiving 1	Steel & Yard Storage 2	Purchased Material Storage 3	Body Fabrication A 4	Body Fabrication B 5	Chassis Fab A & B 6
1	Central Receiving						
2	Steel & Yard Storage				60	40	50
3	Purchased Material Storage						
4	Body Fabrication A						
5	Body Fabrication B						
6	Chassis Fab A & B						
7	Clean & Prime Paint						
8	Sub-Assembly						
9	Assembly Line Model A						
10	Assembly Line Model B						
11	Final Paint Line						

From-To Chart for each class in actual units per period

Step 4. Quantify the flow intensities of each class on each route in actual units, posting to electronic spreadsheets.
In this example; If P-Q = 3 units of Model A per day, then 20 moves per unit of Class a = 60 moves per day on the route (R) from Act. Area 2 to Act. Area 4.

Process chart of material class routings between activity-areas

Figure 4-20. Flow of materials analysis using electronic spreadsheets. See also Figure 4-21 for procedures.

Step 5. Convert flows in actual units to equivalent units and sum for all classes. (If all classes are uniform, simply sum). Post to electronic spreadsheet.

```
='Class a'!F10*0.2
+'Class b'!F10*0.2
+'Class c'!F10*1
+'Class d'!F10*0.5
+'Class e'!F10*1.2
+'Class f'!F10*0.7
+'Class g'!F10*0.2
+'Class h'!F10*0.3
+'Class i'!F10*0.33
+'Class j'!F10*0.5
```

Actual move of each class at column F and row 10 multiplied by its equivalent move factor. Here: 60*0.2=12.0 equivalent moves/day.

FROM-TO-CHART **P-Q-R**

Item(s) Charted:
All material classes in Equivalent Moves per Day

Plant *Hevi-Duti Truck*
Project *New Layout*
Basis of Values:
Actual moves per day at +35% volume
adjusted for: Size, weight, safety, travel speed, load/unload time

No.	Activity or Operation TO Activity or Operation FROM Activity Name	Central Receiving 1	Steel & Yard Storage 2	Purchased Material Storage 3	Body Fabrication A 4	Body Fabrication B 5	Chassis Fab A & B 6	Clean & Prime Paint 7	Sub-Assembly 8	Assembly Line Model A 9	Assembly Line Model B 10	Final Paint Line 11	Finished Truck Yard & Shipping 12	TOTAL
1	Central Receiving	-	2.0	31.5	-	F10	-	-	-	-	-	-	-	33.5
2	Steel & Yard Storage	-	-	-	12.0	8.0	10.0	2.0	-	-	-	-	-	32.0
3	Purchased Material Storage	-	-	-	-	-	3.0	-	21.6	4.5	4.5	-	-	33.6
4	Body Fabrication A	-	-	-	-	-	-	18.0	-	-	-	-	-	18.0
5	Body Fabrication B	-	-	-	-	-	-	12.0	-	-	-	-	-	12.0
6	Chassis Fab A & B	-	-	-	-	-	-	2.5	-	2.1	1.4	-	-	6.0
7	Clean & Prime Paint						5	-	0.9	21.6	14.4	-	-	42.5
8	Sub-Assembly							-	-	2.2	1.4	-	-	3.6
9	Assembly Line Model A							-	-	-	-	1.0	-	1.0
10	Assembly Line Model B							-	-	-	-	0.7	-	0.7
11	Final Paint Line							-	-	-	-	-	2.5	2.5
12	Finished Truck Yard & Shipping	-	-	-	-	-	-	-		-	-	-	-	-
	TOTAL	-	2.0	33.6	12.0	8.0	16.5	34.5	22.5	30.4	21.7	1.7	2.50	185.4

Summary From-To Chart for all classes in equivalent units per period

NOTES:

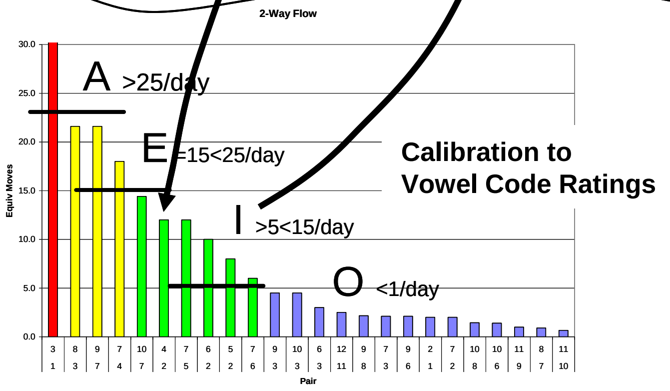
Steps 6 & 7. Total flows in both directions when present, then rank (sort descending) in an electronic spreadsheet.

Line #	Activity-Pair				Two-Way Flow				Flow Rating		
	From	Activity-Area	To	Activity-Area	From	To	From-To	To-From	2-Way	Vowel Rating	Value
1	1	Central Receiving	3	Purchased Material Storage	1	3	31.5	0.0	31.5	A	4
2	3	Purchased Material Storage	8	Sub-Assembly	3	8	21.6	0.0	21.6	E	3
3	7	Clean & Prime Paint	9	Assembly Line Model A	7	9	21.6	0.0	21.6	E	3
4	4	Body Fabrication A	7	Clean & Prime Paint	4	7	18.0	0.0	18.0	E	3
5	7	Clean & Prime Paint	10	Assembly Line Model B	7	10	14.4	0.0	14.4	I	2
6	2	Steel & Yard Storage	4	Body Fabrication A	2	4	12.0	0.0	12.0	I	2
7	5	Body Fabrication B	7	Clean & Prime Paint	5	7	12.0	0.0	12.0	I	2
8	2	Steel & Yard Storage	6	Chassis Fab A & B	2	6	10.0	0.0	10.0	I	2
9	2	Steel & Yard Storage	5	Body Fabrication B	2	5	8.0	0.0	8.0	I	2
10	6	Chassis Fab A & B	7	Clean & Prime Paint	6	7	2.5	3.5	6.0	I	2
11	3	Purchased Material Storage	9	Assembly Line Model A	3	9	4.5	0.0	4.5	O	1
12	3	Pur			3	10	4.5	0.0	4.5	O	1
13	3	Pur			3	6	3.0	0.0	3.0	O	1
14	11	Fin			11	12	2.5	0.0	2.5	O	1
15	8	Sub			8	9	2.2	0.0	2.2	O	1
16	3	Pur			3	7	0.0	2.1	2.1	O	1
17	6	Cha			6	9	2.1	0.0	2.1	O	1
18	1	Central Receiving	2	Steel & Yard Storage	1	2	2.0	0.0	2.0	O	1
19	2	Steel & Yard Storage	7	Clean & Prime Paint	2	7	2.0	0.0	2.0	O	1
20	8	Sub-Assembly	10	Assembly Line Model B	8	10	1.4	0.0	1.4	O	1
21	6	Chassis Fab A & B	10	Assembly Line Model B	6	10	1.4	0.0	1.4	O	1

Closeness Relationships for Reason of Material Flow, rated and listed in order of relative closeness desired.

Step 8. Plot the ranked 2-way flows. (Insert a bar chart into the electronic spreadsheet).

Step 9. Inspect for natural break-points and calibrate into vowel-code ratings: A,E,I,O,U.



Calibration to Vowel Code Ratings

PROCEDURE FOR FLOW-OF-MATERIALS ANALYSIS

1. Classify the materials that move through the layout.
    a. Make a list of representative items, parts, or products moving through the layout. Don't overlook packaging materials, scrap, waste, empty containers and pallets.
    b. Group the items into classes based on similar physical characteristics and transportability: size, weight, shape, risk of damage, condition, value, control...
    c. Assign a lower-case letter to each class.
2. Equate the movement of each material class to a common unit of measure.
    a. If all classes are similar in their transportability, establish a single unit of measure for flow intensity and go to Step 3.
    b. If the classes are diverse, let a move or unit of the dominant or most-handled, or most significant class be the base unit, meaning each of its moves counts as one.
    c. Equate the moves or units of each other class to the base, considering the effort required to move them when compared to the base. Harder or more effort means each move counts more than the base (>1); less effort or easier means each move counts less.
    d. If the handling methods are known, determine relative effort by considering such factors as: size and weight of load, travel speed and time, number of handlers required, risk, danger and safety…
    e. If the handling methods are not yet known or established, use a measure of transportability such as Mag Count and work directly from the characteristics of the materials themselves.
3. Chart the movements of each class through the layout.
    a. Make an operation or flow process chart and label each flow line with the appropriate class-of-material letters moving on that route.
    b. If a process chart is impractical due to complexity or number of moves, consider using a subset of material classes, or select the most critical. Or, use a from-to chart. Flag each box where moves occur and flow intensity is needed.
    c. If your classes are diverse in terms of their transportability, or if you wish to isolate individual classes, then use one from-to chart for each class.
4. Quantify the flow intensities of each class on each route.
    a. Set an appropriate time period for flow intensity: i.e. per hour, peak hour, shift, day, week, month, year…
    b. Use P-Q data and projections to estimate the flow per period of each class on each route. Record these on your process chart or from-to chart(s) for each class.
5. Sum the intensities (flows per period) or equivalent intensities of all classes on each route, posting to the process chart, or to a list of routes, or to a summary from-to chart.
6. Total the flows in both directions when these occur between a pair of activity-areas.
7. Rank the two-way flows between activity pairs.
8. Plot the ranked flows in descending order of flow intensity.
9. Inspect the plot for natural break-points and calibrate into vowel code-ratings: A, E, I, O, U.

Figure 4-21. Procedure for flow-of-materials analysis. The previous Figure 4-20 illustrates this procedure for a particular case.

Chapter 5
Other Than Flow Relationships

In most industrial plants the emphasis is commonly placed on flow of material as the basis for layout arrangement. This has been fully discussed. A flow pattern is determined and diagramed (based on the techniques shown in Chapters 4 and 6) and the rest of the activities are then fitted in and around that pattern. Actually, this is not the best practice as a *general rule* for layout procedure.

Flow Alone Not Best Basis for Layout

There are several reasons that the flow of material – as determined predominantly by the routing – cannot be the sole basis for layout arrangements.

1. The supporting services must integrate with the flow in an organized way. This integration results from total analysis – analysis of the reasons that certain supporting activities should be close to certain producing or operating areas. The maintenance crib, the superintendent's office, the locker and rest room, and the transformer bank, all have a relatively preferred closeness to each of the producing areas and to one another. They are all part of the layout; they must be planned into it, yet they are not part of the flow materials.
2. Frequently, flow of material is relatively unimportant. In some electronic or jewelry plants, only a few pounds of material will be transported during an entire day. In other industries, materials are piped, or one skid-load lasts a worker all week.
3. In completely service industries, office area, or maintenance-and-repair shops, there is often no real or definitive flow of material. Therefore, any general rule must offer a way of relating areas to one another without reference to material flow. And this is true even if we recognize that paper work, equipment, or even people can be considered as the "material" that flows.
4. Additionally, in heavy materials-movement plants, where the influence of material flow will dominate the layout planning, flow will not be the sole basis for arranging the process operations and equipment. Basically, we chart flow to determine the sequence of operations or which departments should be near one another. But flow of materials is only one reason for this closeness. There are many others, which may conflict with or at least cause adjustments in the closeness as based on the analysis of flow. For example, the routing may call for the sequence: form, trim, treat, subassembly, assembly, and pack. For best flow of material, treating should lie between trimming and subassembly. But treating is both a very dirty and a dangerous operation. Therefore, it should be kept away from the delicate subassembly area and its high concentration of workers. The effect of factors like these *and* the distribution of utilities, the cost of controlling quality, product contamination,

and the like must be compared with the importance of material flow and adjustments made as practical.

In any case, some systematic way of *relating service activities to one another* and of *integrating supporting services with the flow of material* is necessary. The Relationship Chart is the best method of meeting this need. This chart is completed in Section 2 of the SLP pattern of procedures through Activity Relationship Analysis.

As discussed in the preceding Chapter 4, Flow-of-Materials Analysis is based on P, Q, and R. Activity Relationship Analysis draws on P, Q, and S. T (time) is involved in both, as in all analyses to some extent.

The Relationship Chart

The relationship chart is a cross-section form where the relationship between each activity[1] (or function or area) and all other activities can be recorded. The basis of the form is shown in Figure 5-1.

The relationship chart shows which activities have a relationship to others. Also, it rates the importance of the closeness between them and supports the rating with coded back-up reasons. These measures make the relationship chart one of the most highly practical and effective tools available for layout planning. It is undoubtedly the best way of integrating supporting services with the operating or producing departments and of planning the arrangement of office or service areas having little or no flow of materials.

The chart itself is almost self-explanatory. Where the activity on down-sloping line 1 intersects the activity represented by up-sloping line 3, the relationship between activity 1 and activity 3 is recorded. In this way, there is an intersecting "box" for each pair of activities involved. The basic idea is how to show which activities should be located close together and which far apart, with all in-between relationships also rated relatively and recorded.

The chart can be likened to a from-to chart which has been folded diagonally so that the from-to and the to-from boxes fall on top of each other. The relationship chart thus shows the total relationship, i.e., in both directions.

Further use of the form is illustrated in Figure 5-2. Note that each box is divided horizontally. The upper part is for the closeness-rating value. The lower half is for

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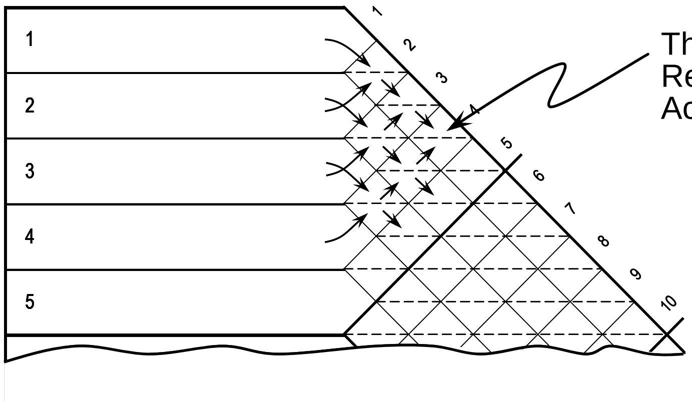
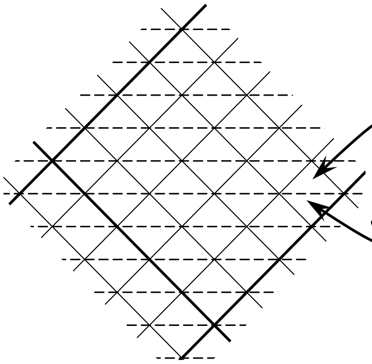
[1] The word "Activity" is a universal term, used throughout this book to designate "things" (other than people and process material) to be located as part of the layout planning. It encompasses, at different levels of planning or in different situations: department, area, function, work center, building, building feature, machine group, operation, and the like.

Figure 5-1. The basis of the Relationship Chart. All activities (areas or features) are listed at the left on lines 1,2,3, etc. Each activity-line slopes away from the list. Where the down-sloping line 1 intersects the up-sloping line 3, record the required (or desired) relation between Activity 1 and Activity 3. As indicated in b, the vowel-letter rating (c) and number-code supporting reasons for each rating (d) are placed respectively in the top or lower half of each intersecting box.



This “Box” shows the Relationship between Activity 1 and 4.

a



Top half of box shows importance of relationship.

Lower half shows reason(s) for importance.

b

VALUE	RELATIONSHIP
A	Closeness absolutely necessary
E	Closeness especially important
I	Closeness important
O	Ordinary closeness OK
U	Closeness unimportant
X	Closeness not desirable

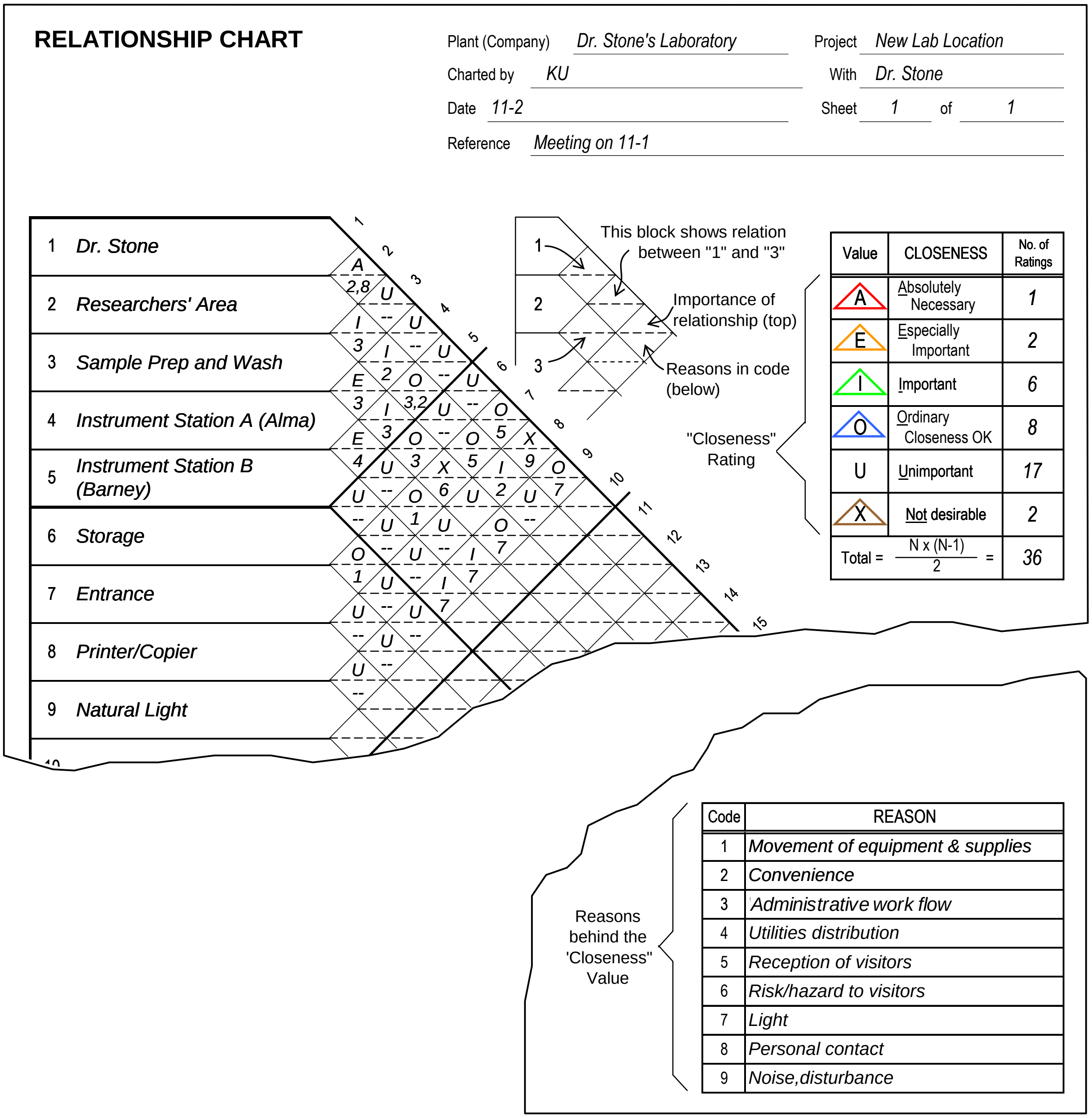
Rate the importance of relative closeness required (or desired) between each pair of activities, using the vowel-letter value scale.

c

Code	REASON
1	
2	
3	
4	
5	
6	
7	
8	
9	

Support the closeness rating with reasons – listing each reason on a line and entering the respective code number (s) for the reason in lower half of appropriate box.

d



RELATIONSHIP CHART

Plant (Company) *Dr. Stone's Laboratory*

Project *New Lab Location*

Charted by *KU*

With *Dr. Stone*

Date *11-2*

Sheet *1* of *1*

Reference *Meeting on 11-1*

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	*1*
E	Especially Important	*2*
I	Important	*6*
O	Ordinary Closeness OK	*8*
U	Unimportant	*17*
X	Not desirable	*2*
Total =	$\frac{N \times (N-1)}{2}$ =	*36*

Code	REASON
1	*Movement of equipment & supplies*
2	*Convenience*
3	*Administrative work flow*
4	*Utilities distribution*
5	*Reception of visitors*
6	*Risk/hazard to visitors*
7	*Light*
8	*Personal contact*
9	*Noise,disturbance*

Figure 5-2. The Relationship Chart is extremely effective for planning all activities not tied together with a significant flow pattern. This chart was prepared for a laboratory conducting chemical research on the composition of rock and dinosaur bone samples. It indicates that Dr. Stone must be near the Researchers' Area, with minor desires to be close to the Entrance and to Natural Light (outside windows) The chart also indicates that Dr. Stone's office should be separated from the Printer/Copier. Reasons are filled in and recorded in lower half of the appropriate boxes. It is normally not necessary, in charting relationships, to include windows or other generally available features or equipment. Natural Light is included here primarily to indicate the degree of detail to which the planner can go if need be.

recording the reason(s) for the designated closeness value. A rating and reason(s) for each relationship is thus recorded.

Closeness is rated according to a value scale A, E, I, O, U, and X. A indicates closeness absolutely necessary; X indicates closeness is undesirable and the activities should be kept apart. E, I, O, and U each indicate varying degrees of closeness.

The vowel letters used for closeness rating have been selected with considerable thought.

1. The letters themselves have meaning (in English). A is for *A*bsolutely necessary; E is for *E*specially important; I for *I*mportant; O for *O*rdinary closeness; U for *U*nimportant; and X, the accepted symbol for wrong, stands for a negative degree of closeness – not desirable.
2. A, E, I, O, and U are vowels most people have memorized in sequence and therefore, are easy to remember in the closeness-rating context.
3. Numbers were not chosen because they imply an accuracy greater than the rating actually has. Moreover, numbers are used to code the reasons and identify the activities. It would confuse the chart to use them also for rating.

The closeness rating is more meaningful when reasons are tied to the rating. For each reason, a code number is assigned and an explanation is recorded in the "reason block" on the sheet. That code number is then entered in its appropriate box(es). This way, two or three reasons can be marked in a relationship box without too much crowding. With this form, a great deal of information is gathered on one page without the need for lengthy notes.

Most reasons for closeness or distance between activities boil down into eight or ten for any one project. (More room is allowed on the form for additional reasons, or additional reason lines can be added to the form if needed.)

Although many terms may be used and many other reasons are possible, typical reasons supporting relationship ratings include the following:

1. Flow of materials*
2. Need for personal contact
3. Use same equipment
4. Use common records
5. Share same personnel
6. Supervision or control
7. Frequency of contact
8. Urgency of service
9. Cost of utility distribution
10. Use same utilities
11. Degree of communicative or paperwork contact
12. Specific management desires or personal convenience

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*As we shall see later on, there is value in saving reason 1 for flow of materials.

Color Coding

Recording ratings and reasons should be done in black text. But, because letters or symbols become confusing when used in profusion, the charted information can be more readily applied if the ratings are flagged in color. Therefore, each box on the chart should be outlined or filled with a coded color. The SLP conventions include the following color code:

A – red
E – orange or yellow
I – green
O – blue
U – uncolored
X – brown

These colors follow the order of the spectrum so their sequence is easy to remember.

For ease in marking the colors and in reading the chart, and since color represents closeness ratings, not reason(s), the colors are used only in the upper half of each box. See Figure 5-3.

The method of coloring depends upon whether the chart is being completed with pencil and paper, or entered directly into an electronic spreadsheet or other electronic document. On paper, add color after the original recording of ratings and reasons. This saves shifting colored pencils while making the chart yet allows color to simplify the problem of "reading" the assembled data. When coloring an electronic spreadsheet, most planners find it easier and faster to apply the color as the rating is entered. In Microsoft Excel ®, coloring can be made automatic for up to three colors.

In most projects, nearly half the boxes will have a value of U. To save time and maintain clarity, the planner does not color the "unimportants," although it can be done. However, so as not to overlook any box, always indicate it has been considered by marking a U in the upper half of the appropriate box. This ensures that all relationships have indeed been considered.

Refinements in Charting

Layout planners not familiar with vowel-letter rating have a great tendency to over-assign A ratings. Operating people fall into this same trap. To prevent this, don't assign A to any pair of activities unless it truly is "absolutely necessary" that the two be adjacent each other. Actually, it is desirable to have an increasing frequency of rating occurrences from A through U – say, 2 to 5% A, 3 to 10% E, 5 to 15% I,10 to 25% O. The frequency of X depends on the nature of the project.

The range from A through U involves four rating changes. Each letter, thus, has a range of 25%. To get greater accuracy, there must be less spread between ratings. Therefore, a minus sign following the letter rating (A- or E-) represents halfway between one rating and the next below it. To color code a minus rating on the chart, use a dotted or broken line of the respective color. The addition of minus signs then allows ranges of accuracy of 12½%.

Another refinement can be used when a rating of extremely undesirable is called for: Use double X (XX) and color the chart black, as indicated in Figure 5-3.

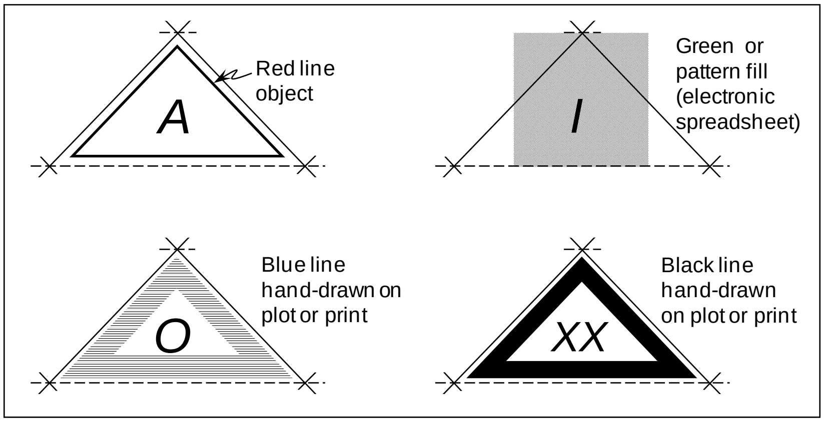

Figure 5-3. Ways to color the relationship chart. When hand-coloring prints or plots, draw a colored border rather than shading the box. The triangular border should be slightly smaller than the relationship rating area. This will preserve legibility.

On electronic spreadsheets, use the drawing toolbar and AutoShapes menu to create a triangular object in each color: red, yellow, green, blue, brown or black. Then, with drawing commands, copy and paste the appropriate colored triangle into the relationship-half of each box.

Another method in electronic spreadsheets is to fill the rating box (worksheet cell) with color. Select the appropriate color using the drawing fill menu or the format-cells-pattern menu. In Microsoft Excel ®, the conditional formatting feature can be used to automate the application of colors. In this way, simply typing the rating applies the appropriate color. However, as shown here in the upper right, the color is filling a square worksheet cell and thus overruns the triangular border on the relationship chart. For examples, see the relationship chart in Figure 5-8 and on the inside front cover of this book.

Standard red and black fill will obscure the rating when the chart is printed in black and white. For these ratings, the text color of the rating letter should be changed to white and the text made bold in order to stand out when printed. This practice can be seen on the A and X ratings in Figure 5-8.

The Procedure

The procedure for making a relationship chart varies, among other things, according to whether or not productive operations are included with service or supporting activities. Both the flow-of-materials chart and the relationship chart can be used separately, or they may be combined.

If there is no service support, that is, no other-than-flow considerations, there is little need for the relationship chart. Flow analysis determines the relationships. But in most cases, it is practical to incorporate the operating activities and the supporting services on the same relationship chart. Thus the relationship of services is integrated with the operating or producing activities they support.

In practice, the SLP procedure most often calls for the following general sequence of steps:

1. Develop the intensities of flow for the operating activities.
2. Rate or classify the intensities between each pair of activities into groupings:
    - Abnormally high intensities …………... A
    - Especially high intensities ……………..E
    - Important intensities …………………...I
    - Ordinary intensities …………………… O
    - Unimportant or negligible intensities ….U
3. Then develop a relationship chart for all the service or other-than-flow factors.
4. Join the flow and other-than-flow ratings in a combined relationship chart.

This sequence of *combining flow and other-than-flow relationships* is explained in detail in Appendix IV.

Special situations with heavy paperwork or people flow may be charted as "material" flow with closeness rated using the calibration technique described in Chapter 4. But when information moves electronically – as it does in most offices – there is no paperwork flow and distance may not matter. Here, the relevant relationships involve the need for face-to-face contact. People movements for this reason are charted as other-than-flow relationships. Similarly, other-than-flow relationships are recorded when factory floor or other situations need lines of sight for visual management and control. In most office or service areas, no flow-of-material analysis is necessary, and all activities are related to one another only through the relationship chart. The method followed depends on the relative importance of flow of materials versus other-than-flow factors. See Figure 5-4.

The relationship chart is especially helpful when the largest portion of the relationships cannot be calculated; and when the planner is faced with only opinions – frequently conflicting at that – with wishful thinking or wrong assumptions, or with other people's desires for status or self-betterment. With the relationship chart the people involved can participate; they see the qualitative approach being used; they are made to explain why. Thus, opinions are sifted and evaluated, and a decision is based on each relationship having a specific closeness value. In planning offices and service areas, the relationship chart is undoubtedly the most practical and important technique available.

In preparing the chart, when productive or operating activities are to be included, the planner converts the flow-of-materials intensity figures (developed by flow-of-materials

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Figure 5-4. Type of work determines procedure to follow. Flow of Materials and Activity Relationships are the two basic procedures to establish the desired (or required) closeness of various areas, activities, or functions to each other.

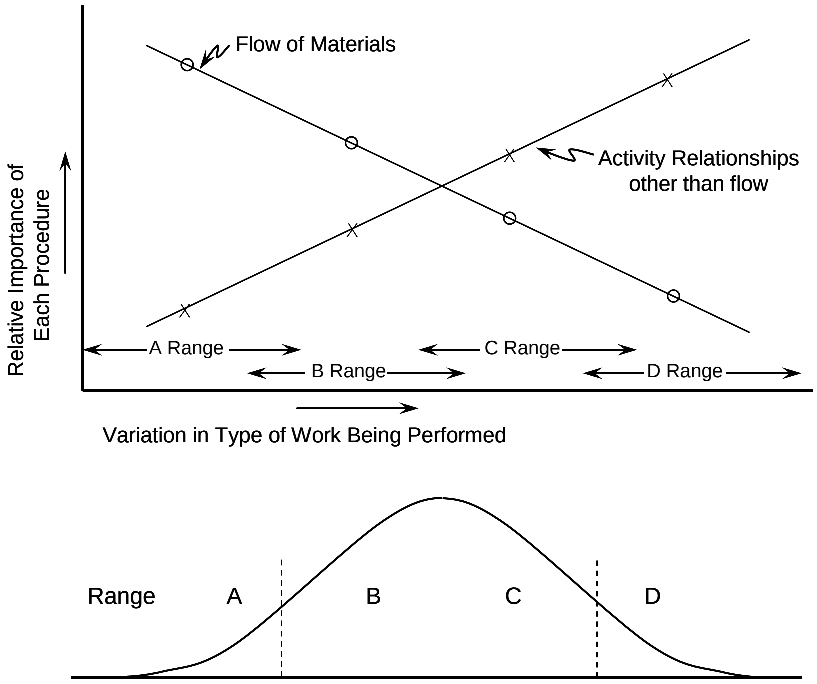
When the materials are large in size or quantity, flow of materials becomes the primary basis for determining the relationship of areas – with activity relationship used to tie-in the service and supporting areas. When there is no problem of size, quantity, or difficulty of moving the product or material, activity relationship becomes the chief procedure – with little if any flow-of-material study being justified.

In between these extremes, both procedures should be used – integrated from the start or independently with subsequent tie-in. In this former method, "flow of materials" becomes just one of the elements or reasons in the construction of the activity relationship chart.

analysis) to the vowel-letter rating. This may seem to dilute the accuracy of these figures. But this is good since flow can be overemphasized and frequently is. Flow intensity calculations are based on anticipated estimates for P, Q, and R – which estimates are probably accurate only to plus or minus 10% at best. Figures un-softened by adjustment to vowel-letter rating suggest greater accuracy than is realistic. Moreover, as pointed out earlier in this chapter, there are factors other than flow of materials that influence the closeness of even the productive or process activities to each other, and the flow figures should be modified anyway by these other factors to establish suitable relationships among the process departments.

These very acts – adjusting the relationships from flow intensities to vowel-letter ratings and relating each service to each operating department – establish the closeness-desired ratings for all relationships on the same basis. That is, a single, common-denominator scale of measure for closeness is used for all relationships.

TYPE OF WORK DETERMINES PROCEDURE TO FOLLOW



Range A.	Plant layouts involving heavy or awkward products or materials, or relatively large quantities of parts or materials. (Flour Mill; Steel Fabricator; Mass Production Manufacturing; Line-feeding work cell).
Range B.	Job shop layouts – having no major clear-cut pattern(s) of material movement. (Tool Making; Custom Plating; General or Specialty Manufacturing.
Range C.	Service Shops with significant amounts of material sequencing or office areas involving heavy flow of paper documents. (Overhaul and Maintenance Shops; Test Laboratories; High-Volume Office Operations).
Range D.	General Office Areas. (Experimental Labs; Engineering Room; Most Office Areas).

In preparing the chart, identify the activities (see Chapter 3, Input Data) and list them on the chart. If the activities have already been ordered, be sure to use the same order. If other-than-flow relationships are to be combined later with those from flow of materials analysis, the activity-areas must be listed in the same order on both the from-to and the relationship chart.

If the activity-areas have not yet been defined or ordered, then group together those which are similar or come under the same supervision. This will make it easier to mark, get approval, and use the chart. Also, it may be difficult to use the chart if too many activities are listed. About 40 or 50 is a practical limit (the working form supplied with this book has room for only 45; the electronic form only 37). It may be necessary to consolidate, segregate, or temporarily overlook certain activities, rather than including too many.

Utility sources and site or building features are sometimes significant and should be listed. North light, neighboring hazards, even passing highways, may be involved as activities. Add these to the bottom of the list to avoid re-numbering and adjusting the flow of materials analysis.

There are a number of ways to establish the relationship ratings. These include:

1. The planner, knowing the operations, does his or her own rating.
2. Calculations, like those for flow intensity or work sampling studies, may serve as the basis for selected relationships, especially when based on people movement or “usage” of some kind. Where records from which to make necessary tallies are not available, actual observations – termed work sampling or ratio delay – may be practical. (A summary of a work sampling study is shown in Figure 5-5.) Recognize the necessity of obtaining representative samples and understand the "booby traps" in recording and in taking work sampling observations. There are several texts available on the subject; those not familiar with the techniques should refer to them.
3. Opinions can be solicited from others involved with the operation or its support in face-to-face discussion. This is frequently done at the same time information on which to base space requirements is gathered. When trying to get others to understand the relative degree of closeness which each vowel letter represents, the planner is wise to establish typical "benchmark relationships," or benchmark ratings similar to those shown in Figure 5-6.
4. Questionnaires like the one in Figure 5-7 can be distributed to persons in charge of the activities involved. The planner cross-compares the responses and posts them on the relationship chart. But note that when two respondents differ in their ratings, the planner will have to follow-up with each to clarify and resolve their differences into a single, reason-supported rating. This reconciliation may take several days or longer.
5. The fastest, most effective way to complete the relationship chart is to assemble a small team to decide jointly on each relationship, the planner or one team member serving as recorder. In this way, hundreds of relationships can be captured in a few hours. For best results, the team should include one or more “voices” for each activity-area – typically supervisors and lead operators. (One way that helps the group keep in mind the specific pair of

WORK SAMPLING STUDY

Studies taken from April 1 to May 1

		Activity							
		Noon Use of Cafeteria		**Use of Exercise Rooms**				**Tool Room**	
				Male		Female			
Dept.	Average No. of Employees (4/1 -- 5/1)	Readings	% of Total	Readings	% of Total	Readings	% of Total	Readings	% of Total
40	82	750	20.5	216	39.3	160	32.6	1300	23.7
41	68	1000	27.4	80	14.6	27	5.5	1188	21.7
42	53	600	16.4	--	--	191	38.9	300	5.5
44	105	500	13.6	163	29.5	53	10.8	2603	47.5
46	42	605	16.5	79	14.3	--	--	51	0.9
49	50	205	5.6	13	2.4	60	12.2	38	0.7
Total Readings		3660	100.0	551	100.0	491	100.0	5479	100.0

Figure 5-5. Work sampling results to be used in locating service areas. The table shows the number of people (frequency) from each of six operating departments using the cafeteria, exercise rooms, and tool room. Work sampling is a method of tallying sample observations at random times. It can be used to measure machine and worker utilization, most prevalent causes of idleness, density and utilization of storage areas, dock utilization and a host of other things that may be relevant to the layout planning.

Ltr.	Pairs of Activities	Reasons for Closeness
A	Steel Storage and Shear Area	Quantity of material moved; Similar handling problems.
	Final Inspection and Packing	Damage to unpacked items; Inspection slip loose until packing completed.
	Clean and Paint	Use same personnel; utilities, supervision; Similar type building.
E	Reception and Visitor Parking	Convenience; Security.
	Metal Finish and Welding	Quantity and shape of material moved.
	Maintenance and Sub-Assembly	Frequency and urgency of service.
I	Shear Area and Presses	Quantity of material moved.
	Sub-Assembly and Final Assembly	Volume of material moved; Share same personnel.
	Vault and Accounting	Movement of records; Security; Convenience.

Ltr.	Pairs of Activities	Reasons for Closeness
O	Maintenance and Receiving	Movement of supplies.
	Salvage and Tool Room	Share same equipment.
	Mail Room and Plant Office	Frequency of contact.
U	Maintenance and Cafeteria	Service is minor.
	Welding and Purchased Parts Storage	Slight contact.
	Engineering and Shipping	Infrequent contact.
X	Welding and Paint	Dirt; Fire hazard.
	Incinerator and Main Office	Smoke, odors, dirt; Appearance.
	Press Shop and Tool Room	Vibration.

Figure 5-6. Benchmark relationships aid consistency and speed when establishing relationship for all pairs of activities. These are benchmarks used in a project involving the relayout of a light manufacturing company.

activities under consideration is to have a set of cards with the number and name of an activity printed clearly and boldly on each card and to have a pair of cards always on the discussion table.)

6. Establish with each supervisor a ranking of the activity's relations to each other activity and then convert the ranking to ratings. (It is often easier for operating managers to force things into a sequence than to make the distinction of specific ratings.) Cards, with the names of each activity for developing the ranking and benchmark relationships for converting to ratings are of help here, too.

OFFICE SPACE RELATIONSHIP SURVEY

Date: Apr. 12

Period Covered +5 years

Activty Area Analytical and Technical Services (Validation)

By:

Location

Sub-Area or Individual

With:

Space Assigned

Note the activity-area, sub-area or individual entered above. Use the vowel-letter ratings below to rate the degree of closeness desired between this activity-area and the others listed on the left below. Ratings should represent closeness desired in an ideal situation. For each rating other than "U" (Unimportant), give one or more reasons using the code numbers below on the right. If the proper reason is not already listed, please write it in next to your rating. Most ratings should be U's and O's. There should be very few E's and perhaps only one or even no A's. Make ratings for the planning period indicated above.

No.	**Activity Area**	Enter Vowel Code for Closeness Desired to: **(Letter)**	For each rating other than "U", please enter one or more Reason Code #s from the list, or write in. **(Number)**
1	Vice President -- Texas Operations		
2	Director -- Finance (incl. Budget & Bus. Info. Analysts)		
3	Director -- Purchasing		
4	Sr. Mgr. -- Production Planning		
5	Sr. Dir. -- Quality Compliance		
6	Sr. Dir. -- Manufacturing Support		
7	Site Director -- Main Plant, incl. Staff		
8	Finance -- Cost Accounting		
9	Finance -- Comptroller, Acctg Svcs, & Gen.Acctg.		
10	Finance -- Payroll		
11	Finance -- Accounts Payable; Accounts Receivable		
12	Central Order Processing		
13	Director -- MIS, incl. IT Audit		
14	MIS Technical Operations, incl. Computer Room		
15	MIS Business Process & Applications		
16	Purchasing		
17	Production Planning		
18	Human Resources, incl. Director		
19	Engineering		
20	Calibration		
21	Facilities Security/Safety-Environment-Health		
22	Process Improvement & Lean Promotion Office		
23	Document Control, incl. storage		
24	Quality Assurance, Sterility & Quality Control		
25	Analytical and Technical Services (Validation)	☒	
26	Immunology & Clinical Studies		
27	Pharma Regulatory Affairs		
28	Plant Production Operations & Maintenance		
29	Training		
30	Mail Room		
31	Reception Lobby, incl. Visitors Rest Rooms		
32	Employee Entrance, incl. Rest Rms, Lockers & Showers		
33	Lunch Room with Vending		

IMPORTANT: If ratings for one or two people, or a small sub-group *differ greatly* from the area listed at the top of the page, please note the exceptions by name or ideally complete a separate survey sheet for this person or sub-group.

Vowel Code Ratings	**Meaning**
A	Closeness Absolutely Necessary "Must be next to each other to function effectively."
E	Closeness Especially Important "Need to be very close -- down the hall or aisle"
I	Closeness Important "Need to be on same floor, side or wing."
O	Ordinary Closeness OK "Occasional interaction. Anywhere in Bldg 100 OK."
U	Closeness Unimportant "Infrequent interaction. No significant relationship."
X	Closeness Not Desireable "Keep separate and away."

Reason Code #	**Meaning**
1	Face to Face Contact
2	Meetings, teamwork
3	Shared staffing
4	Convenience
5	Common type of space
6	Reception of visitors
7	Flow of people
8	Ease of management/supervision
Other	write in next to rating(s)

b

Check and Endorsement

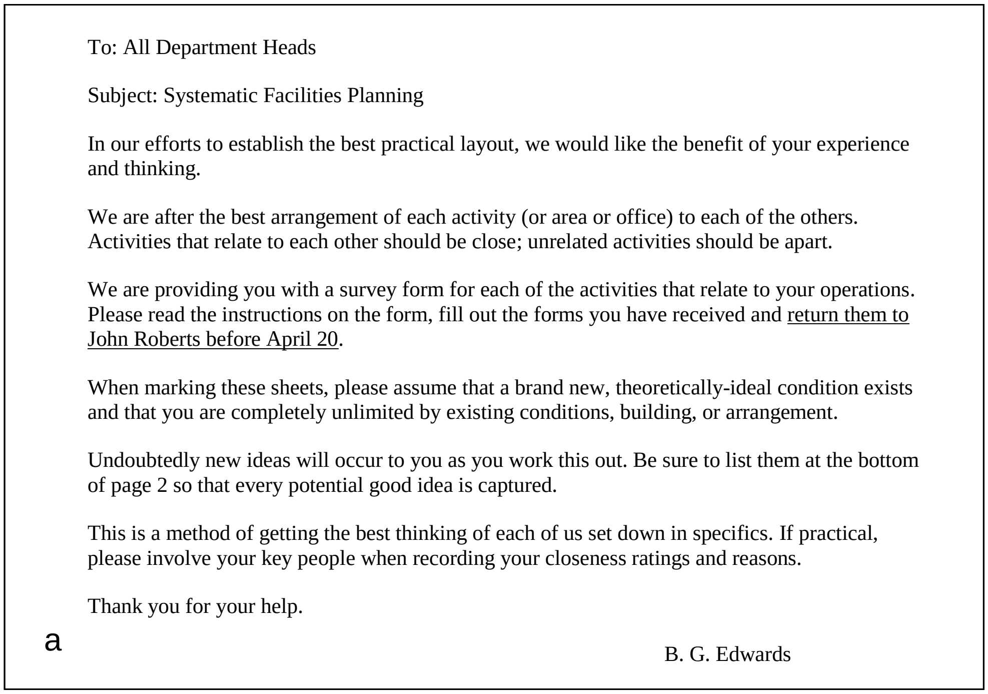
Regardless of which method(s) is used to establish and record the rated relationships, the final chart should be checked by, or with, the people who will actually have to make the layout work.

Several methods of checking, or combinations of methods, can be followed:

1. Take the chart to the department heads, or others in charge of each activity involved, and have them review their relationships.
2. Circulate the chart for approval and have it returned signed "OK" or with suggestions for change
3. Have some independent reviewer check your closeness-rating values and the posting of them in the correct boxes.

Figure 5-8 shows a relationship chart (in Microsoft Excel ®) with signatures for approval. Colors fill the closeness rating cells as *squares*. Manually placing *triangular* colored outlines (without fill) would require more effort but be easier to read.

Suggested alterations or corrections are best recorded on a sheet similar to the modification record shown in Figure 5-9. Activities should be identified by line number on the chart as well as by description in order to speed the work and avoid errors. Also



To: All Department Heads

Subject: Systematic Facilities Planning

In our efforts to establish the best practical layout, we would like the benefit of your experience and thinking.

We are after the best arrangement of each activity (or area or office) to each of the others. Activities that relate to each other should be close; unrelated activities should be apart.

We are providing you with a survey form for each of the activities that relate to your operations. Please read the instructions on the form, fill out the forms you have received and return them to John Roberts before April 20.

When marking these sheets, please assume that a brand new, theoretically-ideal condition exists and that you are completely unlimited by existing conditions, building, or arrangement.

Undoubtedly new ideas will occur to you as you work this out. Be sure to list them at the bottom of page 2 so that every potential good idea is captured.

This is a method of getting the best thinking of each of us set down in specifics. If practical, please involve your key people when recording your closeness ratings and reasons.

Thank you for your help.

a

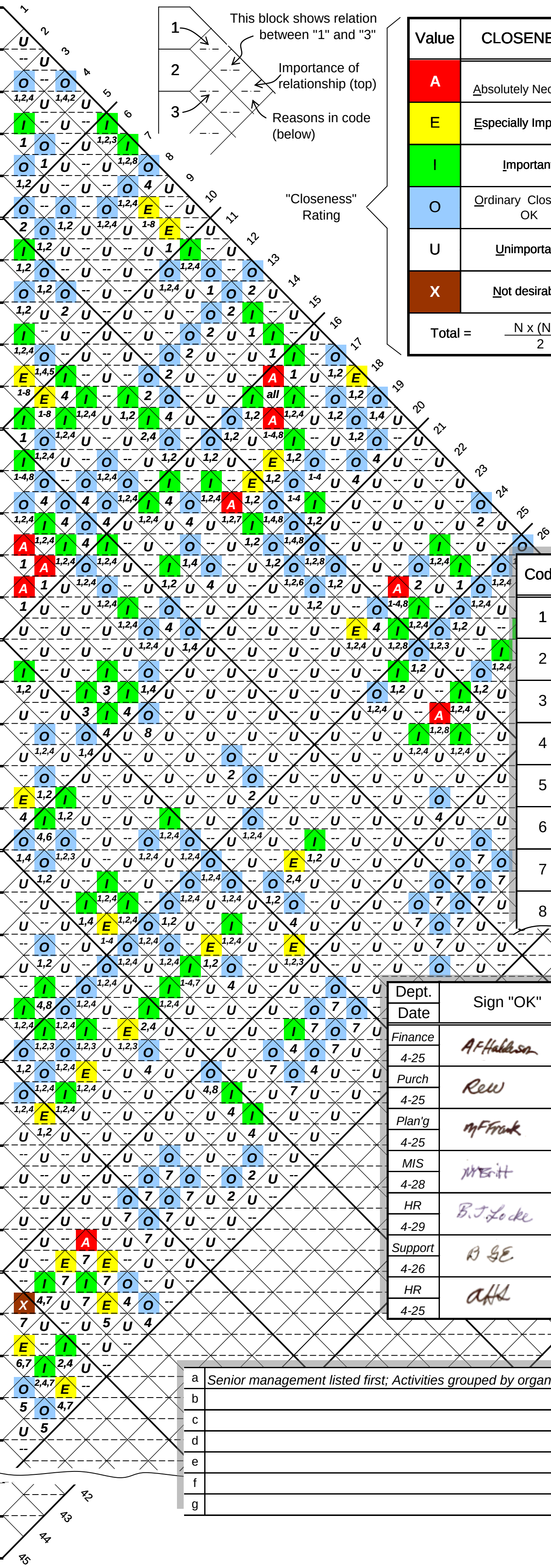
B. G. Edwards

Figure 5-7 a & b. An example of how relations between activities can be established using a questionnaire. Here the memorandum (a. above) instructs the various department heads to record the relationship of each of their activities (or areas or offices) to each of the others on the preplanned Office Space Relationship Survey (b. opposite) – doing so in the same recording conventions as will be used for consolidation on the relationship chart. The example is from the divisional headquarters office of a pharmaceutical company. Figure 5-8 shows the chart made from the consolidation and reappraisal of the returned recording sheets.

RELATIONSHIP CHART

Plant (Company) *Texas Operations*
Project *Office Lay*
Source - Reference *Survey Apr. 12; Mtgs. Apr. 23*
Date *Apr.25*

1 *Vice President -- Texas Operations* ⓐ
2 *Director -- Finance (incl. Budget & Bus. Info. Analysts)*
3 *Director -- Purchasing*
4 *Sr. Mgr -- Production Planning*
5 *Sr. Dir. -- Quality Compliance*
6 *Sr. Dir. -- Manufacturing Support*
7 *Site Director -- Main Plant, incl. Staff*
8 *Finance -- Cost Accounting Main*
9 *Finance -- Comptroller, Acctg. Svcs. & Gen. Acctg.*
10 *Finance -- Payroll*
11 *Finance -- Accounts Payable; Accounts Recievable*
12 *Central Order Processing*
13 *Director -- MIS, incl. IT Audit*
14 *MIS Tech. Operations, incl. Computer Room*
15 *MIS Business Process & Applications*
16 *Purchasing*
17 *Production Planning*
18 *Human Resources, incl. Director*
19 *Engineering*
20 *Calibration*
21 *Facilities Security/SHE*
22 *Process Improvement & Lean Promotion Office*
23 *Document Control*
24 *Quality Assurance, Sterility & QC*
25 *Analytical & Technical Services (Validation)*
26 *Immunology & Clinical Studies*
27 *Pharma Regulatory Affairs*
28 *Plant Production Operations & Maintenance*
29 *Training*
30 *Mail Room*
31 *Reception Lobby (incl. Visitors Rest Rooms)*
32 *Employee Entrance (incl. RR, Lockers & Showers)*
33 *Lunch Room with Vending*
34 *Large Conference Room*
35 *Fitness Center*
44
45



Value	CLOSENESS	Color	No. of Ratings
A	Absolutely Necessary	RED	9
E	Especially Important	OR-YEL	22
I	Important	GREEN	69
O	Ordinary Closeness OK	BLUE	138
U	Unimportant	U	356
X	Not desirable	BROWN	1
Total =	$\frac{N \times (N-1)}{2}$	=	595

Code	REASON
1	*Face-to-Face Personal Contact*
2	*Meetings, Teamwork*
3	*Shared staffing*
4	*Convenience*
5	*Common type of space*
6	*Receception of Visitors*
7	*Flow of people*
8	*Ease of Management/Supervision*

Dept. Date	Sign "OK"	Dept. Date	Sign "OK"
Finance 4-25	AFHalderson	Facil. 4-26	RJL
Purch 4-25	Rew		
Plan'g 4-25	MFFrank		
MIS 4-28			
HR 4-29	B.J.Locke		
Support 4-26	B GE		
HR 4-25			

a *Senior management listed first; Activities grouped by organizational responsibility.*
b
c
d
e
f
g

show the name of the person who is responsible. This, together with any further listing of activities found OK (at the bottom of the modification record sheet), helps ensure that checking is complete.

Since each box involves two activities, any changes in a box's data should be endorsed by representatives of (or those responsible for) both activities (in many cases it is only one person). This means keeping track of who is responsible for each activity. To aid the analyst and the approver, it is easiest if the list of activities is grouped by person responsible for the activity, as in Figure 5-8 for Finance (Activities #8 – #11) and MIS (Activities #13 – #15).

In most cases, the two persons will agree on the relationship desired between each other's activities. Disagreements can usually be best resolved by calling both parties together, although sometimes a full meeting of representatives from all activities is faster and more helpful.

In seeking this check and endorsement, remember that the operating people probably see today's conditions and relationships only, or at least predominantly. It may be that they are not as well informed as you about plans for future product design, production engineering, and marketing programs of the company.

In any event, a sign-off or other official agreement with the relationships recorded on the chart should be considered a must. The data is then formally established so it can be used to begin diagramming the arrangement of the various activities. Getting approval forces the planner to involve the responsible people in the project. Early participation of those who will later operate the areas being laid out gets them into the act, convinces them of the soundness of the approach, places relationships on a more objective basis with reasons to substantiate them, and goes a long way towards

Figure 5-8. Completed relationship chart for the divisional headquarters office of a pharmaceutical company. In such a facility there are actually several different kinds of “people-flow”: people seeking one-on-one, face-to-face meetings; people going to and from team and group meetings, people going to and from entrances, the lunchroom and other support areas. Overlaid upon these relationships are those of shared staffing and formal (organizational) reporting and lines of authority. Note also that some areas are related by their need for the same type of space. The layout will usually be less costly to install when such areas are adjacent. This relationship is also present in most production area layouts and may be as important as many of the material flows. The relationship chart is an ideal technique for untangling in a fairly simple way these diverse types of interrelationships.

In this example, the chart results from the ratings made by each department head in response to a questionnaire. Where the two persons responsible for each pair of activities reported the same relationship and reasons, this rating was accepted as is. Any differences were resolved by the layout planner contacting the people involved. Unresolved differences required the layout planner to have a face-to-face meeting with the two people concerned. Sign offs are used to be sure the data is correct before spending further time planning and then finding errors in this underlying data.

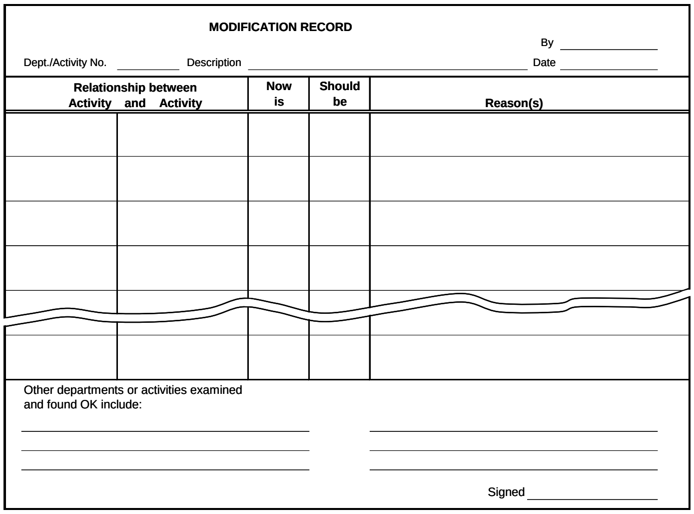
See the inside front cover for a color reproduction of this same illustration. Note how the color makes the chart easy to read. No color and no supporting reasons are used for the unimportant relationships. Note: Because this chart is an electronic worksheet, the coloring fills square cells in the worksheet and overruns the triangular top half of the relationship boxes.

selling the eventual layout plan developed from the charted data. This is one of the most effective ways of getting participation into layout planning long before the physical plans take shape.

Experience indicates it is essential to total all the A's then the E's … including the U's. Every relationship must be accounted for later, when adjusting the layout, or the layout becomes distorted. To check for total verification, the sum of all letter totals should equal the number of potential relationships on the chart, namely,

$$\frac{N \times (N-1)}{2}$$

where N equals the number of activities listed.



MODIFICATION RECORD

By ______________

Dept./Activity No. __________ Description ______________________________ Date ______________

Relationship between		**Now**	**Should**	
Activity	**and Activity**	**is**	**be**	**Reason(s)**

Other departments or activities examined and found OK include:

Signed ________________

Figure 5-9. Sheet used to record changes on the relationship chart. This allows a record of the changes made or suggested since “sign-off.” A modification record like this can be taken along or sent out with a copy of the summary relationship chart to obtain approvals in an organized way.

Other-Than-Flow Relationships in Manufacturing Layouts

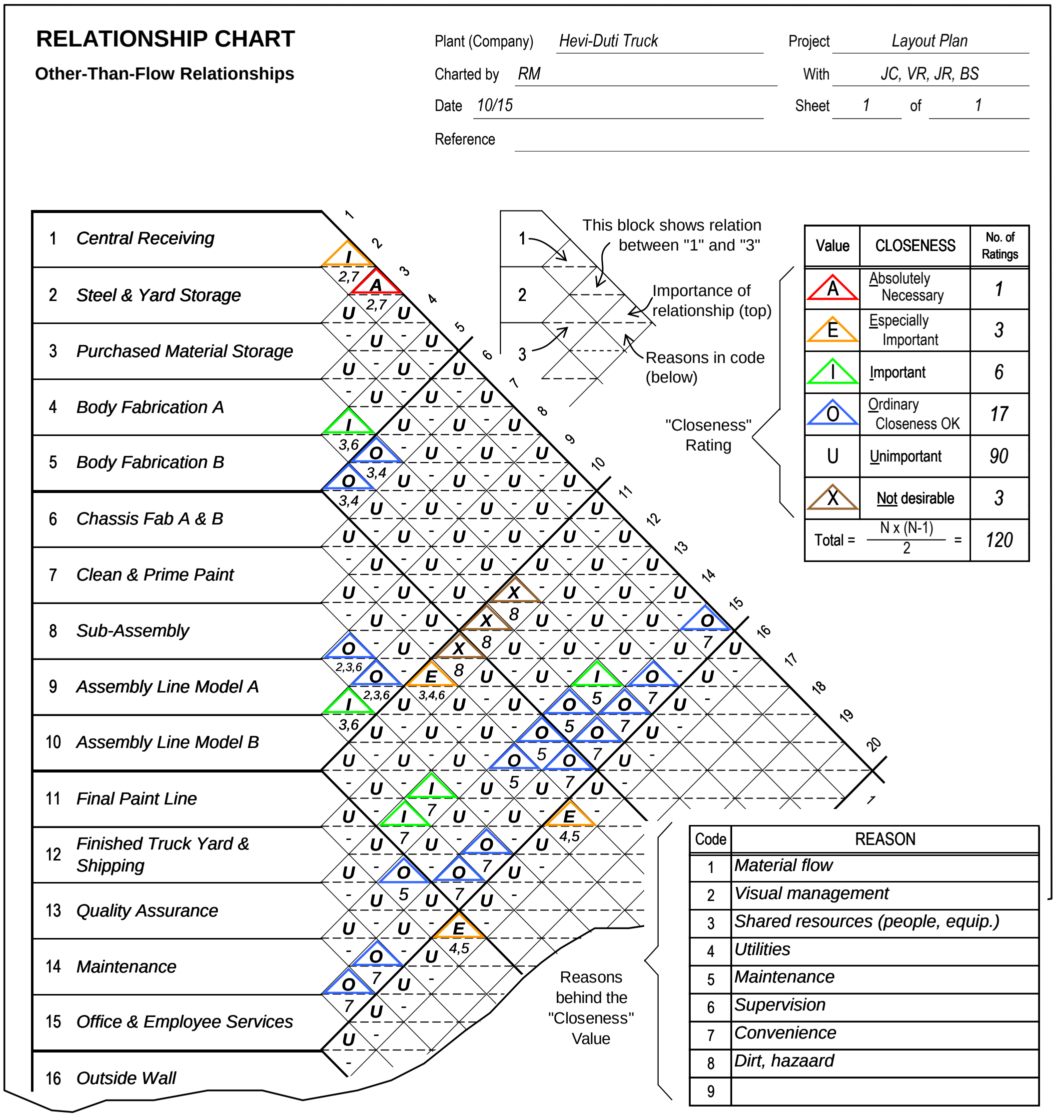
In activity relationship charting for manufacturing layouts, reserve Reason #1 for flow of materials as shown in Figure 5-10. This will allow easier combining of flow with other-than-flow on a Combined Relationship Chart. In this way, the number “1” can be added in front of the other-than-flow reasons, and the rating adjusted when flow is present – typically upward when flow is an important or dominant consideration. Recognize that when following this procedure, the Other-Than-Flow Relationship Chart will show no use of reason #1. Close inspection of Figure 5-10 demonstrates this absence. In practice, it is difficult to get operations people to forget or ignore flow. They will want to give this as their reason for closeness. But the planner should press them for the other reasons, of which there may be several.

Figure 5-10. These relationships will be combined with the flow ratings in Figure 4-20 (Step 9). Note the number and percentage of important or higher ratings and the X’s and their reasons. Note relationships of Paint areas to an outside wall. These are typical of other-than-flow relationships in manufacturing plant layout. Note also that use of triangular outlines rather than color fill makes the chart easier to read.

Conclusion

The rated and reason-supported relationship chart is a systematic means to get data into usable form. It yields a set of relationship requirements to which the layout planning can be keyed – And all this on a single page. Moreover, it provides the planner with ready reasons for departments' being located closely or far away – sound backing for the data and highly valuable when challenged at approval time.

The chart insures that a decision is made for the relation of each activity to each other activity. Thus, it serves as a check sheet. A chart of only ten activities means 45 relationships, and even the best layout planner cannot keep that many decisions in mind. Figure 5-11 summarizes the actual procedure for making the chart.



RELATIONSHIP CHART

Other-Than-Flow Relationships

Plant (Company) *Hevi-Duti Truck*
Project *Layout Plan*
Charted by *RM*
With *JC, VR, JR, BS*
Date *10/15*
Sheet *1* of *1*
Reference

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	1
E	Especially Important	3
I	Important	6
O	Ordinary Closeness OK	17
U	Unimportant	90
X	Not desirable	3
Total = $\frac{N \times (N-1)}{2}$ =		120

Code	REASON
1	*Material flow*
2	*Visual management*
3	*Shared resources (people, equip.)*
4	*Utilities*
5	*Maintenance*
6	*Supervision*
7	*Convenience*
8	*Dirt, hazaard*
9	

PROCEDURE FOR ACTIVITY RELATIONSHIP ANALYSIS

1. Identify all activities involved.
    a. Make a list of departments, areas, operations or features and go over this with department managers or supervisors involved to check coverage and terminology.
    b. Keep like activities or those reporting to same individual grouped together – as in an organization chart.
    c. Do not use more than forty-five activities on any one chart. Consolidate as necessary in advance and re-chart secondary activities.
    d. Include site and building features (rail siding, elevator shaft, transformer) when they are relevant – typically below operational areas on the list.
    e. Reconcile the activity list with any list already established or in use for flow analysis. Activities in the flow analysis must be identical in name and number in order to combine flow and other-than-flow ratings.
2. List the activities on a relationship chart.
    a. If already defined on a process or from-to chart, observe the exact order of activities when entering on the relationship chart.
    b. If no process chart or flow analysis, set down productive operations first, supporting services thereafter, then site and building features.
3. Determine or establish the desired relationship for each pair of activities and the reason(s) therefore. This can be done:
    a. by personal visit and discussion with department managers or area supervisors involved.
    b. by involving those with the most knowledge about the relationships.
    c. by your knowledge of the operating practices.
    d. by making a series of calculations for each major consideration, or reason, just as you would do for flow of material.
4. Enter data on a relationship chart – consolidating all notes, tallies, and calculations – so you have one set of approved, specific relationships and reasons from which to plan your layout.
    a. The chart itself acts as a check sheet to make sure the relationship between every activity and every other activity has in fact been considered.
    b. Get approval of the chart.
    c. Combine with any flow of materials ratings following the procedure in Appendix IV.

Figure 5-11. Procedure for making the Activity Relationship Chart.

Chapter 6

Flow and/or Activity Relationship Diagram

After the relationship of activities has been charted – either by flow-of-materials analysis, activity relationship charting, or a combination of the two – the next step is to diagram this information. This becomes the output of Section 2 in the SLP pattern of procedures.

At this stage, the planner is seeking a visual picture of the data gathered up to this point and of the calculations and analyses made from them. Now the tallied or charted information, which shows the sequence of activities and the relative importance of the closeness of each activity to each other activity, is transferred and translated into a geographic arrangement. This geographic arrangement should in fact now locate the activities according to the degree of closeness charted.

Bear in mind that we are dealing here with Phase II, Overall Layout, not with diagramming detailed layouts. Detailed layouts are covered in Part Three.

Diagramming

There are many techniques available for diagramming. The general sequence is to work from the charted information to a visual diagram. The planner usually starts with the most important relationships and subsequently diagrams those that are less important. Later on, the activities themselves will be represented according to the actual space allotted to each, to develop a space relationship diagram (Section 3 of the SLP pattern).

The essentials for diagramming involve (1) convenient and simple set of symbols for identification of each activity (area or feature); and (2) some method of indicating the relative closeness between activities and/or the direction and relative intensity of materials flow.

When diagramming the relationships from an activity relationship chart, the planner should already have incorporated materials flow with the supporting services and other-than-flow relationships involved. If so, the quantified flow-of-materials and other-than-flow relationships are diagramed as combined relationships.

Diagramming Flow Only

Diagramming materials flow without the integration of service and other activities can be done in one of two ways: Either start with the normal material in-point and continue on through the flow sequence; or, start with the two departments or activities having the greatest intensity of flow and continue in decreasing order of flow intensity. Be sure to note that the total intensity is the sum of the flow in both directions.

The final form of the flow diagram normally is something like that shown in Figure 6-1. The flow is diagramed in such a way that the supporting services can be fitted to it as seems practical.

Normally, diagrams evolve as a series of trials and refinements. That is, the diagram starts in rough form; then as more information is added various successive arrangements appear or occur. In their initial trials, diagrams need not be complicated: In fact, the simpler their construction the better – as long as they can be understood.

When working with pencil and paper, erasures and revisions rapidly make the initial diagram hard to read. It is best to begin successive arrangements on clean paper or to rework the diagram on a tracing-paper overlay. It is not uncommon to go through six or eight trials before an acceptable diagram is developed. Diagrams may also be drawn with markers on a white board and then photographed. Or, they may be made by moving sticky notes around on the white board or a sheet of flip chart paper, adding lines later.

When working in an electronic drawing, be sure to periodically save the file as a version. That way if refinements do not work out and an earlier version seems better, you can return to it. When attempting completion in a single file, earlier arrangements will become lost.

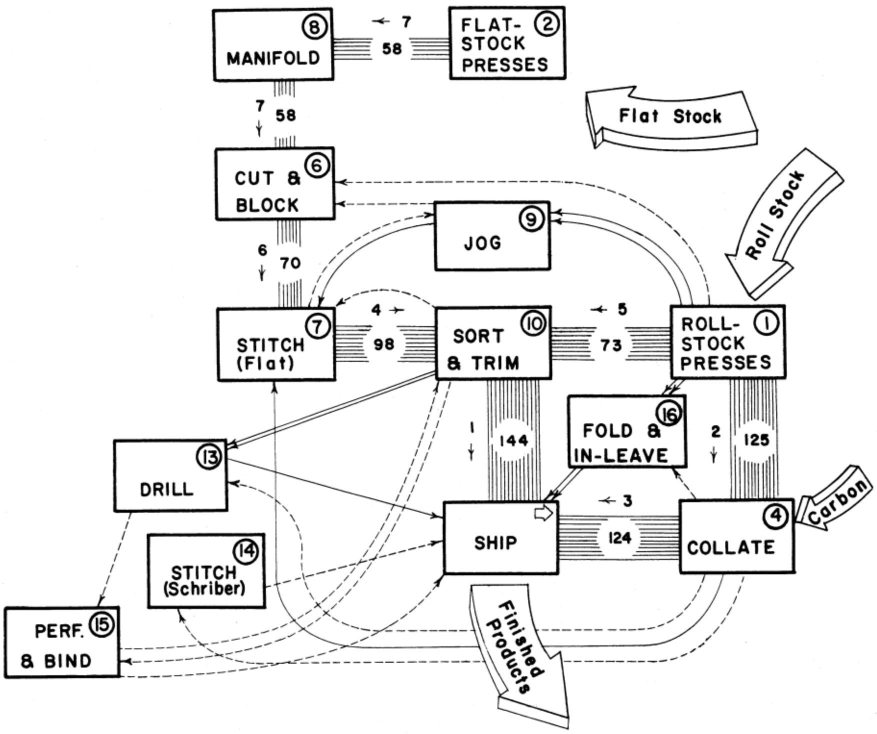


Figure 6-1. The flow diagram for a printing plant making business forms and small booklets. Each departmental area is represented by a rectangular block, and flow intensity, by the number of lines connecting each pair of departments. Each connecting flow-line represents 10 "units of flow." The actual number of flow units is shown inside the cluster of flow lines, and the direction is indicated by an arrow. Beside each arrow is marked the order of magnitude of flow intensity – starting with the largest intensity first. The number of flow lines connecting each pair of departments are shown to the closest 10 units; dotted lines represent five or less units.

Diagramming to Determine Flow

In some cases, it is practical to diagram the existing flow pattern right on a plan of the existing layout and so get a picture of the existing overall relationships. This can then be analyzed for improvements in a way that is easier for operating supervisors or untrained layout planners to understand than figures or charted information. In other cases, to better visualize the problem, it is helpful to rough out a "present" flow diagram before making an analysis of "proposed" flow. The "present" flow diagram then can be compared with the planned-for diagram. Figure 6-2 shows an example of flow diagramming from a current layout.

Often a company has no operations list, process sheets, or written-down routing to work from. This means the planner has to get out in the plant or area involved and actually trace the flow of materials. The easiest way to do this is on a sketch or floor plan of the existing area. The resultant tracing of flow is really a flow diagram. (This is discussed in Chapter 4, and an example of flow diagramming directly on an existing plant layout is shown in Figure 4-14.)

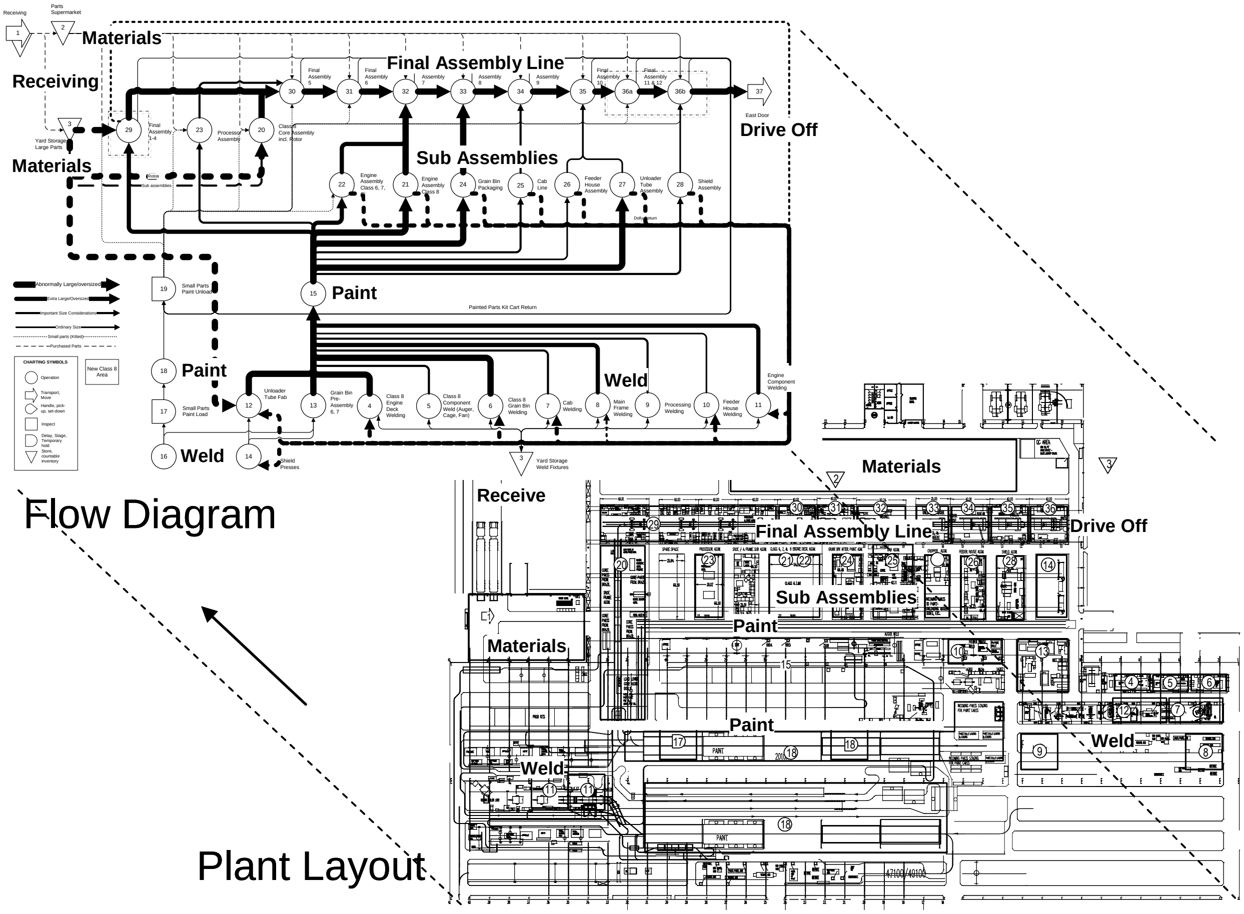
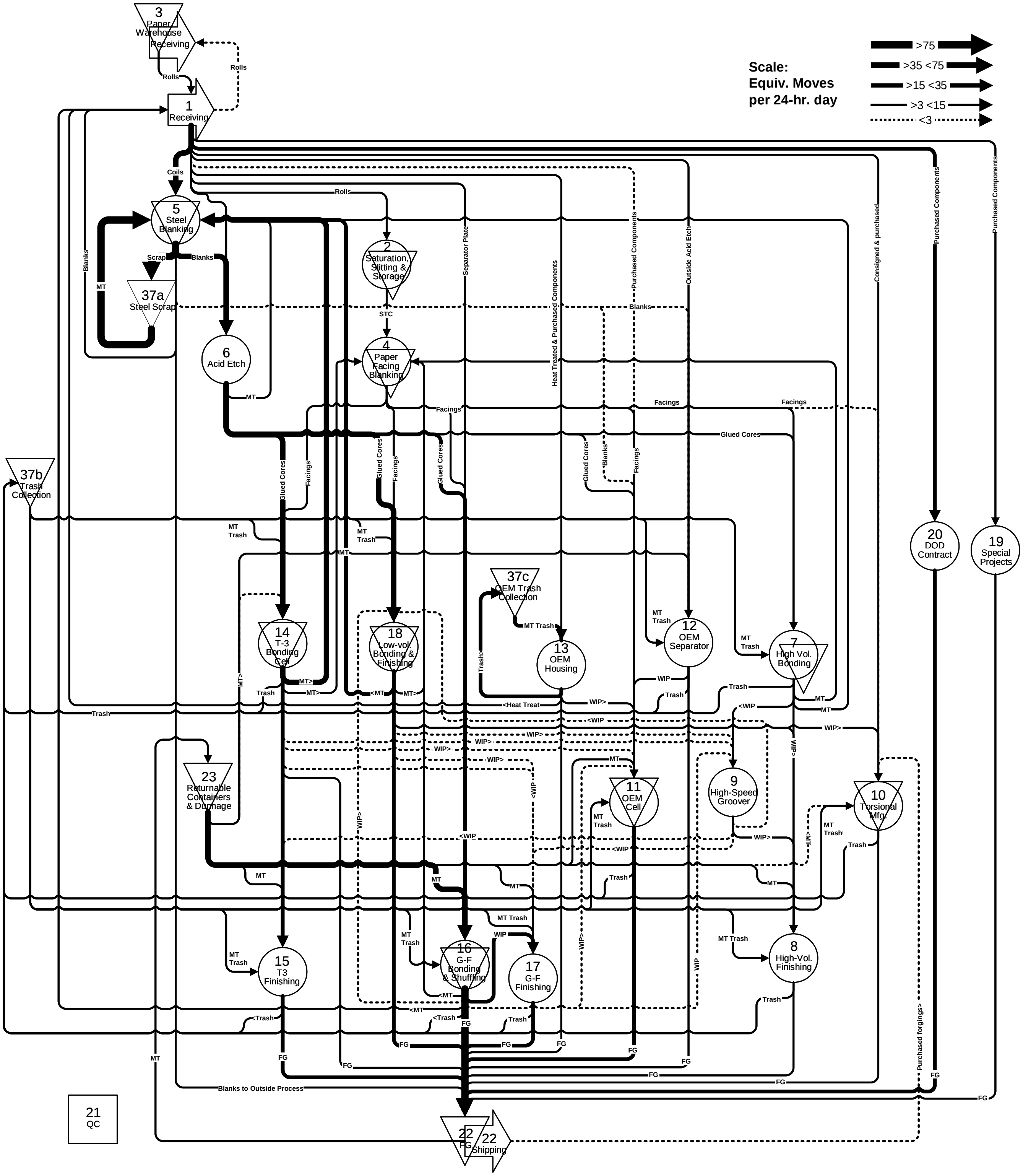


Figure 6-2. Diagram of flow derived by walking through the current plant layout for selected critical items. Line thickness shows flow intensities and thus relative closeness desired between operations. The purpose of the diagram is to show sequence and desired closeness in a new layout. Thus, symbol placements are not an "overlay" of the current layout but do reflect its general arrangement.


Scale:
Equiv. Moves
per 24-hr. day
>75
>35 <75
>15 <35
>3 <15
<3
3 Paper Warehouse
Receiving
Rolls
1 Receiving
Coils
5 Steel Blanking
Scrap
Blanks
37a Steel Scrap
6 Acid Etch
2 Saturation, Slitting & Storage
STC
4 Paper Facing Blanking
Separator Plate
Heat Treated & Purchased Components
Purchased Components
Outside Acid Etch
Consigned & purchased
Purchased Components
Purchased Components
Facings
Glued Cores
37b Trash Collection
MT Trash
20 DOD Contract
19 Special Projects
37c OEM Trash Collection
14 T-3 Bonding Cell
18 Low-vol. Bonding & Finishing
13 OEM Housing
12 OEM Separator
7 High Vol. Bonding
<Heat Treat
WIP>
<WIP
23 Returnable Containers & Dunnage
11 OEM Cell
9 High-Speed Groover
10 Torsional Mfg.
15 T3 Finishing
16 G-F Bonding & Shuffling
17 G-F Finishing
8 High-Vol. Finishing
Purchased forgings>
FG
Blanks to Outside Process
21 QC
22 FG
22 Shipping

Flow for Various Products

It is not uncommon to have several products or classes of materials to be diagramed. There are two ways. (1) Several diagrams can be made – one for each product, group of products, or class of material; or (2) one diagram can be made with different line labels, line colors, letters, numbers, or symbols representing different products, groups, or classes. Figure 6-3 shows an example of one diagram with material class labels on each flow line.

Generally speaking, however, it is better to consolidate all this information at the charting stage rather than at the time of diagramming. That is, analyze the flow of various products or classes of material sufficiently to derive a net, composite analysis of flow. Then the diagram can be converted directly from the flow chart.

Diagramming Activity Relationships

When the planner is not concerned about the direction of material movement or when there is no significant flow of materials involved in the relationships, the diagram can be prepared using only the closeness ratings recorded on the relationship chart. The specific procedure includes a set of conventions for diagramming. These conventions are used both to save time and to aid in understanding and interpretation. A simple diagram using the conventions is described in Figure 6-4.

Cartographers have long known the value of conventions in making maps. They use a host of symbols, letters, numbers, and colors. Diagramming flow and activity relationships is, essentially, applied cartography, so it is not surprising that the SLP procedure utilizes the same types of codes.

Conventions for Diagramming

The conventions used in Systematic Layout Planning are illustrated in Figure 6-4. They include the following:

1. A symbol for the type of activity
2. A number (or letter) identification for each activity
3. A number-of-lines code for the intensity of flow or closeness value
4. A color code, also for the intensity or closeness value (Color use is optional, but recommended for the final diagram.)
5. A color for each type of activity (optional here, but used later when converting to a space relationship diagram)

Figure 6-3. Flow line labels indicate the class of material being moved on each route. Thickness indicates flow intensity between activity-areas. A dozen material classes are shown on 102 routes. Classes can be displayed one at a time by putting flows for each class on a separate layer of the drawing (e.g. only the blanks, or work-in-process, or empty containers, or scrap). This plant makes automotive components grouped into five different product lines. The flow (“value stream”) for each product line can also be labeled, layered and shown in the same way. If flow were the only consideration, a layout could be developed from this diagram. However, even in this high-volume plant, the planners identified more than 100 important other-than-flow relationships.

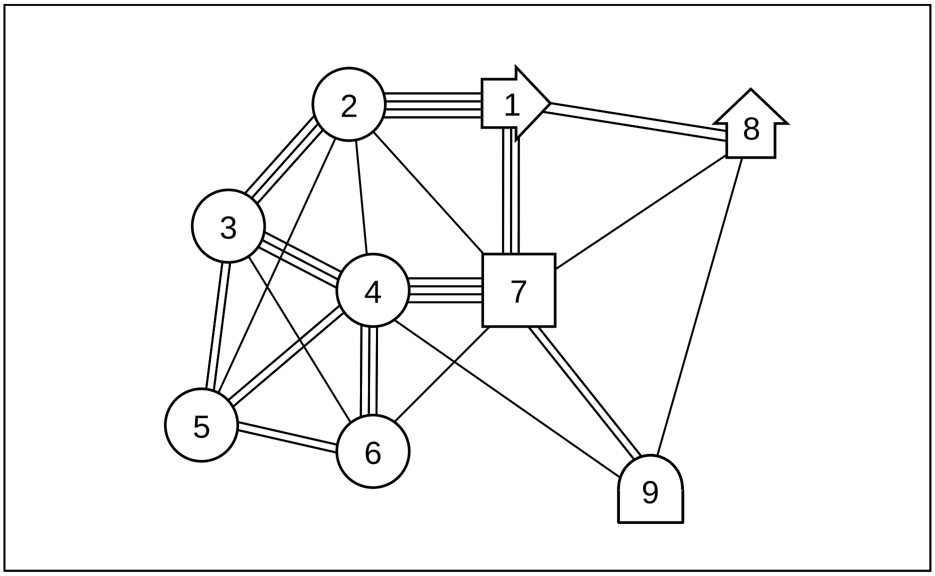


Figure 6-4. The method of diagramming relationships involves connecting the activities by a number-of-lines code. The shape of each symbol indicates the type of activity; the number inside is the activity identification; the number of connecting lines indicates the rated closeness. Here, the shipping-receiving dock (1) relates to the first production area (2) by four lines (closeness absolutely necessary), to final inspection (7) by three lines (closeness especially important), and to the front office (8) by two lines (closeness important). Other activities are similarly related.

The *symbols* are adapted directly from that established in the ANSI standard for process charting. Although two new symbols have been added, each of them is merely a 90-degree reorientation of a conventional symbol. These two include (1) the *turned arrow*, resembling a house, and therefore used to designate building features or office areas, and (2) a *turned D*, or delay symbol, representing service areas and auxiliaries such as maintenance, salvage, compressor room, and the like.

The symbols are provided on the die cut ruler in the Working Forms section of this book and are also available as TQM stencils in Microsoft Visio ®. All but the delay symbol are available as basic shapes in Excel ®, PowerPoint ® and other desktop graphic programs. And of course, they are easily created in any electronic drawing editor.

The activity *number* – usually the line number on the activity relationship chart – is inserted inside each of the symbols.

In connecting each pair of activities, a number-of-lines coding is used to indicate *closeness*.

When making trial diagrams with pencil and paper, or with markers on a white board or flip chart, it is quickest to draw the connecting lines in black and overlay the colors later. The color code is the same as that used on the relationship chart. Adding the colors is thus a good time to go back through the chart and make sure that all relationships have been visualized in the diagram.

When diagramming in Visio, Excel, PowerPoint or other electronic tool, it is fastest to make colored-line objects for each connecting-line convention: 4 red lines, 3 yellow lines, 2 green lines and 1 blue line. These can then be copied, rotated and stretched in the long dimension as needed, and then dragged into the desired positions between activity symbols. Turn the snap feature off so that placement remains flexible and the connecting-line objects and symbols do not become inadvertently distorted. On the final diagram, select the activity symbols, make sure they are filled in the color white, and bring them to the "front". This will give a neat appearance where connecting lines meet symbols. Figures 6-4 and 6-6 were both drawn in this manner.

For a negative number of lines, use a wiggly line (or two wiggly lines) to represent an X (or XX) closeness rating. The wiggly line resembles a spring pushing the two activities away from each other, in contrast to straight lines which can be likened to elastic-rubber bands pulling the activities together.

Process Chart Symbols & Action*	Symbols Extended to Identify Equipment & Space	Color Ident.	Black & White**
* ○ Operation	○ Forming or Treating Equipment & Space	Green**	▧
	○ Assembly, Sub-Assembly, Dis-Assembly	Red**	▥
* ⇨ Transportation	⇨ Transport-related Equipment & Space	Orange Yellow**	░
⬡ Handling	⬡ Handling Areas -- Pick-up & Set-Down	Orange Yellow**	░
* ▽ Storage	▽ Storage Equipment and Space	Orange Yellow**	░
* ◗ Delay	◗ Set-down or Hold Areas	Orange Yellow**	░
* □ Inspection	□ Inspect, Test, Check Equipment & Space	Blue**	▤
* A.N.S.I. Standard ** MHMS (IMMS) Standard (Adopted as basic to SLP procedure)	⌓ Service & Support Equipment & Space	Blue**	▤
	⇧ Office or Planning Areas, or Building Features	Brown** (Gray)	▦

Vowel Letter	No. Value	No. of Lines	Closeness Rating	Color Code
A	4	////	Absolutely Necessary	Red**
E	3	///	Especially Important	Orange Yellow**
I	2	//	Important	Green**
O	1	/	Ordinary	Blue**
U	0		Unimportant	Uncol-ored**
X	-1	〰	Not Desirable	Brown**
XX	-2,-3, -4,?	〰 〰	Extremely Undesirable	Black

Figure 6-5. Conventions used for diagramming activity relationships. A minus sign, indicating half a degree of closeness, is diagramed as a broken line. Planners should work primarily in black and white; color for the relationship lines is optional. Later, when adding space to the diagram, the planner will use color to emphasize type of area.

A dotted line can be used for a half degree of closeness value and is consistent with the minus sign and dotted triangle used in coding half degrees on the relationship chart.

Sometimes the department number, rather than the chart line number, is used inside the symbol to identify the activity. And where it seems helpful, both the chart line and the department number or meaningful letter(s) can be used.

Although the shape of the symbol identifies the type of activity, a color code is also set up for these symbols. This color, in contrast to that indicating closeness, is for type of activity and will be particularly helpful in Sections 3 and 4 of the SLP pattern when arranging space relationship diagrams.

Some of these conventions may seem a bit superfluous, but it is best to have the full range of them available and standardized so that they can be used when wanted. Enough alternatives or options are included in the conventions so that diagramming can be done quickly and in a meaningful way. At the same time, the work sheets can be dressed up for presentation to others.

The color codes for closeness rating and for type-of-activity identification are identical to those approved by the Materials Handling & Management Society (MHMS) (formerly IMMS, the International Material Management Society) – after a seven-year study – and adopted as its standard. See Figure 6-5 and Appendix V.

Procedure for Making Activity Relationship Diagram

Working from a relationship chart or form for combining flow and other relationships (see Appendix IV), the planner starts with the A relationships. These are shown in red on the relationship chart. The appropriate symbol for the type of activity is drawn and the activity number is inserted within it. This is then connected by four lines to the A-related activity with its appropriate symbol and its activity number placed therein. See Figure 6-6. Follow down diagonal-sloping row 1 for any A's, then row 2 ... to obtain an orderly sequence of transferring the relationships.

Figure 6-6. Relationship diagramming procedure for a general overall layout of a small research laboratory. This layout project involved new lab space for a professor and his research assistants.

The chart of these activity relations was shown back in Figure 5-2. Here, charted relationships are diagramed to give a geographical arrangement of the activities. Each activity is shown with a symbol as well as by number identification. These conventions are an inherent part of the SLP methodology. Note that in office and lab areas, the circle symbol is used for office and lab operations.

First diagramed are the most important relationships: the A's with four connecting lines. Then the E's are added, with three connecting lines. They are spaced farther apart – theoretically 1.33 farther apart than four-line relationships, but in practice up to twice. In Diagram 3, the A and E relationships are rearranged and the I-rated relations added. Finally in Diagram 4, the O's and X's are added and the diagram rearranged for final "best fit". Here also, activity "9" – natural light – is spread out, for windows are provided along one wall of the available location, and not as a concentrated “spot.”

It usually takes from three to eight diagrams – each successively increased and refined – to get the most satisfactory arrangement. Once diagramed, the space allowed each activity can then be applied to the activities, as will be discussed in Chapter 8.

DIAGRAM 1
1 A (4 Lines – Red)

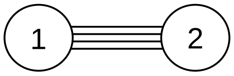


DIAGRAM 2
1 A (4 Lines – Red)
2 E's (3 Lines – Or.-Yel.)

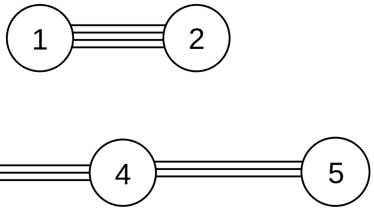


DIAGRAM 3
1 A (4 Lines – Red)
2 E's (3 Lines – Or.-Yel.)
6 I's (2 Lines – Green)

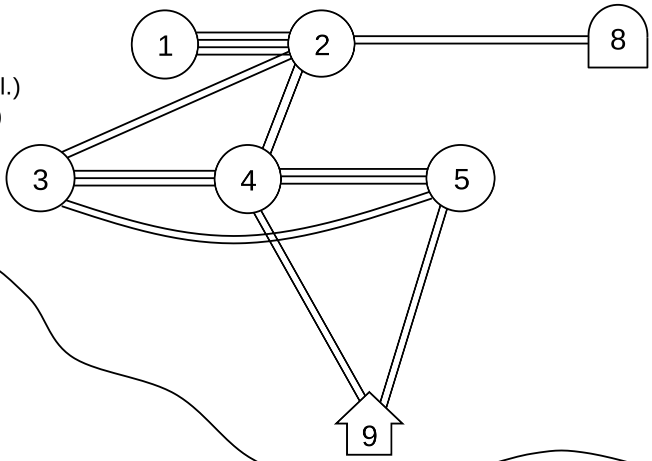
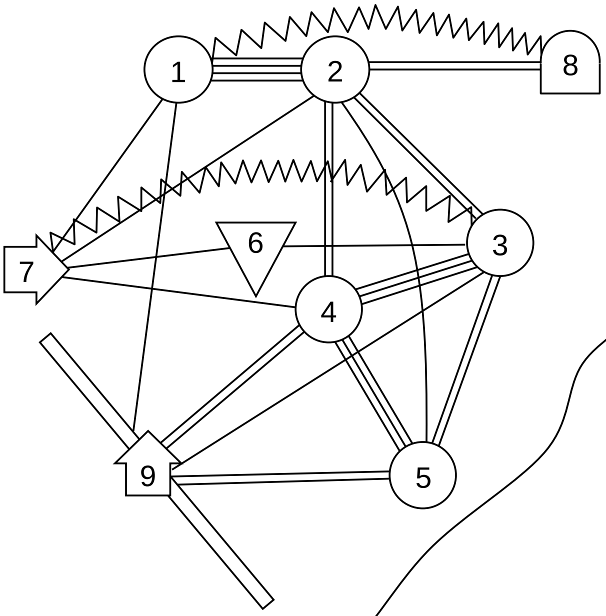
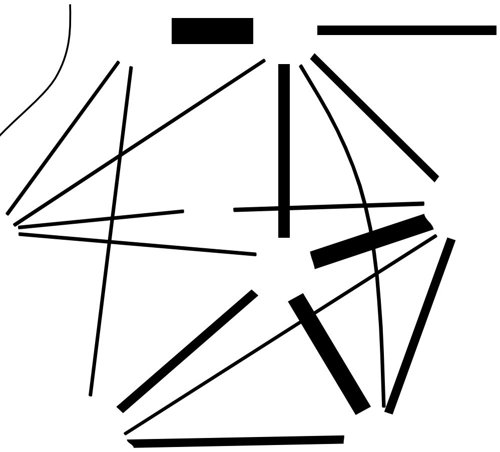


DIAGRAM 4
1 A (4 Lines – Red)
2 E's (3 Lines – Or.-Yel.)
6 I's (2 Lines – Green)
8 O's (1 Line – Blue)
2 X's (Wiggly – Brown)





Note: The ideal diagram equalizes the lengths (separations) of equal-strength relationships, while also attempting to equalize the areas under the "bands" of connecting lines and minimize the total area under all bands. At the same time, "X" relationships should be honored.

After all A relationships are diagramed, generally by spreading them appropriately on the drawing, the next most important relationships are added. These are the E's, or three-line relationships. This usually means rearranging the four-line relationships before adding the three-line ones. Again, the pertinent type-of-activity symbol is used with the activity number inside.

By this time, ordinarily the diagram must be rearranged because the pattern drawn did not give a correct geographic diagram. What the planner seeks, of course, is an arrangement where the distances between E-rated activities (length of three lines) are the same and approximately 1.33 to twice that between A-rated activities (length of four lines). Guidelines for symbol separation are shown in Figure 6-7.

Then I relationships are added. Again it is usually desirable to rearrange the diagram, starting a new drawing or in a fresh position on the same page or sheet, to make an improved pattern or orientation of the A, E, and I activities.

The same is done for the O relationships and for the X and the XX relationships. Double wiggly lines, when they are used, are usually considered to have a negative value of approximately minus three, or about as bad as an E relationship is good. Therefore, any double wiggly lines should usually be added at the same time the I values are diagramed.

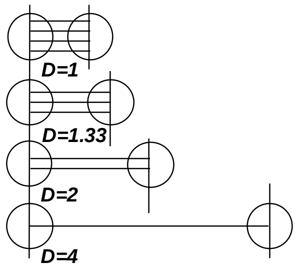
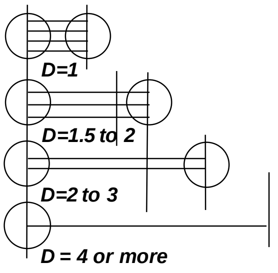
	Theoretical separation to equalize areas under connecting lines (between "bands")			**Practical separation** for ease of recall and effective visualization
Rating	**Number of lines** (width & "strength" or "intensity")	**Desired separation** in diagram (length or "distance")	**Areas** under connecting lines	**Desired separation** in diagram (length or "distance")
A	4 x	1 =	4	1
E	3 x	1.33 =	4	1.5 to 2
I	2 x	2 =	4	2 to 3
O	1 x	4 =	4	4 or more
U	Not shown			
X & XX	Should be long if the X means that distance is actually required (and not merely enclosure of one or both activity-areas).			
				

Figure 6-7. If our closeness ratings are mathematically linear, then we should place symbols according to the theoretically desired separations shown here on the left. This equalizes the areas under the "bands" of connecting lines. That is, the area under an "A" will be equal to that under an "E, I or O." But in practice, 1.33 vs. 1 is difficult to discern, so 1.5 to 2 is a better degree of separation for E-rated pairs, as is 2 to 3 for I-rated pairs and 4 or more for O ratings.

If “X” means that one or both areas need to be enclosed or somehow separated physically but without the need for distance, then X-rated pairs may be close. When X ratings reflect the need for a clean room or ventilation or privacy, they may be better left out of the diagram and treated instead as physical features required for the areas involved.

The planner may draw from three to eight diagrams – successively increasing and refining – before being satisfied with the arrangement. The diagram is considered complete when all the boxes on the chart have been diagramed, and when the diagram's arrangement best meets the desired conditions of closeness. That is, with short four lines and long wiggly lines and relatively appropriate lengths for the other relationships in between.

Be sure to verify your count of each vowel-letter’s frequency. Check each successive drawing to make sure that no relationships were missed or left behind.

The finished diagram represents the theoretically ideal relationship of the activities, independent of the area required for each, and before modifying considerations, such as the handling system or storage equipment, have been incorporated. Figure 6-8 shows an example of a diagram, before color coding, based on the above procedure.

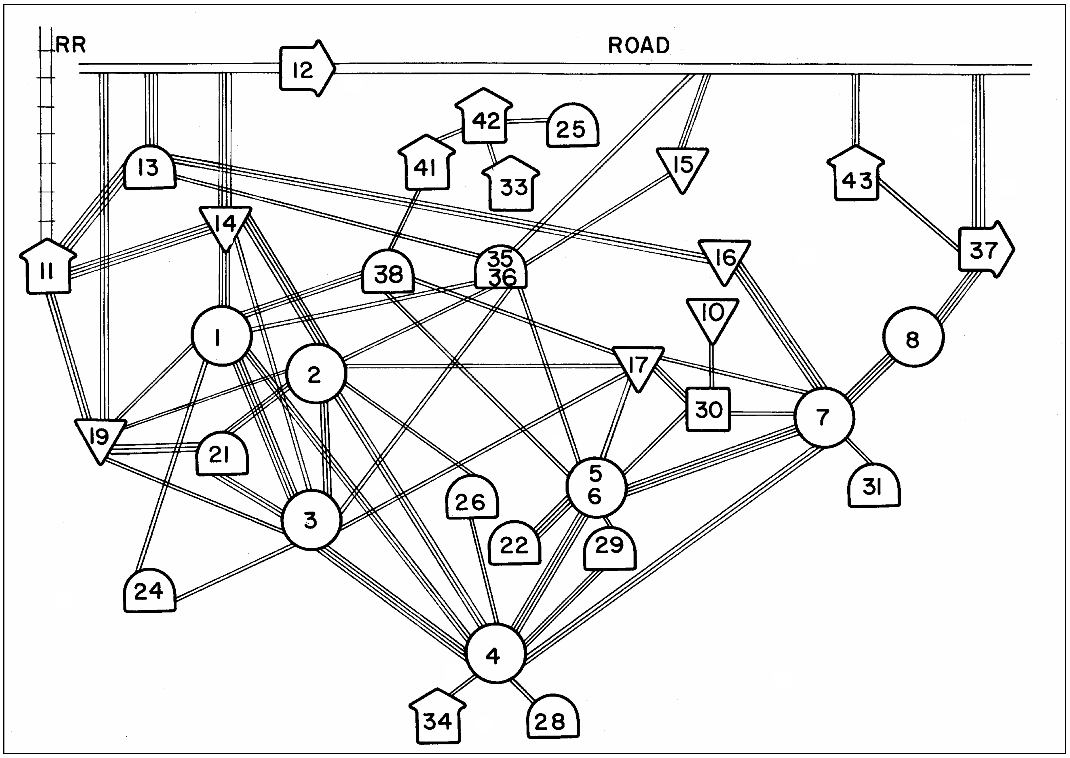


Figure 6-8. A combined flow and other-than-flow relationship diagram for a new ball-and-roller-bearing plant. This shows the diagram carried only to the "Important" (2-line) relationships. This diagram will be adjusted on a fresh sheet and then the "O" and "X" relationships added.

Flow and other relationships have already been combined on the relationship chart before diagramming was begun. The symbol conventions are used to identify the type of activity, although the numbers inside each activity symbol agree with line number of the previously made relationship chart for full identification. A rail siding and road access are shown merely to help identify the activities further. Note that activities 5 and 6 were consolidated into one activity – probably during the relationship charting.

Refinements

In making the diagram, the planner can avoid unnecessary obscuring or tangling of connecting lines by recognizing, yet withholding from the diagram, certain activities and relationships. Service areas or features that may be distributed throughout a layout are commonly treated in this way – for example rest rooms that will be provided according to building code, or conference and team meeting rooms, or fire exit doors.

Also, to illustrate that an activity has to be close to many other activities, the shape of the normal symbol can be distorted to aid in visualizing the relationships diagramed. Figure 6-6 shows this in Diagram 4 for the windows (natural light).

Whenever one activity has connecting lines to a great many other activities, it is a pretty good sign that the activity might better be divided or decentralized. This is especially true of such activities as toilets or rest rooms, foremen's offices, files, storage, and various utilities. At the same time, such connecting lines highlight the need for careful placement when such activities will not be decentralized – for example, a central tool room, or stock room, cafeteria, or main personnel entrance and security.

We have pointed out already that in preparing the diagram, one can use one of two methods. The planner can work directly from the relationship chart, taking one activity after another to pick off the significant rating color being diagramed. With this method, be sure to check the diagram at each trial, for example, by counting the number of red triangles on the chart and matching this with the number of four-line connections.

A second method, useful when some twenty or more activities are involved, interposes another step: a separate recording is posted of each relationship on the chart, grouping them according to closeness rating. The diagram is then made from this listing rather than directly from the chart. This intermediate step helps avoid errors and on complex diagramming it will actually save time. See Figure 6-9.

By calibrating or converting the flow-of-materials values into vowel-letter values before diagramming, the accuracy of the extensive flow calculations that have been made is weakened or decreased. (We discussed this in Chapter 5.) But remember that the flow of materials is based on projected P's, Q's, and R's. It is highly unlikely that these projections themselves are accurate to more than 12½% – the limits of accuracy of the vowel-letter conventions when the half degree with its dotted-line indicator is used. For these and other reasons, the majority of layout-planning projects should be based on a set of combined flow-and-activity-relationships following the procedure in Appendix IV.

To keep it simple and clear, this explanation of diagramming has been concentrated on single-level operations. The same practice generally applies in *multi-level* diagramming. Begin exactly the same way and complete the diagram as if on one level. When the areas have been established for each activity and the space relationship diagram(s) begun, the planner adjusts and rearranges for multiple-level buildings. (A specific procedure for multi-level applications of SLP is explained in Appendix VI.)

ACTIVITY RELATIONSHIPS GROUPED BY CLOSENESS RATING

Activity-Pair				Vowel Rating	Number of Lines	Color
1	Punch Press	3	Lathes	A	4	Red
1	Punch Press	14	Steel Storage	A	4	Red
2	Screw Machine	14	Steel Storage	A	4	Red
3	Lathes	4	Heat Treat	A	4	Red
4	Heat Treat	5	Grinding	A	4	Red
5/6	Grinding (5); Grinding Washer (6)	7	Assembly	A	4	Red
5/6	Grinding (5); Grinding Washer (6)	22	Coolant Cleaner	A	4	Red

Figure 6-9. Recapping the relationship chart prior to diagramming. When there are many relationships to be diagramed, a recap of these relationships will help avoid errors and save repeated scrutiny of the chart. This is done by listing each pair of activities, grouping them by rated closeness – all A-rated (red) relationships first, then E-rated relationships. This lists all activities in the order in which the diagramming will be done. The example here is for the same ball-and-roller bearing plant diagramed in Figure 6-7. Actually, the diagram was made from this recap.

However, sometimes, in working with an existing structure, the planner knows in advance of diagramming that certain fixed features definitely cannot be altered. The planner recognizes these, lists the significant ones (elevator, basement boiler room, second floor show room, and the like) on the activity relationship chart, and designates that fixed activity when diagramming.

Location Considerations

Diagramming relationships can be done with or without considerations of the actual location to be used. Generally speaking, the planner attempts to diagram the ideal arrangement of the various activities and so should use a theoretical diagram based on the data gathered. For this reason, we prefer to make the diagram completely independent of any existing buildings or existing site plans. This makes it possible to develop any arrangement without preconceived ideas, without forcing the planners into practical limitations too early. If this "arranging" is approached with a free and open mind and the theoretically best relationship is diagramed, then there is the possibility of capturing real contributions for the layout plans. There is ample time later on to adjust the theoretical or ideal arrangement to the practical limitations of fixed site and building restrictions.

On the other hand, it may take somewhat longer to go through this approach. Moreover, in some cases it is known that an existing building structure or a certain floor of a specific building must be used with no possibility of changing building features. In these situations, it may be practical to do the diagramming directly on a floor plan of the existing site or building.

At this point, the planner is diagramming only the activities, not the space they require. That is, the planner is not attempting to fit certain areas together according to their size, but interested only in visually relating the activities to each other according to the relative closeness established. Later on, the space to be allowed each activity is incorporated with the diagram. But at this stage the planner works only with the activities themselves.

Conclusion

There are many methods for diagramming flow of materials and activity relations, but the simple orderly procedure described in this chapter is the fastest and most practical way to proceed. Many further refinements can be made on complicated or sophisticated layout projects, but for most cases this technique is adequate. In fact, this procedure is the most universally applicable approach to arranging in a geographical pattern the relationship of activities to one another, for it is usable in planning industrial plants, service industries, and offices or service areas. And it has a specific convention for diagramming negative relationships, often overlooked in less universal methods of diagramming.

Figure 6-10 summarizes the procedure for diagramming flow and activity-relationships.

PROCEDURE FOR DIAGRAMMING RELATIONSHIPS

1. Identify by number and name the activities (areas or features) to be diagramed. Code these by type-of-activity symbol – preferably right on the relationship chart.

2. If not already done in making the relationship chart, calibrate or otherwise relate flow-of-material intensities to the vowel-letter closeness-rating values, combine them with other-than-flow relationships, and record the combined relationship ratings.

3. Diagram the A (4-line) relationships first, as diagram one.

4. Rearrange to get approximately equal lengths of all 4-line relationships, then add the E (3-line) relationships. This will usually be diagram two. Add any XX (double zig-zag or double wiggly line) relationships at this time.

5. Rearrange, trying to get approximately equal lengths of the 3-line relationships but making them visibly longer than the 4-line relationships – theoretically 1.33 times as long, but more likely 1.5 to 2.

6. Then add the I (2-line) relationships and rearrange as necessary. Try to equalize the lengths of the 2-line relationships and make them visibly longer than the 4-line and 3-line. Target 2 to 3 times the length of the 4-line relationships.

7. Add the X (one wiggly line) relationships when adding the O (1-line) relationships. Then rearrange, perhaps by making two or three more diagrams to get the most acceptable fit – the arrangement having the single lines approximately four times as long as the four lines, and the other lines in similar reverse proportion.

8. Check and recopy the final diagram. It will become the basis for the layout when space is added and adjustments are made for modifying considerations and practical limitations.

Figure 6-10. The SLP procedure for diagramming relationships.

Chapter 7

Space Determinations

Up to this point in Phase II of the SLP pattern of procedures, we have ignored space. But once the geographic arrangement of the various activities involved is worked out, the planner must establish the space for each activity. The space, or area, is then fitted to the activity relationship diagram in a Space Relationship Diagram.

The space relationship diagram is actually a crude layout. Refined and rearranged, and incorporating the modifying considerations and their practical limitations, the diagram becomes the layout. But the diagram cannot be drawn without first determining the *space required* and balancing it against the space *available*. This chapter deals with these steps which fall in Section 3 of the SLP pattern.

The omission of space considerations up to this point does not mean that space calculations have to wait until the activities have been diagramed. Actually, space calculations can be made any time after the operating and the supporting activities have been established. However, generally the planner has a much better idea of the breakdown or division of activities, and therefore of the division of space involved, if space determination is not undertaken too early. Wait at least until the input data has been analyzed, preferably until the flow of materials and activity relationship chart has been prepared.

Obviously, this rule doesn't hold for establishing the total space in order to solve a Phase I (Location of the Area to be Laid Out) problem. To decide which location is suitable, one must know how much space is required. Such a figure, however, is generally a rough estimate or an overall figure, calculated without necessarily extensive analysis.

What is covered in this chapter is the area determinations necessary to effective Phase II planning (General Overall Layout).

Because, for best results the phases overlap, in practice, the planner may have to consider Phase II space requirements to satisfy a Phase I solution. Similarly, the planner frequently must consider fairly detailed data on machinery, equipment, services, and the like (normally dealt with in Phase III) in order to determine the overall space requirements suitable for solving the general overall layout of Phase II.

Surveying and Measuring Space Currently Assigned

When activity-areas already exist and will be changed in the layout plan – expanded, consolidated, rearranged, or moved – the planner must start by measuring the space now occupied by each activity, its utilization (tight or loose), and probably its condition or suitability in terms of physical features and overall shape or configuration.

This is usually done with a “take-off” on an existing drawing, either paper or electronic. The current boundaries of each activity-area are drawn onto the current layout and the area within them is measured and posted to a worksheet. Utilization, features and configuration or shape are assessed by visiting and observing the area in operation, and speaking with those who supervise and work within it.

In practice, most existing layouts are found to be out-of-date. So the space measurement itself will require time in the area to establish and/or verify current boundaries and the positions of equipment currently within them. While taking measurements can be disruptive during working hours, it is always best to do this when operators are present to clarify and enlighten the planner on space utilization and needs. Of course, if this poses a danger to the planner or the operators, then off-hours must be used.

When measuring current space, decide in advance how you will account for main aisles separating activity-areas. Then be consistent in how you do it. Two approaches are common:

1. Aisles between areas are measured as aisles and accounted for separately. The space measured for each activity-area is thus “net” – to its boundaries.
2. Aisles are allocated to the activity-areas they serve. The space measured for each activity-area is to the center lines of the aisles that serve it. This will reduce the amount of space carried as “main aisles.” When the layout is planned, main aisles will be “carved out” along selected area boundaries.

Be assertive, direct and open when assessing space utilization. But be prepared for resistance from operators and supervisors if you conclude that they have more space than they need. You may be right, but saying so can be challenging – a bit like being told that your home workshop could be smaller, or your kitchen, if you did a better job managing your pantry inventories and getting rid of all your seldom-used dishware, pots and pans.

Be sure that you allow for recurring peaks or unusual conditions in dynamic areas. For example, assessing a shipping area’s space in the early morning, early in the week and/or month may give a different impression than during the last hour of the week, month or quarter. In storage areas, input data on inventory levels will help to understand “normal” and peak periods. Walk the storage aisles to check the utilization of storage positions. Look into stock boxes and shelves to check cube utilization. Don’t overlook loaded containers, trailers, or off-site storage, or yard storage that should perhaps be inside.

If space reductions from current allocations are predicated on the adoption of different shop or materials management practices, the planner should be confident that the reductions will be realized before “baking them in” to future space requirements. Many easily-projected space reductions prove difficult to achieve.

Often, the layout itself will be key to space savings. By rearranging equipment, or by changing the ins, outs, and flow pattern through an area, significant space can be saved. An example appears in Figure 7-1. In terms of the SLP method, this is an example of the overlap between Phase II overall layout planning and the Phase III detail. In some key areas, the planner may find it valuable and even necessary to “dip down” into detail layout, in order to establish sound future space requirements for an overall layout plan.

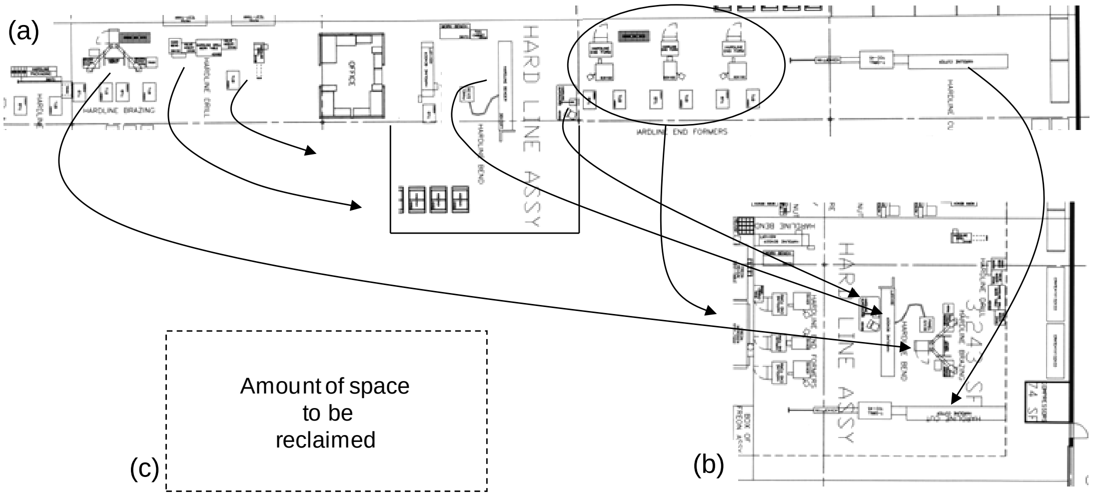


Figure 7-1. Space savings through rearrangement. Here an existing layout has been surveyed to determine current space (a). The area measured is long and spread out. The planner has sketched a compact alternative (b) that will some save space (c). In such situations, the “should have” or “could have” space becomes the starting point for determining future space requirements. The sketch is not the final detail layout, but rather a graphic estimate of space actually required.

Space Requirements

Basically, there are five ways in which to determine space requirements. Each has its place; all may even be used on the same project. Different methods of determining space requirements tend to check each other, thereby giving more credence to the figures. Moreover, very precise methods of space determination may be suitable or required when fixed investment is large. Conversely, in the planning of warehouses or general office areas, there is somewhat less at stake, and accurate details may be more of an exercise in mental gymnastics than of practical use.

The five ways of determining space requirements include:

1. Calculation
2. Converting
3. Space standards
4. Roughed-out layout
5. Ratio trend and projection

These are arranged generally in the order of greatest accuracy, and probably also in the order of most frequent use.

Machinery and Equipment Inventory

Before the calculation method of determining space requirements can be used, the machinery and equipment involved in the project must be identified. If no inventory of equipment is on hand, the planner may have to take a physical inventory in the existing layout areas and then modify it for future conditions. We suggest accounting for each piece of equipment by department or activity so that the information will conform to the activity relationship diagram and the other preceding work.

One can also work from a file of equipment location records. It may be necessary to work from an accounting department asset record or from a professional appraiser's list. Or maybe, equipment-history records are available in the maintenance department.

In small plants, service industries, and office areas, maintaining an equipment inventory on an up-to-date basis may not be practical. Large companies, on the other hand, especially those with frequent rearrangement of facilities or a major investment in machinery and equipment, usually find such a record almost a necessity.

There are various ways in which companies can keep their equipment inventories. We suggest the form shown in Figure 7-2, a simple and convenient form for recording and filing the necessary information – especially that needed for plant layout work. Although all of the detail may not be needed for a Phase II layout, it will in all likelihood be needed later on when the detail layout is being planned.

For initially gathering inventory information, it may be practical to use a shop worksheet and then transfer the information to the Machinery & Equipment Layout Data sheet. Such a worksheet is shown in Figure 7-3.

In addition to a record of machinery and equipment, it is highly useful to have a classification system for the equipment. This is generally set up by equipment type, thereby establishing a filing system. At the same time, this allows cross-filing by departmental areas or activities. There are many systems of classification available, and no simple one is universally used. We recommend a letter prefix indicating the class of equipment followed by a numerical system, with suffix letters as appropriate. For example:

Prefix letter(s) indicating the general class or type of machinery or equipment:

W – welding equipment; P – positioners; C – cutting torches and equipment;
L – lathes; H – handling equipment

Numbers indicating subtype of equipment: W1 – DC arc welders floor mounted;
W6 – spot welders; W8 – gas welding equipment

Suffix letter(s) indicating still further breakdown or accessories

---

Figure 7-2. Machinery and Equipment Layout Data sheet used for space planning and as an inventory record. Here is a standard form with sketch, photographs, specifications, and service requirements. Note that one master document can be made for several duplicate pieces of equipment.

Such a record is better than a graphic template alone and can save valuable time in working out plant layout problems. For equipment currently in use, a copy of its original sheet can be filed according to the activity or area where it is located. And when the equipment is moved, this copy can be re-filed for the new location. This way we can keep a complete inventory by type of equipment and at the same time by area where equipment is in use. The same applies for areas in their planning stages when equipment is to be used. Data sheets for equipment held in storage and available for use can be filed as "free and available." When the machine is disposed of, the record is closed out and the document moved to a history file or archive.

MACHINERY & EQUIPMENT LAYOUT DATA

Company/Unit/Plant *Sola Tech* Project *Housing Cell*

Prepared by *WF* With *TJ* Date *3-Nov*

Water *self-contained coolant* Steam *--* Drains *--*

Comp. Air *6 bar; 150 liters/min.* Gas *--*

Foundation *--* Pit *--* Level/Lag *level*

Exhaust *--* Sp'l. Elect. *--*

Electrical	H.P.	Volts	Cycle	Phase	Amps.		
Drive Motor	*Total connected power 48 kVA*						
Auxiliary Motor							
Auxiliary Motor							

Max. Height *105"*

Weight (less attatch.) *approx. 5500 lbs.*

Name/Type *Machining Center* File *CA-17843*

Manufacturer *Chiron* Size/Model *FZ12S*

Speed/Capacity *18 ci/min. (facemilling ST 60)* Signif. Ident.

Left-Right *60"*

Front-Back *180" incl. hopper*

Net Floor Area ⓐ *70 sq. ft.*

Worker/Main.Area *20 sq. ft.*

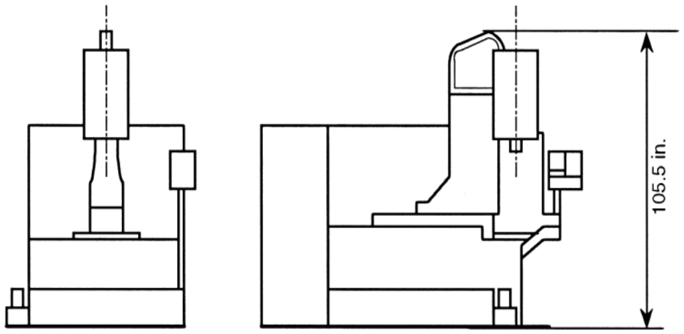
Material Set-down *incl. in Work Area*

Area for Aisles *54 sq.ft.(1/2 aisle)*

Service/Other *36 sq. ft.*

Gross Area (plan for) *180 sq. ft.*

Co. Mach./Equip. Identification Numbers Covered by this Sheet		
CA-17843-01		
CA-17843-02		
CA-17843-03		
CA-17843-04		

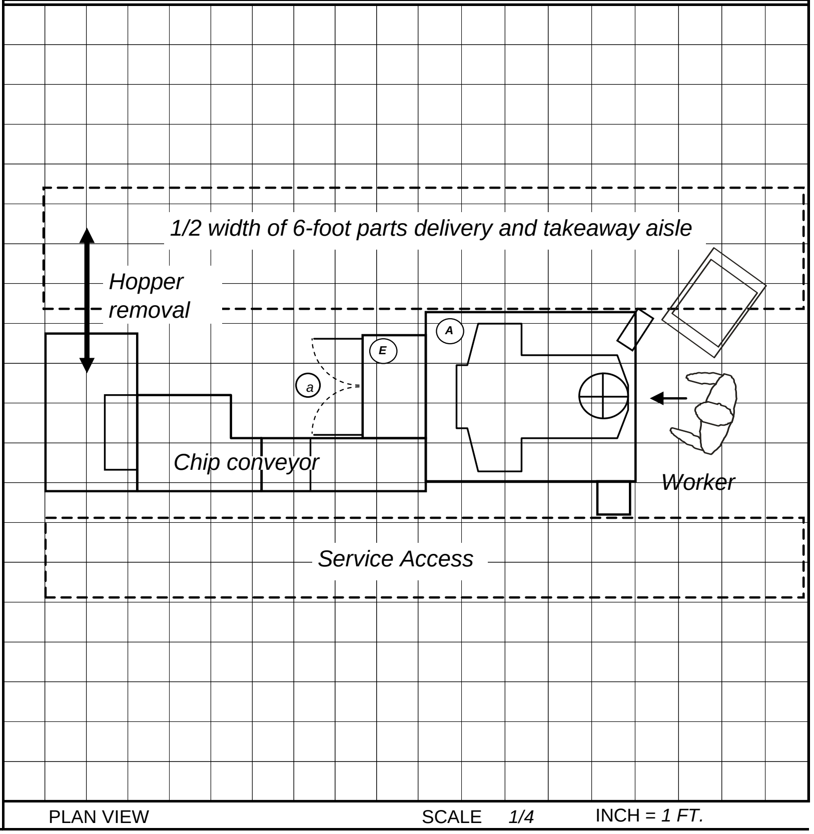


Note:

1. Chip removal conveyor and hopper not shown

2. Open doors on electrical cabinet not shown.

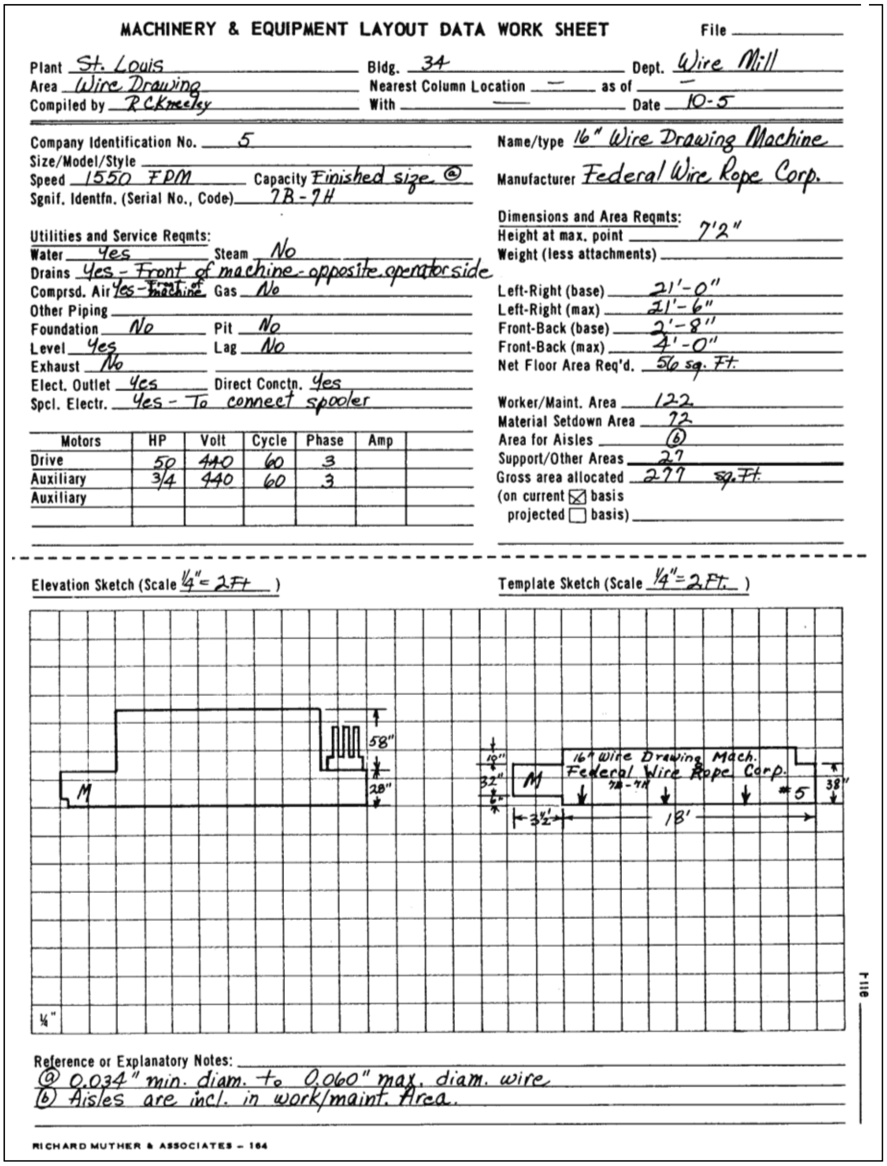
ELEVATION SKETCH OR PHOTO SOURCE *MFG.* DATE *11/2*



PLAN VIEW SCALE *1/4* INCH = *1 FT.*

Reference Notations/changes ⓐ *Access to electrical panel (behind machine) included in net area.*

The classification described above refers only to the type of equipment, not identification of a particular piece of machinery or equipment. To identify specific items of equipment an identification or "tag" number should be assigned each. This is usually done from a master log – not infrequently by the accounting group responsible for fixed asset records and depreciation schedules. Tag numbers should match the number tagged to or otherwise marked on the equipment. While there are many systems, perhaps the easiest is simply to start with 10,001 and keep a numerical sequence, using the same letter prefix mentioned above to tie class of equipment to each tag number. See Appendix VII for details of a simple identification system.



MACHINERY & EQUIPMENT LAYOUT DATA WORK SHEET

File

Plant St. Louis
Bldg. 34
Dept. Wire Mill
Area Wire Drawing
Nearest Column Location — as of —
Compiled by R C Kneeley
With —
Date 10-5

Company Identification No. 5
Size/Model/Style
Speed 1550 FPM
Capacity Finished size ⓐ
Sgnif. Identfn. (Serial No., Code) 7B-7H

Name/type 16" Wire Drawing Machine
Manufacturer Federal Wire Rope Corp.

Utilities and Service Reqmts:
Water Yes
Steam No
Drains Yes - Front of machine - opposite operator side
Comprsd. Air Yes - Front of machine
Gas No
Other Piping
Foundation No
Pit No
Level Yes
Lag No
Exhaust No
Elect. Outlet Yes
Direct Conctn. Yes
Spcl. Electr. Yes - To connect spooler

Motors	HP	Volt	Cycle	Phase	Amp
Drive	50	440	60	3	
Auxiliary	3/4	440	60	3	
Auxiliary					

Dimensions and Area Reqmts:
Height at max. point 7'2"
Weight (less attachments)
Left-Right (base) 21'-0"
Left-Right (max) 21'-6"
Front-Back (base) 2'-8"
Front-Back (max) 4'-0"
Net Floor Area Req'd. 56 sq. Ft.
Worker/Maint. Area 122
Material Setdown Area 72
Area for Aisles ⓑ
Support/Other Areas 27
Gross area allocated 277 sq. Ft.
(on current ☒ basis
projected ☐ basis)

Elevation Sketch (Scale ¼" = 2Ft)

Template Sketch (Scale ¼" = 2Ft.)

Reference or Explanatory Notes:
ⓐ 0.034" min. diam. to 0.060" max. diam. wire
ⓑ Aisles are incl. in work/maint. Area.

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Figure 7-3. Worksheet to gather information concerning details of each piece of machinery or equipment. Data will be used to develop space requirements, to establish utilities and services needed, and as a basis for template or model preparation. This is the working or shop survey sheet, from which the machinery and equipment layout data sheet (like Figure 7-2) is prepared. This latter document then becomes a permanent record.

Calculation Method of Determining Space

The *calculation method* of determining space requirements is generally the most accurate. It involves breaking down each activity or area into the sub-areas and individual space elements that make up its total space.

First, determine the *amount* of area for each space element, then multiply by the *number* of elements required to do the job, and add any *extra* space not generally apportionable to any of the elements.

For industrial plants this calculation can be compiled as shown in Figure 7-4. Here, each element of machinery and equipment is listed and data recorded for the area occupied by the equipment itself, for the operator's work and maintenance area, and for material set-down area – all built into a total area per machine or piece of equipment.

To calculate the number of machines or pieces of equipment needed on any project, the operation times for each part number, the number of pieces per year or per period, and allowances for downtime, scrap, and the like, must be known. (See Appendix VIII for more on calculating machine requirements.) The number of machines required – ignoring scrap, downtime, and the like – equals:

$$\text{Number of machines required} = \frac{\begin{array}{c}\text{pieces per hour to meet}\\\text{production requirements}\end{array}}{\begin{array}{c}\text{pieces per hour}\\\text{per machine}\end{array}} = \frac{\begin{array}{c}\text{time per piece}\\\text{per machine}\end{array}}{\begin{array}{c}\text{time per piece to meet}\\\text{production requirements}\end{array}}$$

In calculating machines required, certain precautions must be taken.

1. Part of a machine obviously can not be purchased. Generally the planner must go to the full, or next full, machine, when a fraction of a machine is required.
2. One hundred percent good work is not possible. We must decide how much we expect in yield or spoilage and make an allowance in determining the number of machines.
3. Known or anticipated capacity-reducing delays – whether due to the operator or to the operating practices of the plant – must be incorporated, if they have not been built into the figures as a delay allowance when the operating times per piece were established. Of course, such delays should always be challenged and their causes reviewed.
4. Machine utilization, due to changeover or set-ups, failure of utilities, repair, or maintenance, is an important factor in all plants and must be compensated for on an individual machine basis.
5. Some plants compute “overall equipment effectiveness” (OEE) for their machines and production lines. OEE is a single statistic that takes into account: machine availability, performance (cycle time or run rate) and quality (yield). As such, it can be a starting point for discussions about future operating practices and effectiveness that may impact the number of machines required.

MACHINERY & EQUIPMENT AREA & FEATURES SHEET

Project *73513*
By *O.M. Cramer* With *D.F. Addis*
Company/Plant *Nortot* Bldg/Dept/Area *Cafeteria-Kitchen* Date *8-3* Sheet *2* of *2*

Identification Data		Space									Physical Features Required															
Machine or Equipment Identification Number	Name and/or Description	Left -- Right *Inches*	Front -- Back *Inches*	Height *Inches*	Area for Machinery or Equip. in *Sq. ft.* ⓓ	Operator(s) Work & Maintenance Area	Material Set-down Area	Total Area each Machine or piece of Equip.	No. of Machines/Equip.	Total Net Area* (in *Sq. ft.*)	110 - A.C.	120 - A.C.	Other Power	Ampere Rating		Water	Steam	Drains	Compressed Air	Other Piping *Gas*	Foundation/Pit	Exhaust/Hood	Dust Collector			Comments - - - - - Shape/Configuration Special Requirements
Area Total	*Brought Forward from Page 1*									*1218*																
Bake																										
D-1	*Sink*	*24*	*24*	*--*	*4*	*6*	*4*	*14*	*1*	*14*	-	-	--	--		✓	-	✓	-	--	-	-	-			
D-2	*Food Prep Table*	*120*	*30*	*--*	*25*	*111*	*--*	*136*	*1*	*136*	✓	-	--	--		-	-	-	-	--	-	-	-			
D-3	*Steamer (Stag)*	*19*	*30*	*25*	*4*	*4*	*--*	*8*	*1*	*8*	✓	-	--	--		✓	✓	✓	-	✓	-	✓	-			
D-4	*Proof Box*	*21.5*	*28*	*63*	*4*	ⓐ *10*	*--*	*14*	*1*	*14*	✓	-	--	--		-	-	-	-	--	-	-	-			
D-5	*Bake Oven*	*60*	*40*	*--*	*17*	*23*	*--*	*40*	*1*	*40*	-	-	--	--		-	-	-	-	✓	-	✓	-			*Use tray 18 x 26*
D-6	*Portable Mixer, Hobart A-200*	*18*	*18*	*--*	*2*	*5*	*4*	*11*	*1*	*11*	✓	-	--	--		-	-	-	-	--	-	-	-			
Cook Area																										
F-7	*Range*	*29*	*34*	*--*	*7*	ⓑ *17*	*--*	*24*	*1*	*24*	-	-	--	--		✓	-	-	-	✓	-	✓	-			
F-8	*Range*	*29*	*34*	*--*	*7*	ⓒ *17*	*--*	*24*	*1*	*24*	-	-	--	--		✓	-	-	-	✓	-	✓	-			
F-10	*Portable Slicer, U.S. Model 806*	*26*	*20*	*20*	*4*	*9*	*6*	*19*	*1*	*19*	✓	-	--	--		-	-	-	-	--	-	-	-			

* Required space for main or delivery aisles and service areas not included.

Total Net Area Required* (in *Sq. ft.*)	*1508*
Aisles	*720*
Services	*305*
Other	*--*
Total Area Req'd.	*2535*

Reference Notes:

a. *Door swing is 21-1/2 inches*
b. *Door swing is 17 inches*
c. *Door swing is 17 inches*
d. *Areas rounded to nearest sq. ft.*
e. *Total area rounded to nearest 5 sq. ft.*

6. Peak demands – if not already built into the requirement figures – should be allowed for. Actually, these may vary from machine to machine, depending upon the critical nature of the operation, whether or not the work is tightly scheduled, and whether or not the work can be put on alternate machines or sent outside to subcontract shops. If the machine is already operating on two or three shifts, the possibility of solving this problem by overtime is unlikely.
7. In balancing production lines, the planner must account for the fact that extra machine capacity may be available for use by other areas, but that because it is segregated for use in the production line, it may not be practical to move other materials in and out of the machine.
8. Where only a small portion of an additional machine is required, an attack on methods improvement or simplifying the job may reduce operating time sufficiently to avoid the investment in an additional machine which would be used only a small portion of the time.

For calculating space for office areas, the working form shown in Figure 7-5 is highly practical. No specific standard form has been developed for calculating storage and service-area space because of the wide diversity of activities that go on in these types of areas. Therefore, we should make our own worksheets to suit the particular requirements of the layout planning project. Examples of such worksheets are shown in Figure 7-6. Not infrequently, one must dig much deeper than merely gathering the data for these forms. We are trying to keep this presentation simple, but the planner should not hesitate to use more detailed or more sophisticated methods of space calculation whenever it is warranted.

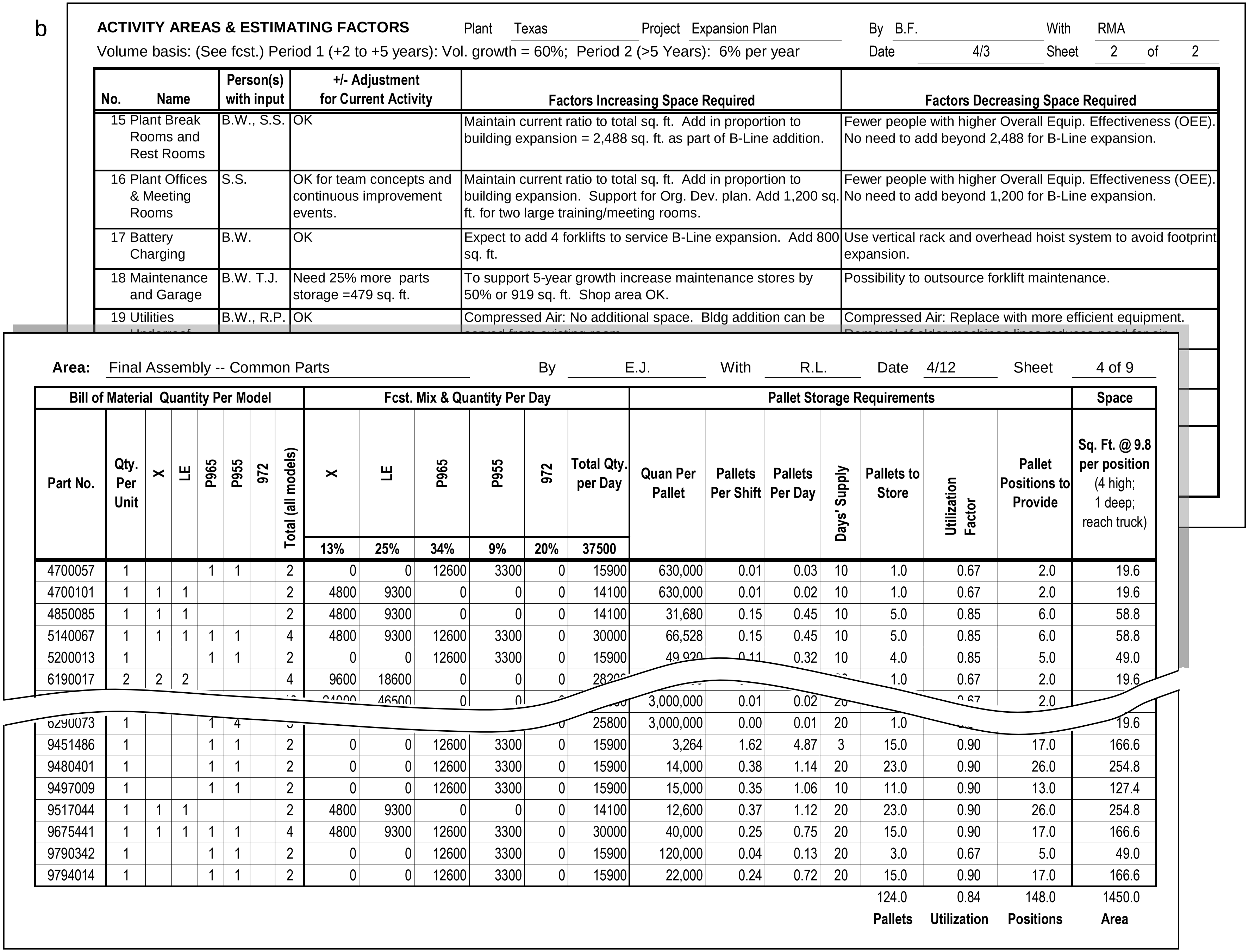
Note that service area space for boiler rooms, compressors, and power supplies must often be accounted for even though these areas are fixed and will not change. Their requirements are typically determined through conversion or rough layout.

The Converting Method of Space Determination

A second method of determining space requirements is known as the *converting,* or factoring, *method:* establishing what space is being occupied at the present time and converting it to what will be required for the proposed layout. This conversion is usually a matter of logic, best estimate, or educated guess.

In using the converting method there is a great temptation merely to jump directly from "what we have now" to "what we anticipate needing." Do not be drawn into this trap. The layout planner must be more discriminating. Adjust the existing space to what is actually needed now and then convert it for each individual area. The form in Figure 7-7 is recommended for it allows sound decision-making at each stage.

Figure 7-4. Calculation of space requirements by measuring individual units of machinery and equipment. Equipment is listed by identification and name at left. On the same line are entered the dimensions and the space calculations. At the bottom are added requirements applicable to the activity in question but not assignable to any specific piece of equipment. Note that at the time the equipment is examined for dimensions, its physical features are also recorded (at right). This information may not seem necessary, but undoubtedly will be needed later on and this is a logical time and way to get it.



b

ACTIVITY AREAS & ESTIMATING FACTORS Plant Texas Project Expansion Plan By B.F. With RMA

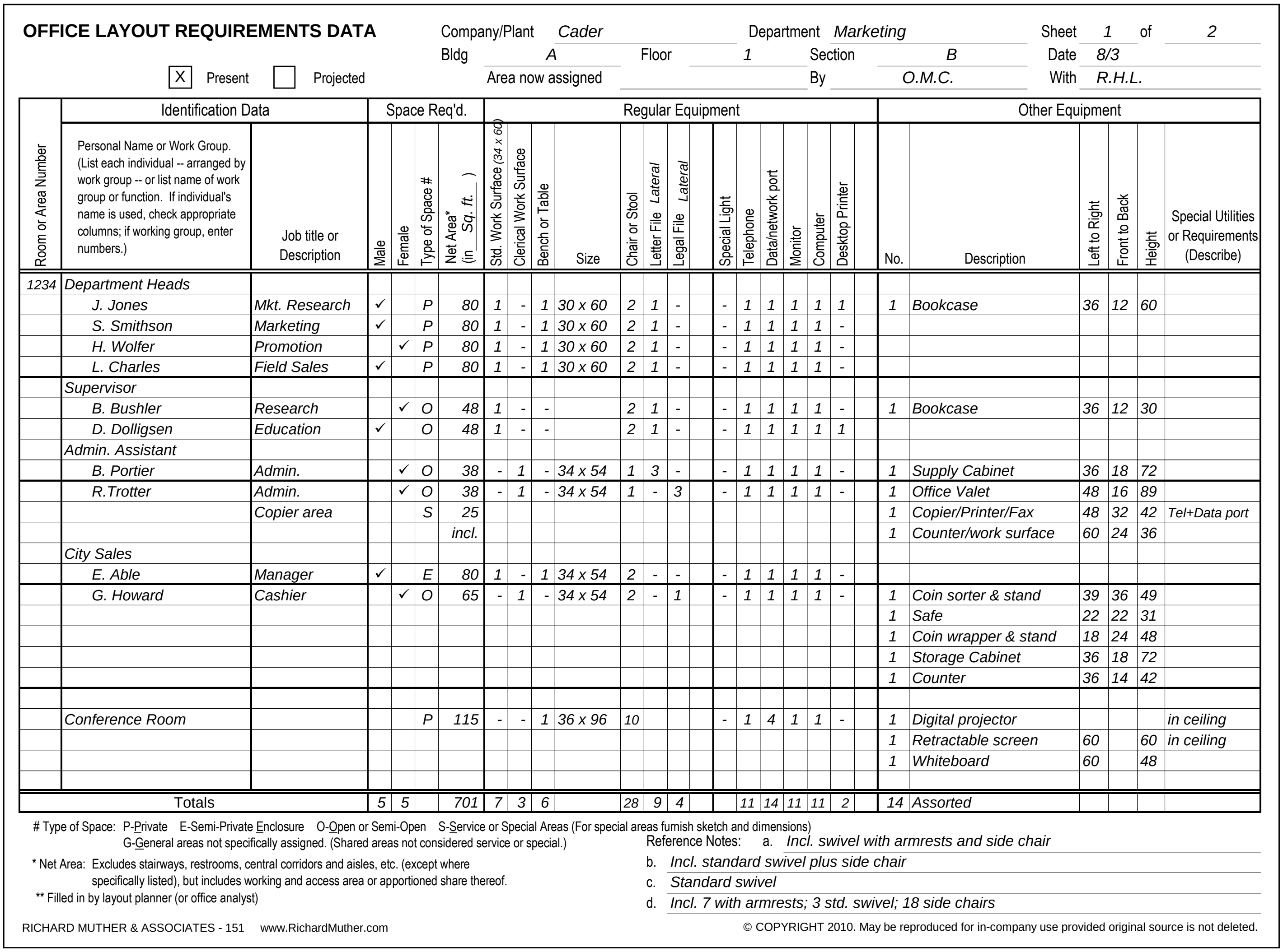
Volume basis: (See fcst.) Period 1 (+2 to +5 years): Vol. growth = 60%; Period 2 (>5 Years): 6% per year Date 4/3 Sheet 2 of 2

No. Name	Person(s) with input	+/- Adjustment for Current Activity	Factors Increasing Space Required	Factors Decreasing Space Required
15 Plant Break Rooms and Rest Rooms	B.W., S.S.	OK	Maintain current ratio to total sq. ft. Add in proportion to building expansion = 2,488 sq. ft. as part of B-Line addition.	Fewer people with higher Overall Equip. Effectiveness (OEE). No need to add beyond 2,488 for B-Line expansion.
16 Plant Offices & Meeting Rooms	S.S.	OK for team concepts and continuous improvement events.	Maintain current ratio to total sq. ft. Add in proportion to building expansion. Support for Org. Dev. plan. Add 1,200 sq. ft. for two large training/meeting rooms.	Fewer people with higher Overall Equip. Effectiveness (OEE). No need to add beyond 1,200 for B-Line expansion.
17 Battery Charging	B.W.	OK	Expect to add 4 forklifts to service B-Line expansion. Add 800 sq. ft.	Use vertical rack and overhead hoist system to avoid footprint expansion.
18 Maintenance and Garage	B.W. T.J.	Need 25% more parts storage =479 sq. ft.	To support 5-year growth increase maintenance stores by 50% or 919 sq. ft. Shop area OK.	Possibility to outsource forklift maintenance.
19 Utilities	B.W., R.P.	OK	Compressed Air: No additional space. Bldg addition can be	Compressed Air: Replace with more efficient equipment.

a

Area: Final Assembly -- Common Parts By E.J. With R.L. Date 4/12 Sheet 4 of 9

Bill of Material Quantity Per Model							Fcst. Mix & Quantity Per Day						Pallet Storage Requirements							Space
Part No.	Qty. Per Unit	X	LE	P965	P955	972	Total (all models)	X	LE	P965	P955	972	Total Qty. per Day	Quan Per Pallet	Pallets Per Shift	Pallets Per Day	Days' Supply	Pallets to Store	Utilization Factor	Pallet Positions to Provide	Sq. Ft. @ 9.8 per position (4 high; 1 deep; reach truck)
								13%	25%	34%	9%	20%	37500								
4700057	1			1	1		2	0	0	12600	3300	0	15900	630,000	0.01	0.03	10	1.0	0.67	2.0	19.6
4700101	1	1	1				2	4800	9300	0	0	0	14100	630,000	0.01	0.02	10	1.0	0.67	2.0	19.6
4850085	1	1	1				2	4800	9300	0	0	0	14100	31,680	0.15	0.45	10	5.0	0.85	6.0	58.8
5140067	1	1	1	1	1		4	4800	9300	12600	3300	0	30000	66,528	0.15	0.45	10	5.0	0.85	6.0	58.8
5200013	1			1	1		2	0	0	12600	3300	0	15900	49,920	0.11	0.32	10	4.0	0.85	5.0	49.0
6190017	2	2	2				4	9600	18600	0	0	0	282					1.0	0.67	2.0	19.6
								24000	46500	0	0			3,000,000	0.01	0.02	20		0.67	2.0	
6290073	1			1	4							0	25800	3,000,000	0.00	0.01	20	1.0			19.6
9451486	1			1	1		2	0	0	12600	3300	0	15900	3,264	1.62	4.87	3	15.0	0.90	17.0	166.6
9480401	1			1	1		2	0	0	12600	3300	0	15900	14,000	0.38	1.14	20	23.0	0.90	26.0	254.8
9497009	1			1	1		2	0	0	12600	3300	0	15900	15,000	0.35	1.06	10	11.0	0.90	13.0	127.4
9517044	1	1	1				2	4800	9300	0	0	0	14100	12,600	0.37	1.12	20	23.0	0.90	26.0	254.8
9675441	1	1	1	1	1		4	4800	9300	12600	3300	0	30000	40,000	0.25	0.75	20	15.0	0.90	17.0	166.6
9790342	1			1	1		2	0	0	12600	3300	0	15900	120,000	0.04	0.13	20	3.0	0.67	5.0	49.0
9794014	1			1	1		2	0	0	12600	3300	0	15900	22,000	0.24	0.72	20	15.0	0.90	17.0	166.6
																		124.0	0.84	148.0	1450.0
																		Pallets	Utilization	Positions	Area



OFFICE LAYOUT REQUIREMENTS DATA

☒ Present ☐ Projected

Company/Plant *Cader* Department *Marketing* Sheet *1* of *2*
Bldg *A* Floor *1* Section *B* Date *8/3*
Area now assigned By *O.M.C.* With *R.H.L.*

Room or Area Number	Identification Data		Space Req'd.				Regular Equipment															Other Equipment					
	Personal Name or Work Group. (List each individual -- arranged by work group -- or list name of work group or function. If individual's name is used, check appropriate columns; if working group, enter numbers.)	Job title or Description	Male	Female	Type of Space #	Net Area* (in *Sq. ft.*)	Std. Work Surface *(34 x 60)*	Clerical Work Surface	Bench or Table	Size	Chair or Stool	Letter File *Lateral*	Legal File *Lateral*		Special Light	Telephone	Data/network port	Monitor	Computer	Desktop Printer		No.	Description	Left to Right	Front to Back	Height	Special Utilities or Requirements (Describe)
1234	*Department Heads*																										
	J. Jones	*Mkt. Research*	✓		*P*	*80*	*1*	*-*	*1*	*30 x 60*	*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*1*		*1*	*Bookcase*	*36*	*12*	*60*	
	S. Smithson	*Marketing*	✓		*P*	*80*	*1*	*-*	*1*	*30 x 60*	*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*-*							
	H. Wolfer	*Promotion*		✓	*P*	*80*	*1*	*-*	*1*	*30 x 60*	*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*-*							
	L. Charles	*Field Sales*	✓		*P*	*80*	*1*	*-*	*1*	*30 x 60*	*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*-*							
	Supervisor																										
	B. Bushler	*Research*		✓	*O*	*48*	*1*	*-*	*-*		*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*-*		*1*	*Bookcase*	*36*	*12*	*30*	
	D. Dolligsen	*Education*	✓		*O*	*48*	*1*	*-*	*-*		*2*	*1*	*-*		*-*	*1*	*1*	*1*	*1*	*1*							
	Admin. Assistant																										
	B. Portier	*Admin.*		✓	*O*	*38*	*-*	*1*	*-*	*34 x 54*	*1*	*3*	*-*		*-*	*1*	*1*	*1*	*1*	*-*		*1*	*Supply Cabinet*	*36*	*18*	*72*	
	R.Trotter	*Admin.*		✓	*O*	*38*	*-*	*1*	*-*	*34 x 54*	*1*	*-*	*3*		*-*	*1*	*1*	*1*	*1*	*-*		*1*	*Office Valet*	*48*	*16*	*89*	
		Copier area			*S*	*25*																*1*	*Copier/Printer/Fax*	*48*	*32*	*42*	*Tel+Data port*
						incl.																*1*	*Counter/work surface*	*60*	*24*	*36*	
	City Sales																										
	E. Able	*Manager*	✓		*E*	*80*	*1*	*-*	*1*	*34 x 54*	*2*	*-*	*-*		*-*	*1*	*1*	*1*	*1*	*-*							
	G. Howard	*Cashier*		✓	*O*	*65*	*-*	*1*	*-*	*34 x 54*	*2*	*-*	*1*		*-*	*1*	*1*	*1*	*1*	*-*		*1*	*Coin sorter & stand*	*39*	*36*	*49*	
																						1	*Safe*	*22*	*22*	*31*	
																						1	*Coin wrapper & stand*	*18*	*24*	*48*	
																						1	*Storage Cabinet*	*36*	*18*	*72*	
																						1	*Counter*	*36*	*14*	*42*	
	Conference Room				*P*	*115*	*-*	*-*	*1*	*36 x 96*	*10*				*-*	*1*	*4*	*1*	*1*	*-*		*1*	*Digital projector*				*in ceiling*
																						1	*Retractable screen*	*60*		*60*	*in ceiling*
																						1	*Whiteboard*	*60*		*48*	
Totals			*5*	*5*		*701*	*7*	*3*	*6*		*28*	*9*	*4*			*11*	*14*	*11*	*11*	*2*		*14*	*Assorted*				

\# Type of Space: P-Private E-Semi-Private Enclosure O-Open or Semi-Open S-Service or Special Areas (For special areas furnish sketch and dimensions)
G-General areas not specifically assigned. (Shared areas not considered service or special.)

* Net Area: Excludes stairways, restrooms, central corridors and aisles, etc. (except where specifically listed), but includes working and access area or apportioned share thereof.

** Filled in by layout planner (or office analyst)

Reference Notes:
a. *Incl. swivel with armrests and side chair*
b. *Incl. standard swivel plus side chair*
c. *Standard swivel*
d. *Incl. 7 with armrests; 3 std. swivel; 18 side chairs*

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Figure 7-5. Calculating space requirements for office areas. This example shows the gathered information for an existing office being relocated. If the operations, organization, or size of staff are to be different at the new location, another sheet with projected space and equipment requirements should be made up.

Figure 7-6 a & b. Work sheets (opposite) to gather facts for calculating storage and service area space requirements. Form (a) was used to determine purchased parts storage space in an electronics assembly plant. The target days of supply (Q) for each stored item (P) were provided by the materials manager; the storage rack utilization factor by the warehouse manager. The space per pallet assumes storage and handling methods determined by the warehouse manager and the layout planner.

Form (b) was used to determine space requirements for 35% volume growth in a plant making plastic packaging material. Assessments of current space and the factors increasing and decreasing space required are enumerated for each activity-area. Initials identify the person(s) providing the inputs and assumptions. This worksheet is good estimating practice for all activity-areas on every layout project.

SPACE REQUIREMENTS -- CONVERTING

See fcst.Period 1 (+2 Years) Vol. growth = 60%; Period 2 = 6% per year

Basis (year, period, quantity) of Columns e, f, g *+2 Years* Columns h, j, k *+5 Years*

Plant *Texas* Project *Expansion Plan*

By *B.F.* With *RMA*

Date *4/3* Sheet *1* of *1*

a Activity-- Area or Dept. Unit →	b Area Now Occupied Sq. Ft.	c + or - Adjstmt. % or Sq. Ft.	d Should Have Now Sq. Ft.	e Increase Decrease Sq. Ft.	f Req'd Area Determined Sq. Ft.	g Plan-For Area Sq. Ft.	h Increase Decrease Sq. Ft.	j Req'd Area Determined Sq. Ft.	k Plan-For Area Sq. Ft.
1. *Blending*	*3,287*	*0*	*3,290*	*1,000*	*4,290*	*4,290*	*0*	*4,290*	*4,290*
2. *Extrusion*	*19,035*	*0*	*19,040*	*3,400*	*22,440*	*22,440*	*0*	*22,440*	*22,440*
3. *Film & Tape Storage*	*6,146*	*0*	*6,150*	*0*	*6,150*	*6,150*	*0*	*6,150*	*6,150*
4. *Tape Slitting*	*4,000*	*0*	*4,000*	*0*	*4,000*	*4,000*	*-4,000*	*0*	*0*
5. *Commodity Receiving & Storage*	*20,292*	*0*	*20,290*	*2,029*	*22,320*	*22,000*	*0*	*22,320*	*22,000*
6. *A Line Bag Production*	*4,221*	*0*	*4,220*	*0*	*4,220*	*4,220*	*0*	*4,220*	*4,220*
7. *B Line Bag Production*	*19,775*	*0*	*19,780*	*61,540*	*81,320*	*81,200*	*20,000*	*101,320*	*100,000*
8. *Old Style Bag Prod.*	*43,600*	*0*	*43,600*	*-6,300*	*37,300*	*37,300*	*-18,000*	*19,300*	*19,000*
9. *Food Bag Production*	*26,000*	*-50%*	*13,000*		*13,000*	*13,000*	*-13,000*	*0*	*0*
10. *Central Palletizing*	*0*	*0*	*0*	*10,000*	*10,000*	*10,000*	*0*	*10,000*	*10,000*
11. *Curing Ovens*	*3,000*	*-33%*	*2,000*	*0*	*2,000*	*2,000*	*-2,000*	*0*	*0*
12. *Shipping (Staging)*	*14,213*	*+50%*	*21,230*	*6,369*	*27,600*	*26,500*	*13,000*	*40,600*	*39,000*
13. *Club Inventory*	*7,191*	*0*	*7,190*	*2,373*	*9,560*	*9,000*	*4,500*	*14,060*	*13,000*
14. *Reclaim*	*9,518*	*0*	*9,520*	*0*	*9,520*	*9,520*	*0*	*9,520*	*9,520*
15. *Plant Break Rooms & Rest Rooms*	*6,706*	*0*	*6,710*	*0*	*6,710*	*6,710*	*0*	*6,710*	*6,710*
16. *Plant Offices & Meeting Rooms*	*4,668*	*0*	*4,670*	*0*	*4,670*	*4,670*	*0*	*4,670*	*4,670*
17. *Battery Charging*	*1,219*	*0*	*1,220*	*800*	*2,020*	*2,020*	*0*	*2,020*	*2,020*
18. *Maintenance & Garage*	*6,025*	*480*	*6,510*	*919*	*7,430*	*6,540*	*890*	*8,320*	*8,400*
19. *Utilities Underroof (Mechanical, Electrical, Chillers)*	*7,902*	*0*	*7,900*	*1,700*	*9,600*	*9,600*	*0*	*9,600*	*9,600*
20. *Front Offices (Admin., Engineering & QC Lab)*	*11,315*	*0*	*11,310*	*625*	*11,940*	*11,940*	*625*	*12,565*	*12,580*
TOTALS	*218,100*	*500*	*211,600*	*84,500*	*296,100*	*293,100*	*2,000*	*298,100*	*293,100*

NOTES:

Converting is a highly practical method, especially applicable:

1. When the project involved must be done in a hurry
2. When space requirements for Phase I only are being planned
3. When the nature of the work done in any activity or area is so diverse and complicated that detailed calculations are not warranted, e.g. maintenance or repair, or some receiving and shipping operations
4. When key elements required for calculation, such as the product or quantity information, are too general or too indefinite to justify using the calculation method – often the case when making estimates for 2 to 5 years hence
5. As a check on detailed calculations for future periods

It is not uncommon to calculate space requirements for manufacturing areas and then use the converting method for establishing supporting service and storage areas.

Space Standards

The use of pre-established space standards is a practical way to determine requirements for many projects. Basically, once the area requirements for a given machine or space element are established, the planner should be able to use that figure over and over again. See Figure 7-8 for an example of space standards.

In actual practice, however, this does not always work. In fact, there is great danger in using standards established by someone else unless the planner understands what is involved in the space element, what the working conditions are – or are anticipated to be – and how to refer to and get access to the back-up data supporting the standards.

Figure 7-7. The conversion method of space determination. Activities are listed at the left with the space each currently occupies shown beside it. Note that the space unit at the top of each column can be varied, depending on the area (square feet, square meters, acres, etc.) or whether an amount or a percentage figure is used (columns c, e, and h).

Before converting the present areas to the plan-for areas, several steps should be taken. First, present space should be adjusted from what it "happens to be" to "what it should be" to do the current job satisfactorily. This results in the figures in column d. Then, based on the expansion or contraction plans, the basis of which is identified at the top of the form, an increase or decrease figure is assigned for each activity. This is much more accurate and discriminating than using a blanket figure for all activities. The conversion is then made to the required areas (column f). The final step is to compare the required area with the area available. Adjustments between the two will then result in the plan-for areas shown in column g.

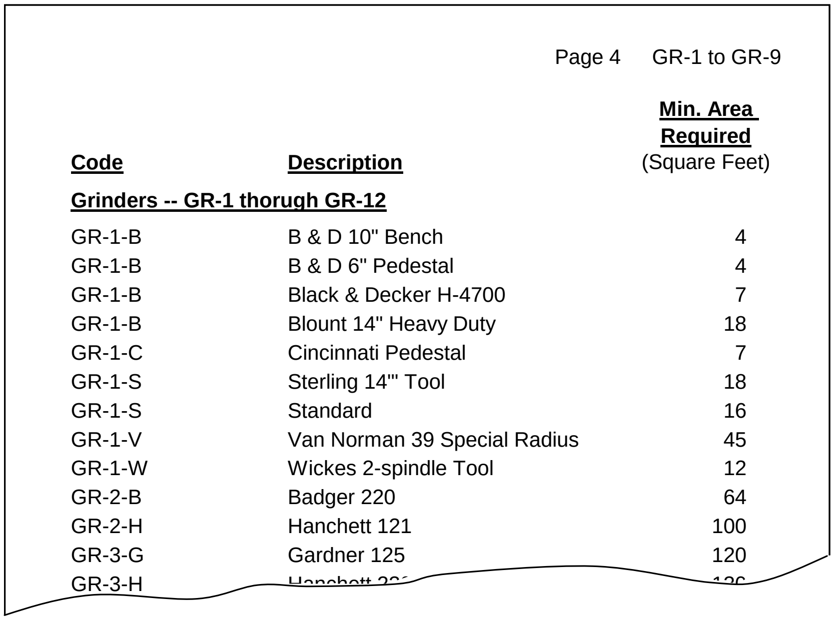
The example shown here is for the expansion of a plant making plastic packaging material. Note how the planners have used the form to plan an initial expansion for the next two years in columns e, f, and g, and have projected their space plans for 5 years hence in columns h, j and k. Note that the plant cannot be made larger than 293,100 square feet – less than the future space required in both periods. This form makes explicit which areas will be squeezed to fit within the space available. This alerts the planners, supervisors and managers of these areas to look for space saving tactics.

Notes and assumptions supporting these space requirements are recorded on the worksheet in Figure 7-6b and can be seen for activity-areas 15 – 18. It is good practice to keep such notes either on a separate worksheet or perhaps as comments directly in the cells of this worksheet when used in its electronic form.

For example, a space standard of 300 square feet gross area per automobile for parking lots is acceptable for plants in the United States. However, this same standard does not apply in Europe where smaller cars predominate.

Similar discrepancies exist in various publications. It is tempting to use certain published standards. But these may have been established for specific companies under specific conditions and may not apply generally. Therefore, we suggest using pre-established space standards developed by others as a guide only. Of course, once you develop your own standards and keep a record of how they were established, they can be used over and over again in your company so long as the same conditions prevail.

Be aware that standards for restrooms, automobile parking truck trailer parking may be set by local regulation in building and zoning codes.



Page 4 GR-1 to GR-9

Code	**Description**	**Min. Area Required** (Square Feet)
Grinders -- GR-1 thorugh GR-12		
GR-1-B	B & D 10" Bench	4
GR-1-B	B & D 6" Pedestal	4
GR-1-B	Black & Decker H-4700	7
GR-1-B	Blount 14" Heavy Duty	18
GR-1-C	Cincinnati Pedestal	7
GR-1-S	Sterling 14'" Tool	18
GR-1-S	Standard	16
GR-1-V	Van Norman 39 Special Radius	45
GR-1-W	Wickes 2-spindle Tool	12
GR-2-B	Badger 220	64
GR-2-H	Hanchett 121	100
GR-3-G	Gardner 125	120
GR-3-H	Hanchett 22	12

Figure 7-8. Estimating space requirements by use of pre-determined space standards. Here is a sample sheet from space standards developed by a multi-plant manufacturer operating several hundred machine tools.

"Minimum area required" in square feet is established as left-right and front-back dimensions including table travel, overhang, and service doors open; plus 18 inches on three sides for cleaning or adjusting the machinery plus two feet on the operator's side.

These figures are then multiplied by a factor based on the anticipated space required for set-down space, access ways, and departmental service areas. The factor ranges from 1.3 for normal layouts to 1.8 where handling and stocking of material in the department is a real problem. The total estimated area for the department equals the sum of the minimum areas required for all the machines times the concentration-or-dispersion factor.

Almost any plant or office can set-up this kind of space standards. The organization of the data for ready reference and the estimating of the factor value are the important practical limitations to this method.

Roughed-Out Layout

In some layout projects, calculating or converting is impractical, and no standards are available. If a scale plan of the area is available, if templates or models of the equipment involved are already on hand, and particularly if certain activities are critical or represent very high investment, it may be advisable to rough out detail layouts of certain areas and use them for space requirements. This preliminary detail planning is a perfect example of phases' overlapping – here Phase II into Phase III. This method of space determination is expected to be used for critical areas of high investment, relatively fixed equipment, large machinery, or multiple work stations that should line up (as a conveyorized assembly line). What's more, both management and operating supervisors have more confidence in the planner's space requirements when they can see an intended layout. A typical example of rough layout is shown in Figure 7-9.

For areas where equipment can be easily moved, it is unnecessary to be too specific in the arrangement. That is a Phase III job. Only sufficient attention is given to the roughed-out layout to assure that it is an acceptable arrangement that can be made to work. Everyone should understand that this roughed-out layout is not the layout which will eventually be selected. In fact, the eventual shape of the area may be quite unlike the roughed-out version. However, this technique is adequate for establishing the space requirements for use in planning Phase II, general overall layout.

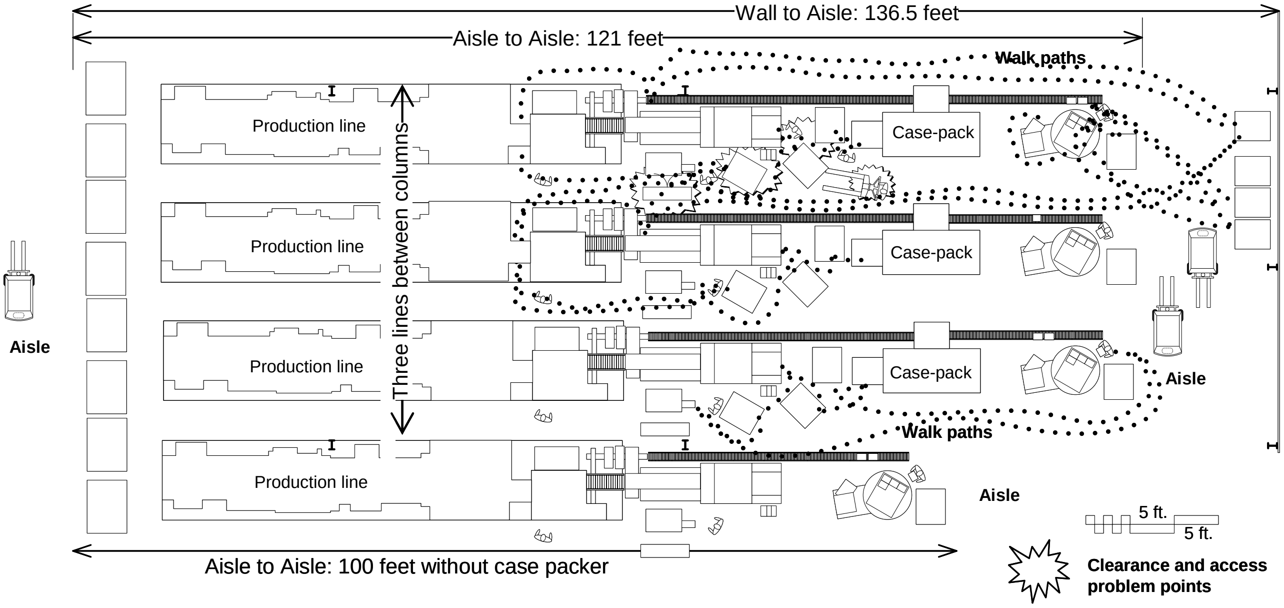


Figure 7-9. Rough layout for new packaging lines. This sketch establishes the aisle spacings, space allowance and lengths of packaging lines, with and without case-packing machines. It also verifies that 3 lines can be placed in each column bay. The project was to rearrange an existing layout to accommodate 20 expensive and highly-fixed new lines. Operator walk paths, pallet access, control panels, and clearance problems are included on the sketch. The equipment on the left-half of the sketch already existed. Machines on the right were still being designed by the machine supplier. So this is not the final detail layout. In fact, its findings were used to influence machine design.

Ratio Trend and Projection

The *ratio trend and projection method* establishes a ratio of space (square meters or square feet) to some other factor: square feet per unit shipped, for example, or square feet per labor-hour per year. It is limited to total or general space requirements and cannot be applied to individual activity-areas. Ratio trend and projection is perhaps the least accurate of any of the five methods. Still, in terms of long-range planning, it may be fully adequate, especially in areas of offices and general storage, where equipment is movable, fixed investment is relatively low, and the property can be used for more than one purpose. Or, when estimating the total amount of space needed in a Phase I Location planning assignment.

First establish what the ratio was in several past periods, going back as far as you can. Space history will not be found in an information system. This must typically be constructed from old records, drawing files, and memories of long-time employees.

From the ratios for past periods, one establishes a trend for the ratio and projects into the future what the ratio is likely to be. With software such as Microsoft Excel ® or similar tools, curves can be fitted to the historical data and the best fit used for the projection. With a projection of the companion portion of the ratio (units, labor, etc.), the space to meet those projections can be derived. An example of the method applied is shown in Figure 7-10 for a long-range facilities plan.

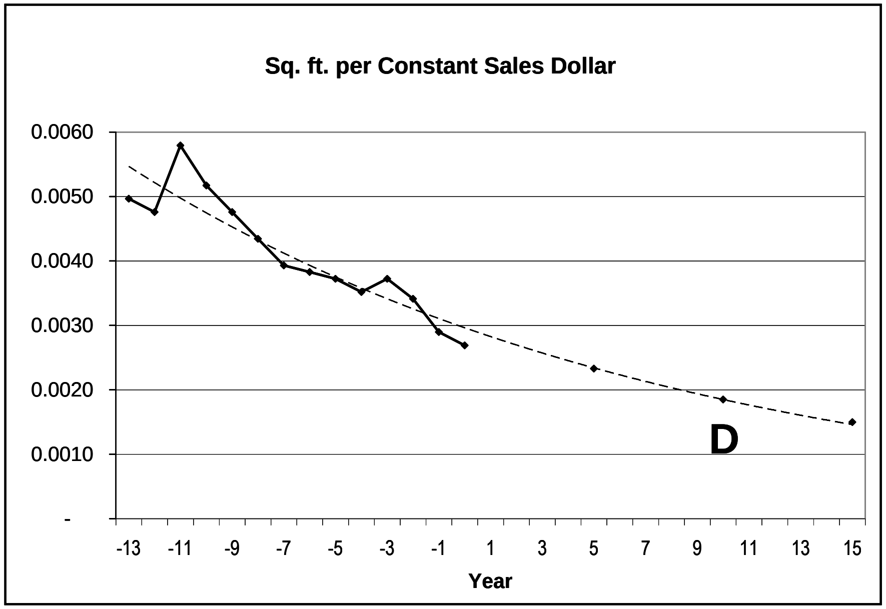
Space per unit produced is perhaps the best ratio to use. Historical sales revenue will be easiest to obtain but is subject to inflation. Revenue history should always be adjusted – generally upward – to the current value of the currency being used. Other ratio factors not illustrated which may be used include space per dollar of investment and space per operation.

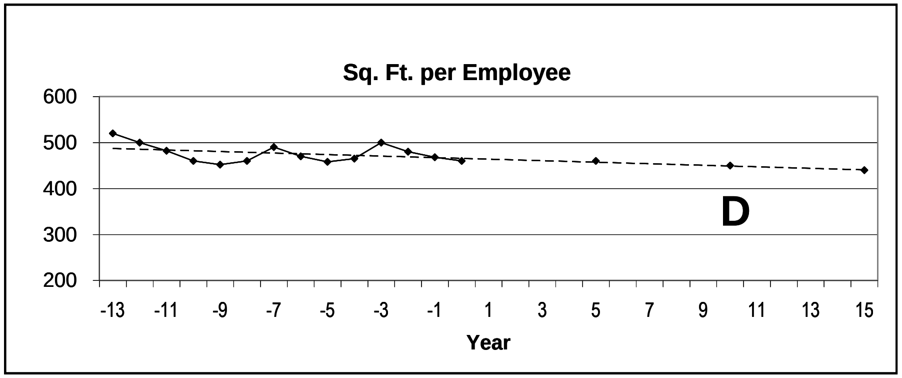
Activities Area and Features Summary

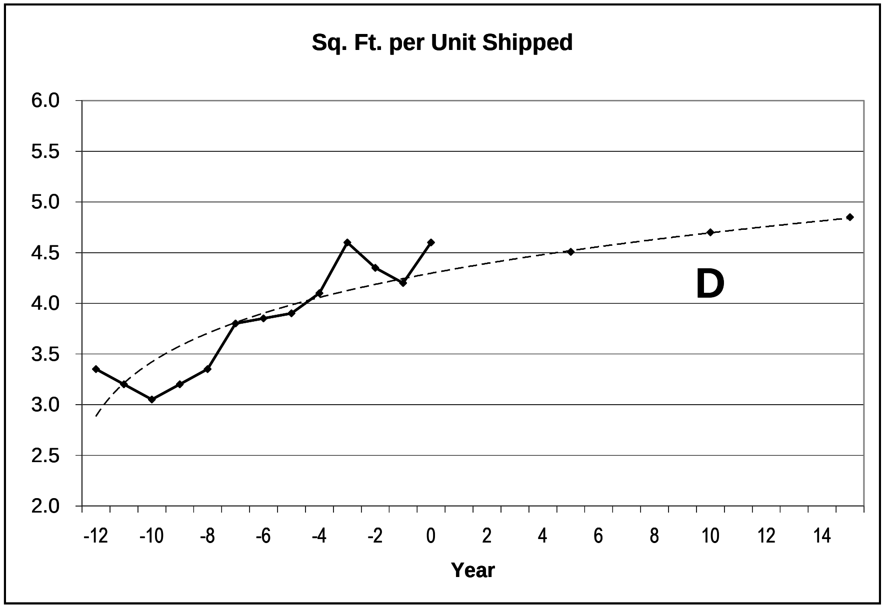
In this chapter, we have concentrated, thus far, on the amount, or quantity, or size, of space required. Actually, space for planning purposes involves *amount*, *kind*, and *shape* or configuration. In determining space requirements for each activity, it is logical to consider also the physical features or special requirements that distinguish its kind and shape.

And when the planner documents and summarizes space amounts for each subactivity (subarea), all the pertinent features (*kind*) and *shape* (configuration) required should also be indicated. The Activities Area and Features sheet is designed for this purpose. It is illustrated in Figure 7-11.

Figure 7-10. Ratio trend and projection method of determining area required. Figures are established for past and present sales, production, labor hours and area allocated (A). From these, ratios are calculated (B). Then sales and production figures are forecast for future periods of time (C) and ratios are projected based on trends and anticipated operating conditions (D). Using forecasts and the projected ratios in various combinations, calculations are made for the square feet probably required (E). These calculated area requirements are then modified by judgment and the likely space available to program expansion plans.







		A	**Base Data**			**B** **Ratios Derived from Base Data**		
	Year	**Sq. Ft. Underroof**	**Sales (Constant Dollars)**	**Units Shipped**	**Employees**	**Sq. ft. / Sales Dollar**	**Sq. ft. / Unit Shipped**	**Sq. Ft. / Employee**
Historical Records	-13	250,000	50,347,000	59,524	481	0.0050	4.2	520
	-12	250,000	52,536,000	74,627	500	0.0048	3.4	500
	-11	450,000	77,679,000	140,625	934	0.0058	3.2	482
	-10	450,000	87,000,000	147,541	978	0.0052	3.1	460
	-9	600,000	126,087,000	187,500	1,327	0.0048	3.2	452
	-8	600,000	138,095,000	179,104	1,304	0.0043	3.4	460
	-7	800,000	203,509,000	210,526	1,633	0.0039	3.8	490
	-6	800,000	209,009,000	207,792	1,702	0.0038	3.9	470
	-5	900,000	241,667,000	230,769	1,965	0.0037	3.9	458
	-4	900,000	255,882,000	219,512	1,935	0.0035	4.1	465
	-3	900,000	241,667,000	195,652	1,800	0.0037	4.6	500
	-2	900,000	263,636,000	206,897	1,875	0.0034	4.4	480
	-1	1,153,000	398,060,000	274,524	2,464	0.0029	4.2	468
	0	1,153,000	428,67[illegible]	250,652	2,507	[illegible]0027	4.6	460
			C **Forecasts**			**D** **Projected Ratios**		
	+5	?	449,500,000	350,000	3,300	0.0023	4.5	460
	+10		652,500,000	425,000	3,600	0.0019	4.7	450
	+15		870,000,000	450,000	4,100	0.0015	4.9	440

E

	Future Space Projections Based on			
	Sales Fcst. and Sq. Ft. per Sales trend	**Unit Fcst. and Sq. Ft. per Unit trend**	**Employee Fcst. and Sq. Ft. per Employee trend**	**Plan-for Sq. Ft. (Midpoint of Projections)**
+5	1,047,335	1,577,625	1,518,000	1,312,000
+10	1,207,125	1,997,500	1,620,000	1,602,000
+15	1,305,000	2,182,500	1,804,000	1,744,000

ACTIVITIES AREA & FEATURES SHEET

Plant *Hevi-Duti Truck*
Project *New Building Layout*
By *RM* With *DS*
Date *11/15* Page *1* of *1*

Activity
Physical Features Required
Sub-Activities or Areas

No.	Name	Area in *sq.m.*	O'Head Clearance	Max. Overhead Supported Load	Max. Floor Loading	Min. Column Spacing		Water & Drains	Steam	Compressed Air	Foundations - or Pits	Fire or Explosion Hazard	Special Ventilation	Special Electrification		Requirements for Shape or Configuration of Area (Space)
		Total:	Enter Unit and Required Amount under each					Relative Importance of Features A - Absolutely Necessary E - Especially Important I - Important O - Ordinary Importance — - Not Required								Enter Requirements for Shape or Configuration and Reasons therefore
		12,475	*m*	*tons*	*t/m^2*	*m*										
1.	*Central Receiving*	*225*	*8*	*2T*	*8*	--	--	--	--	*O*	--	--	--	--		*10 meters wide for dock doors*
2.	*Steel & Yard Storage*	*1050*	--	*10T*	*20*	--	--	--	--	--	--	--	--	--		
3.	*Purchased Material Storage*	*1300*	*12*	--	*8*	--	--	--	--	--	--	--	--	--		*Entrance to outside yard storage*
4.	*Body Fabrication A*	*1200*	*12*	*20T*	*20*	*20*	--	--	--	*O*	--	*O*	*A*	*A*		
5.	*Body Fabrication B*	*1200*	*12*	*20T*	*20*	*20*	--	--	--	*O*	--	*O*	*A*	*A*		
6.	*Chassis Fab A & B*	*1200*	*12*	*10T*	*20*	*20*	--	*O*	--	*E*	*I*	*O*	*A*	*A*		
7.	*Sub-Assembly*	*550*	*8*	*3T*	*8*	*10*	--	--	--	*A*	--	--	--	--		*Feeds first 50 meters of assy line*
8.	*Clean & Paint*	*800*	*12*	*20T*	*8*	--	--	*A*	*A*	*A*	*I*	*A*	*E*	--		
9.	*Mixed Model Assembly Line*	*1400*	*12*	*20T*	*8*	*10*	--	--	--	*A*	--	--	--	--		*70 m. long by 20 m. wide; incl. 5 meter aisle along full length of line*
10.	*Finished Truck Yard & Shipping*	*1500*	--	--	*20*	--	--	--	--	--	--	--	--	--		
11.	*Quality Assurance*	*150*	*3*	--	*1*	--	--	--	--	--	--	--	--	--		
12.	*Maintenance*	*150*	*8*	*2T*	*8*	*10*	--	*A*	--	*A*	--	--	--	*O*		
13.	*Office & Employee Services*	ⓑ *450*	*3*	--	*1*	--	--	*A*	--	--	--	--	--	--		*Two floors, each 450 sq.m.*
14.																
15.	*Main Aisles allowance*	ⓐ *1300*														

A B C D

Notation References

a *Aisles within fab and assembly are included in their area requirements. Main aisles are for crossing movements past and between areas.*

b *Ground floor area. Second floor another 450 sq. m.*

c

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No. ______ Activity ______ Sheet ______ of ______

This sheet can be used as a recap sheet – with the total area required listed on the top line and each of the subactivities or subareas listed on a separate line thereunder. Or one sheet can be used for each of the departments or subareas involved – with the subareas listed on each line. Further, several sheets can be used, one for the various activities in the plant, another for the office areas, and still another for the outdoor or yard areas, with a covering recap sheet on the front. A larger form, with lines spaced to match the number of activities on the relationship chart, is most frequently employed.

In any event, the activity is identified down the left-hand column – by number and by name. The third column contains the area required in square feet or square meters (as determined by one of the five methods described above). The total figure can be entered at the top, beside the name for the activity to which the sheet applies.

On the same sheet, the physical features and the shape or configuration required for the area in question are noted, in the center and right-hand portions of the form. The left-hand center section has six columns where the major characteristics of each subactivity's space can be recorded. These usually affect or pertain to the building itself. Enter the unit of measure above the double line so that numbers only need be entered on each line.

When it comes to utilities and auxiliary services, the planner does not have full information on them when determining the space. The pipe diameter and water pressure necessary, for example, are unknown. Still, the planner knows for certain types of operations, water and drains are a vital part of the installation. Therefore, a system of rating the relative importance of such features is necessary, but at this stage the planner is not concerned with questions of detail capacities or specifications for the services.

Here again, the A-to-U value rating system is used. The appropriate vowel is placed where called for under each auxiliary or utility on the line involved to indicate the relative importance to the layout planning it is likely to play. Note that where no utility or auxiliary service is required a dash is entered. The letters serve as red flags, telling where the planner must be concerned with certain features.

Figure 7-11. Summary recording of area amounts and characteristics. This form is divided into several sections: (A) the areas for each activity, (B) the desired physical features pertaining to building structure, (C) the desired features pertaining to auxiliaries or utilities, and (D) any requirements as to shape or configuration of the areas involved. Note space at the bottom is for explanations or comments – with letter-code reference to the point needing explanation. With this form, we can consider and record the characteristics of the space for each activity at the time we determine its required area.

In using the section on physical features, the left portion shows the physical requirements of the space that relate to the structure of the building. At the right, specific dimensions for the utilities and auxiliaries will not yet be known or it will not pay to engineer them at this time. Instead of size of water lines or pressure of steam, a relative-importance vowel-letter rating is used. Each activity requires relative degrees of attention being given to its various utilities and supporting auxiliaries. Thus, the rating letter identifies, or signals, the relative importance of these features in the same way as closeness was rated on the activity relationship chart.

Note that an allowance is made for main aisle space on Line 15. The alternative to an explicit allowance is to include a main aisle allowance in each activity area.

In the far right column, requirements for shape or configuration of the space are recorded. For example, if the rail dock is one subactivity, its long and narrow nature should be indicated. Or in planning a steel rolling mill, which must by its very nature have so many stands in line, indicate the area as so-and-so long by such-and-such wide. In general storage or bench-assembly areas, the requirements for shape or configuration are of less importance and need not be recorded.

At the bottom of the sheet is a place for notation references. Any additional comments are marked here and coded back to the point they refer to by marking the respective lowercase a, b, or c, at that point on the sheet. Or, in the electronic version, a short comment may be inserted into the worksheet cell that needs explanation. Using this feature is a convenient way to capture assumptions and/or follow-up questions as estimates are being made. However, if lengthy notes or assumptions are needed, the planner will be better served by a separate worksheet.

Whether the activities area and features sheet is used or not, some recap summary of the amount and nature of the space is needed. When doing such a recap, list the *same* activities used in the materials flow and activity relationships analyses, the same numbering identification, with the same order of listing, even though it may mean regrouping the activities for a space summary.

Accounting for Main Aisles and Circulation

The planner should understand how main aisle and circulation requirements have been accounted for. These can be included in each area's requirement and the actual aisles carved out as layouts are developed. See Figure 7-12. Or, it can be called out as in Figure 7-11. But it should be treated consistently and never be overlooked.

The primary purpose of main aisles is to enable the movement of materials and people – to and from, between, and past the activity-areas of the layout. From time to time, these aisles will also be used to bring in, take out and move machinery and equipment. Aisle space requirements thus depend upon the volumes, size and nature of the items being moved, and their methods of movement – push cart, fork truck, tug and train of carts, conveyor, overhead crane. They are also influenced by company or plant policies and standards, such as providing extra width for separation of people from handling, or the use of a perimeter aisle for appearance and tour routes around production. For these reasons, aisle widths and allowances tend to be industry- and plant-specific.

In most manufacturing layouts, main aisle space ranges from 15 to 20% of total area. It can be higher – as much as 25% – when large fabrications must be routinely moved on the floor. It can be as little as 12% when small items are produced on small equipment in tight conditions. Some of the range depends upon how the open space is accounted for in receiving and shipping areas.

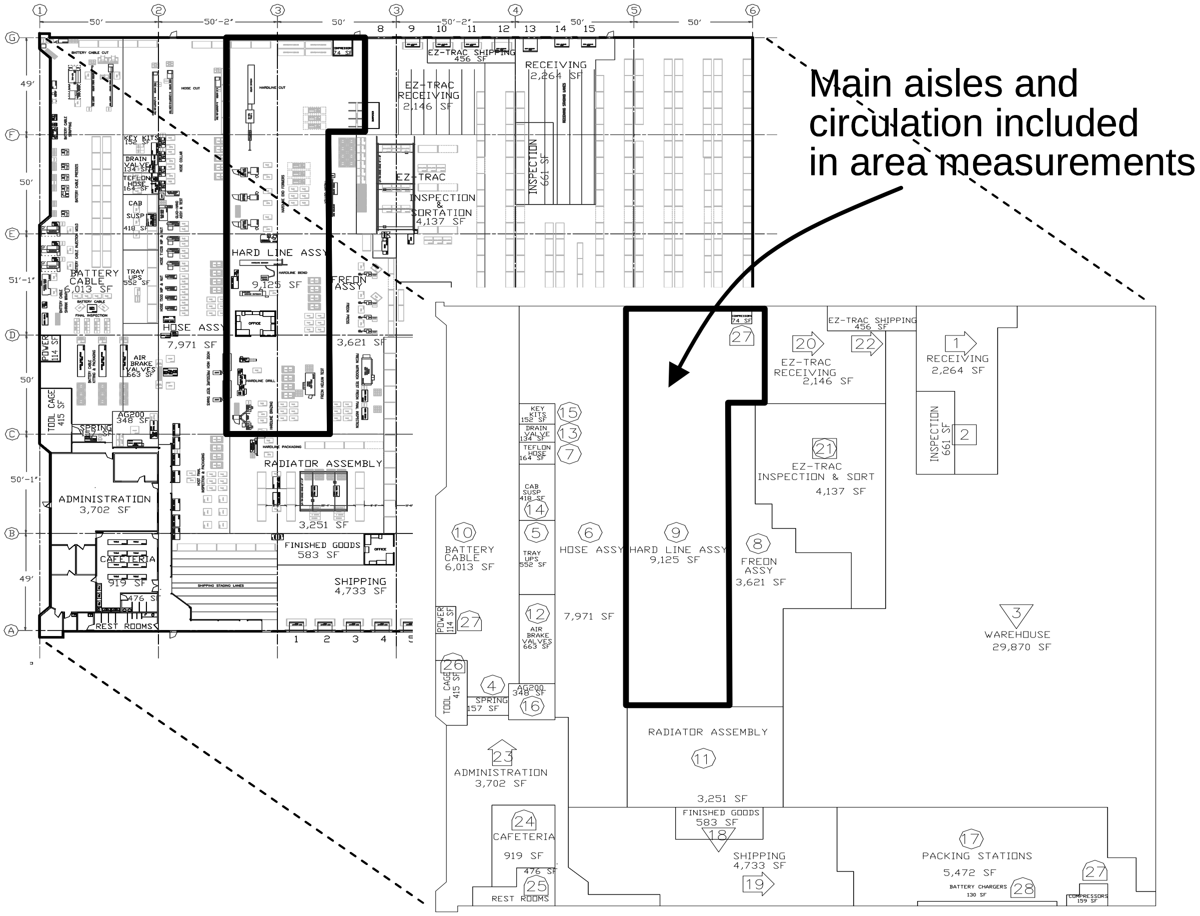
Figure 7-12. Main aisles included in area requirements. Here, each activity-area includes its share of main aisle space. Thus, the activity-area requirements account for all the space. If aisle space were called out separately, there would be "white space" between the activities. Either way, the placement and width of aisles will be determined during adjustment into layout plans.

Space Requirements versus Space Available

As often as not, a layout planning project is more restricted by space limitations than any other factor – except investment money. Reduced investment funds themselves usually result in reduced space available whenever modernization of buildings or new construction is involved. Regardless of cause, the planner seldom has – and probably should not be permitted to have – all the space desired. This means compromising or balancing what is determined as space required with what can logically be made available. Section 3 of the SLP pattern is aptly termed the shoehorn-and-paring-knife stage of layout planning, for it directly involves balancing space required against space available.

The problem of balancing space requirements against space available is really three problems:

1. Will the total amount of space available be adequate?
2. Will the divisions of space available (buildings, floors, rooms) match in amount the various areas (departments, activities, organizational groups) required?
3. Will the character or condition of the available space or space divisions be suitable for the work required to be done in the various areas?



Balancing total amount is usually a simple matter of adding and comparing. If the area requirements will not fit, the requirements must be trimmed or squeezed. Rather than making a single percentage reduction for all areas involved, make the required reductions in the areas where the least hurt to total company operation will result. This means rating (preferably with vowel-letter values) each area in order to establish which must retain its amount and which can afford to be reduced.

Usually, general, open, flexible, multipurpose areas without fixed equipment are the ones that can be reduced. After all, one can always somehow manage to find additional storage or office space when it is needed. But, this is also one reason that many layouts "go in" with inadequate storage and service areas.

A harder job than balancing totals is matching the various divisions of available space with the individual areas in both amount and condition. The more honeycombed or divided the physical space available, and the more diversified its physical features or characteristics, the more difficult matching is and the greater is the likelihood of waste or idle space.

Finding More Space

We should point out that not only is there more than one way to skin a cat, there is more than one way to solve the problem of limited space. The easiest is to ask top management for more space or for money to construct more. In many, if not most, cases, this simply isn't practical. Other courses of action, ways of finding additional "equivalent space" without going to new construction, are listed below.

1. Increase working hours – third shift, weekends, overtime.
2. Improve methods, processes, equipment.
3. Redesign products or simplify product line or components.
4. Readjust inventory policy, possibly with revised plan of distribution.
5. Overhaul production planning and control to get more from existing facilities.
6. Initiate a housekeeping campaign and scrap drive to capture wasted space.
7. Rearrange the existing layout for better space utilization – even though something else may have to be sacrificed.
8. Go up or overhead – with mechanical handling, stacking, service-storage balcony.
9. Lease nearby space and move storage, offices, or customer service areas there, thus freeing space to expand operations at the existing plant. (The use of public warehouses falls into this category.)
10. Buy, rather than make, items that are marginal; subcontract certain products or components.
11. Sell the existing building, rather than expand, and buy or lease another.
12. Decentralize. Divide the operations into two or three groups and spread to leased or available buildings in other communities.
13. Buyout or merge with another company and integrate the work of both.

Some of these actions will show immediate results and may be counted on to reduce short-term space requirements in some area. Others will be of long-term interest only.

Impact of Materials Management

In a typical manufacturing plant, with dock areas at 5% to 10% of total space under roof, and storage areas at 10% to 20%, the materials management department may be one of the largest users of space. And it will be the largest user of main aisles – typically another 15% to 18%. Even in plants that have concentrated on reducing inventories and have moved receiving and storage off site, the remaining materials management activities may still consume 7 to 15% of total space, before main aisles.

Note that several actions above – at least # 2, 4, 8, 9 and 10 – are related to materials management policies and practices. These determine how much material must be stored and where; also the frequency and size of receipts and how much space is needed for their unloading, staging and inspection. Closely related and often under the same department manager, are choices of material handling and storage methods. These include rack and shelving types, heights, and depths; truck types and their aisle width requirements. Choices here will largely determine the space requirements for a given level of stored material.

The general principles of space-saving materials management and the practices that implement them are as follows:

1. Hold less material – sourcing (location); order quantities, order frequency; scheduling: make-to-stock; make-to-order…
2. Keep it moving – supplier certification to reduce incoming inspection; pre-receiving by carriers or at stops in-transit; advanced shipment notification; dock scheduling (workload leveling), labeling, material handling scheduling (always available during production with no need to stage for off-shifts)… Remember: Every set-down requires space.
3. Hold at greater density – higher, deeper, narrower, smaller… But recognize that this may result in slower operation. Typically, this principle pulls stock back from workplaces in production, either to local storage areas (sometimes called “supermarkets”) or to central storage (warehouse).
4. Replenish in standard quantities and containers –variability results in over-provision of space in staging and storage.
5. Hold elsewhere – off-site, at suppliers, at contract warehouse or logistics service company

Be aware also that the amount of material presented within the workplace – at machines, assembly stations and within manufacturing cells – is governed largely by materials management practices, even though the space is attributed to production. Aside from the issue of how much “point of use” inventory is needed, pulling these stocks back to well-designed and equipped storage areas may result in smaller production footprints, and a net reduction in total space required. However, making such a pull-back typically requires the commitment of production management as well as materials management.

Kitting of parts can often save significant space at the workplace since the parts are no longer delivered individually or held in bulk quantity. Picking the kits usually can be done in the same aisles where materials are stored in bulk, so no additional space is required. Of course, the material handing organization must be staffed for the activity.

Delivering more frequently in smaller quantities and containers can also reduce workstation space requirements, and even the warehouse when applied to purchasing and production lot sizes. Clearly this practice will likely increase costs in handling, transport, and production changeovers, and it will reduce visual control in production since workers and supervisors cannot spot missing materials as early as before. And of course, any stock-outs will have costly consequences. But if the need for space is paramount, smaller lots and more frequent delivery may be worth exploring.

The introduction of returnable containers – desirable perhaps for environmental reasons and/or cost savings – typically requires more space than realized for storage and handling, and may offset other space saving tactics.

Managers and planners considering "profit per unit of floor space," may conclude that a logistics service company with less costly space and perhaps lower wages should perform receiving and storage off site. This is a "game changer" for layout planning.

When the potential impact is great, the layout planning team should include a person from materials management who can determine if and when policies may change. Since it may take years to realize space savings, the impact of changes will typically show up in future periods' space requirements. In the short-term, options are always limited.

Conclusion

Figure 7-13 summarizes this chapter. When space requirements balance with space available and any shortages are resolved, we are ready to proceed with planning.

PROCEDURE FOR DETERMINING SPACE

1. Identify the activities (areas or features) involved, using the same numbering and terminology as for charting and diagramming.
2. Identify the machinery and equipment involved or at least the general type of machinery and equipment – both operating and supporting.
3. Determine for the operating activities:
    a. The area requirements, based on the plan-for P, Q, and R, and the operating times involved.
    b. The nature or condition required for each area of operating space.
4. Determine for the supporting activities:
    a. The area requirements, based on the plan-for P, Q, and S, and the times involved.
    b. The nature or condition required for each area of the supporting space.
5. Recap the amount and condition of the space required and balance this against the space available or possibly available.
6. Adjust, rebalance, and refine as necessary.

Figure 7-13. Procedure for determining space allocation or allowance.

Chapter 8

Space Relationship Diagram

We are now ready to tackle the Space Relationship Diagram. This is the output from Section 3 of the SLP pattern of procedures. Flow and activity relationships having been determined and diagramed into a geographical arrangement, the space requirements for each activity having been established and balanced against the space available, the planner applies the space to the diagram. The resulting *space relationship diagram* is perhaps the single most effective aid to layout planning.

Fitting Space to Diagram

In fitting space to the diagram, the planner again begins with the flow and/or the activity relationship alternatives. That is, the planner can

1. apply space to the flow diagram only;
2. apply space to the activity relationship diagram; or
3. apply space to a combined flow and other-than-flow relationship diagram.

The method chosen depends upon the relative importance of materials flow and the relationship of supporting services – as emphasized in Chapter 5.

When using the flow diagram as the basis, convert each activity designated on the diagram from its identifying symbol to its allowed size. Work to some convenient scale to designate the areas. Generally, when working on paper, this is much easier to do on a sheet that is printed with cross-section grid lines. Even in an electronic drawing, the task will be easier when a convenient grid is displayed.

Each activity is still identified by symbol, number, and, possibly, name, but now – in addition to diagramming to scale – the actual area (square feet, square meters) may be written in. This way, the space is recorded both in actual numbers and shown to scale, in relative size. An example of this is shown in Figure 8-1.

When working from the activity relationship diagram – either service-only or combined flow and other-than-flow – proceed in a similar way. Enlarge each activity symbol into its specific size at a convenient scale. Retain the same geographical arrangement of the activity relationship diagram to the greatest extent possible. Each area is thus adequately identified to refer to the previous charting and diagramming. An example is shown in Figure 8-2.

Many refinements of space relationship diagrams can be made to show particular information pertinent to the layout planning project at hand: Existing buildings versus new construction; number of employees; need for, or profit potential of, expanding or relocating any activity; fixity or difficulty of relocating; required condition of the area; suitability of existing location – all may be coded into the diagram by use of colors,

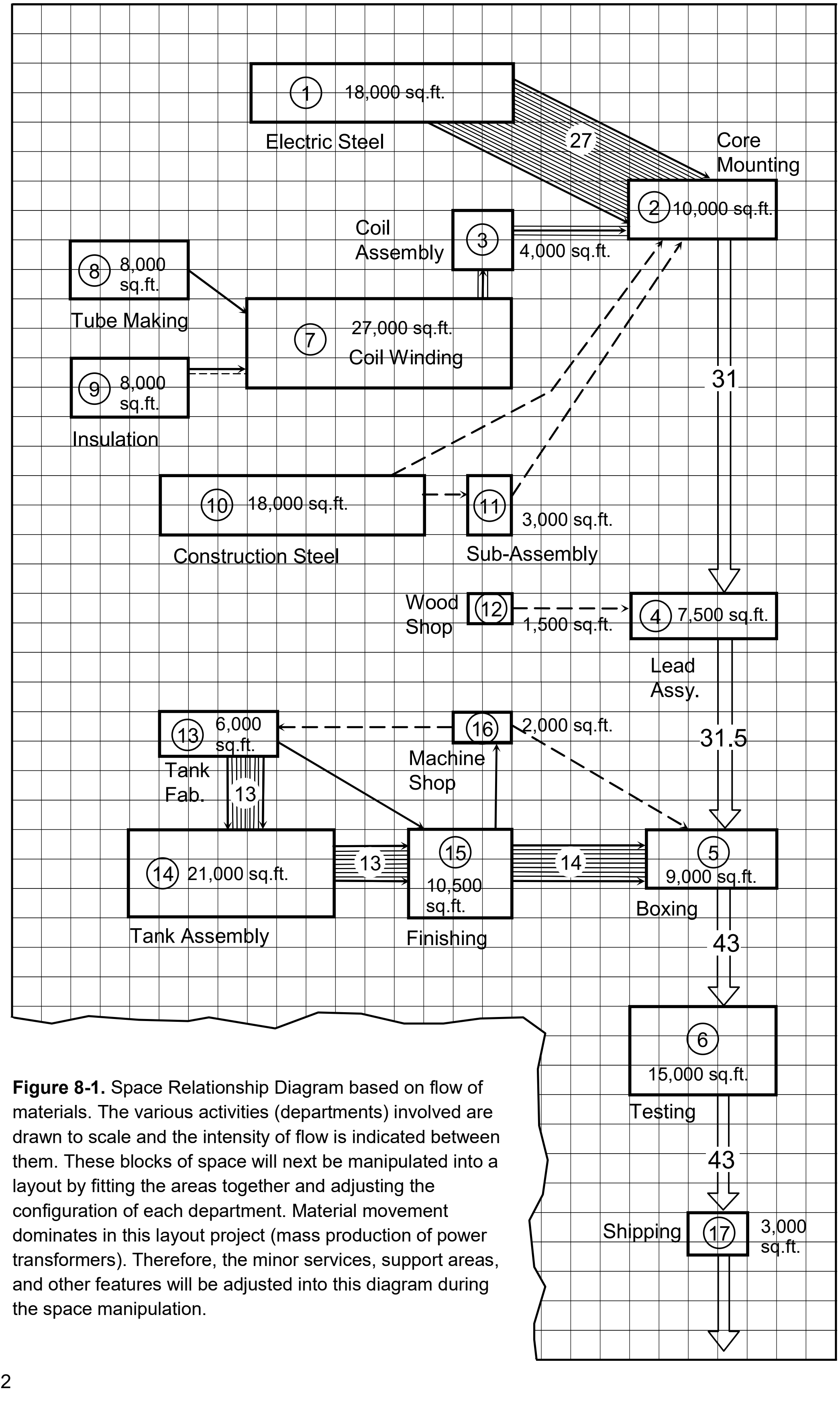


Figure 8-1. Space Relationship Diagram based on flow of materials. The various activities (departments) involved are drawn to scale and the intensity of flow is indicated between them. These blocks of space will next be manipulated into a layout by fitting the areas together and adjusting the configuration of each department. Material movement dominates in this layout project (mass production of power transformers). Therefore, the minor services, support areas, and other features will be adjusted into this diagram during the space manipulation.

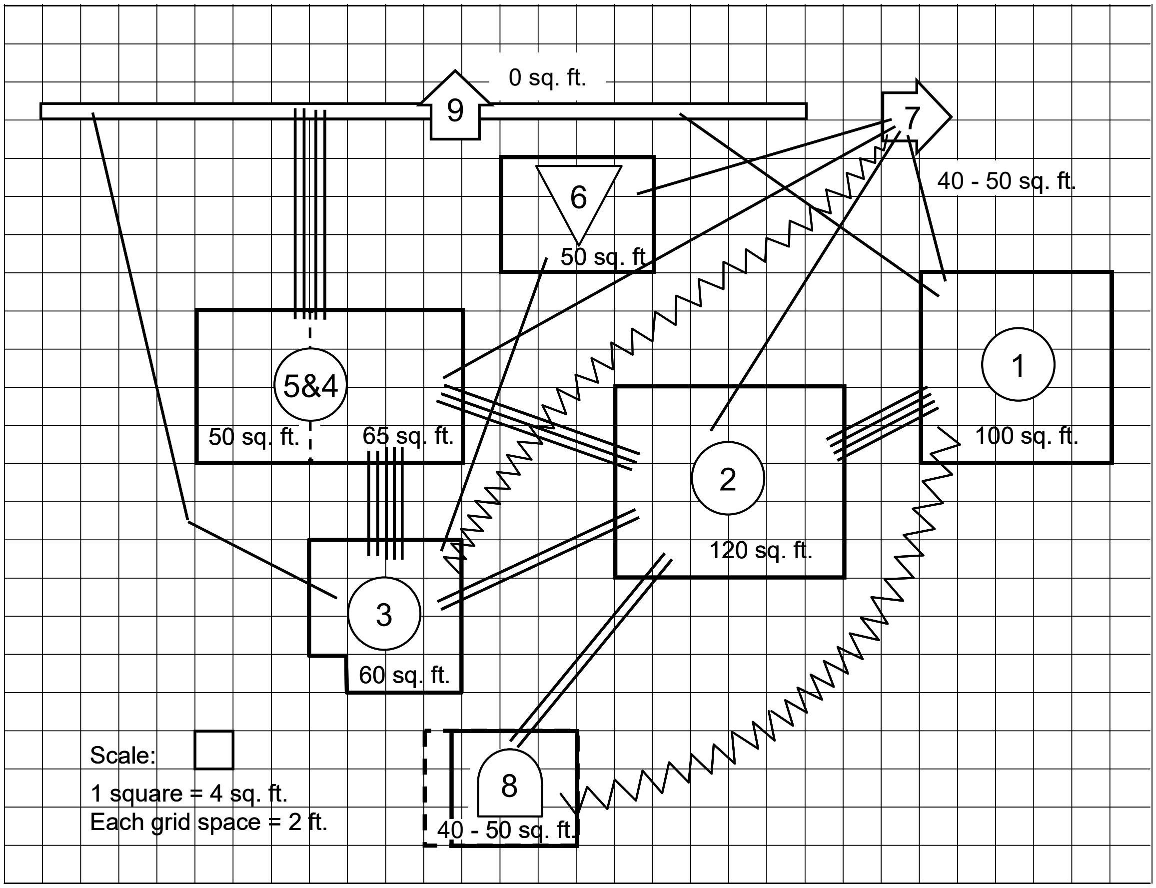
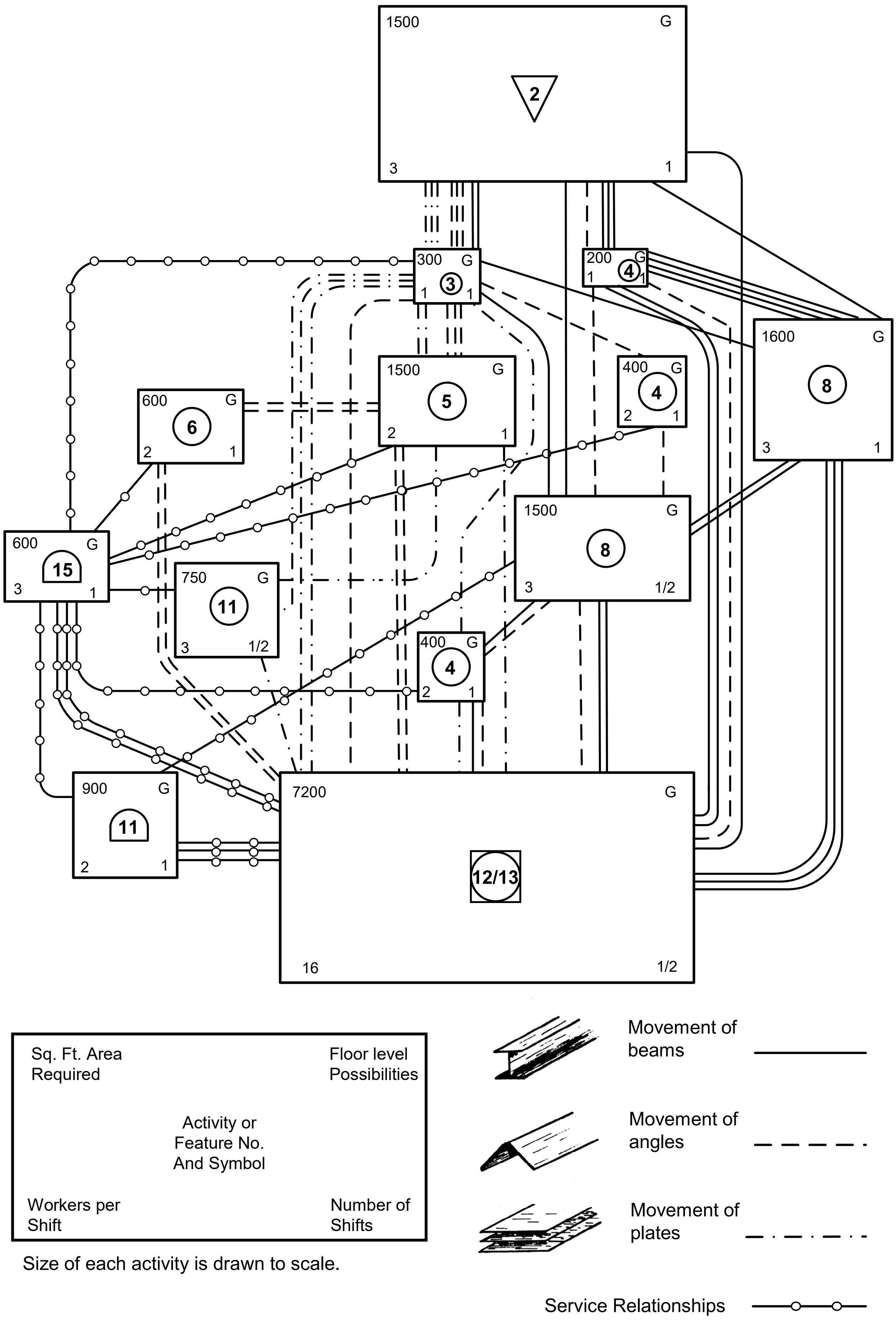


Figure 8-2. Space Relationship Diagram based on activity relationship chart and diagram. This example is for planning of the same laboratory discussed in Figures 5-2 and 6-6. The space allowed is merely added to its proper designated symbol on the activity relationship diagram. Approximate size representations may be used to save time when drawing, provided the actual requirements are stated.

If space requirements were determined as ranges, these are handled by diagramming the minimum figure in solid lines and dotting-in the additional amount as with Activity 8 above. Note also that some of the activities may be combined. When this occurs, the rated-closeness lines are added together. Here activities 4 and 5 are combined. They have common relationships with 2, 3 and 9. In practice, each relationship for combined activities should be re-examined. In this example, two two-line relationships to the window (#9) don't necessarily equal one four-line “absolutely necessary closeness”.

symbols, letters, and the like. An example of refinements built into the space relationship chart is shown in Figure 8-3. In complex layout problems, showing such refinements may make the diagram too confusing. In such cases, it may be better to prepare the diagram in several versions, to show different significant information on each copy. (For example, see coding for multi-level layouts in Appendix VI.)

If a specific location for the layout has already been definitely decided, it may be practical to draw the space relationship diagram directly on floor plans of the designated building. However, such a short cut in the planning can also lead to jumping to conclusions and missing real opportunities to make major improvements or contributions to the layout. Therefore, to realize the full potential of planning the layout to ideal conditions without the limitations of existing columns, walls, rail sidings, and



Size of each activity is drawn to scale.

the like, it is better to work out the space relationship diagram to meet the conditions of the activity relationship diagram. Later, when adjusting the space diagram to the modifying considerations and their practical limitations, the planner has ample opportunity to bring the theoretical diagram within the constraints of existing buildings or other fixed features.

On the other hand, if it is known that certain fixed building features, such as walls, columns, or floor loads, definitely cannot be changed in the layout planning project at hand, it may be unnecessary to go all the way toward the fully-ideal space diagram. Then it is better to recognize the physical features and shape of the available space and to place the space diagram in this specific location from the start. So long as there is no possibility of missing a real improvement, it is alright to follow this course of action. But be aware that many potential savings can be lost by this very shortcut.

While it may be useful to draw the space relationship diagram within the walls of an existing or proposed building, in normal use the diagram is not drawn on a current layout. Rather it is a separate document tying together *relationships* and *space* in their ideal arrangement – without (or with minimal) respect to the location available, its constraints or current layout. The diagram is thus a "target" to be achieved by *adjustment* into alternative layout plans. However, the space relationship diagram can also be a useful diagnostic tool when drawn on an existing or proposed layout. An example appears in Figure 8-4.

Drawing the Space Relationship Diagram

As we can see from the above text and illustrations, we are practically at the layout stage. A space relationship diagram is, in effect, a layout when the space is joined together and fitted in the appropriate way. This joining and fitting of spaces can be done in two ways:

1. By sketching with pencil or marker pen to scale, on cross-section paper or colored and gridded card stock.
2. By electronic drawing to scale and printing or plotting the result

With a pencil and cross-section grid paper, the planner simply sets an appropriate scale and accounts for the number of squares to represent the first activity. A border is drawn around the squares and the appropriate symbol and identification drawn inside it. This is repeated for the next area and any connecting relationship lines are added. For ease of interpreting the diagram, these connecting lines should be drawn so that they extend slightly into the areas being connected as shown in Figures 8-2 and 8-4. When drawn only to the edges of areas, as in Figure 8-3, a busy diagram can be harder to read.

In space relationship diagrams, the areas are colored or shaded according to their type of space, using the SLP conventions presented in Figure 6-5. But here, relationship lines are shown only in black, since their color would compete with the space colors and make the diagram almost impossible to read.

Figure 8-3. Space Relationship Diagram with added refinements. This was used in planning a rearrangement of a structural steel fabricating plant. The activities (or areas) are drawn to scale, based on the area requirements anticipated. Activity identification is in the center and other information as explained is indicated in each of the four corners. The relationships are shown in number-of-lines code. However, the reason for the relationship is partially indicated by the four different types of lines – three for material movement and one for service relationships.

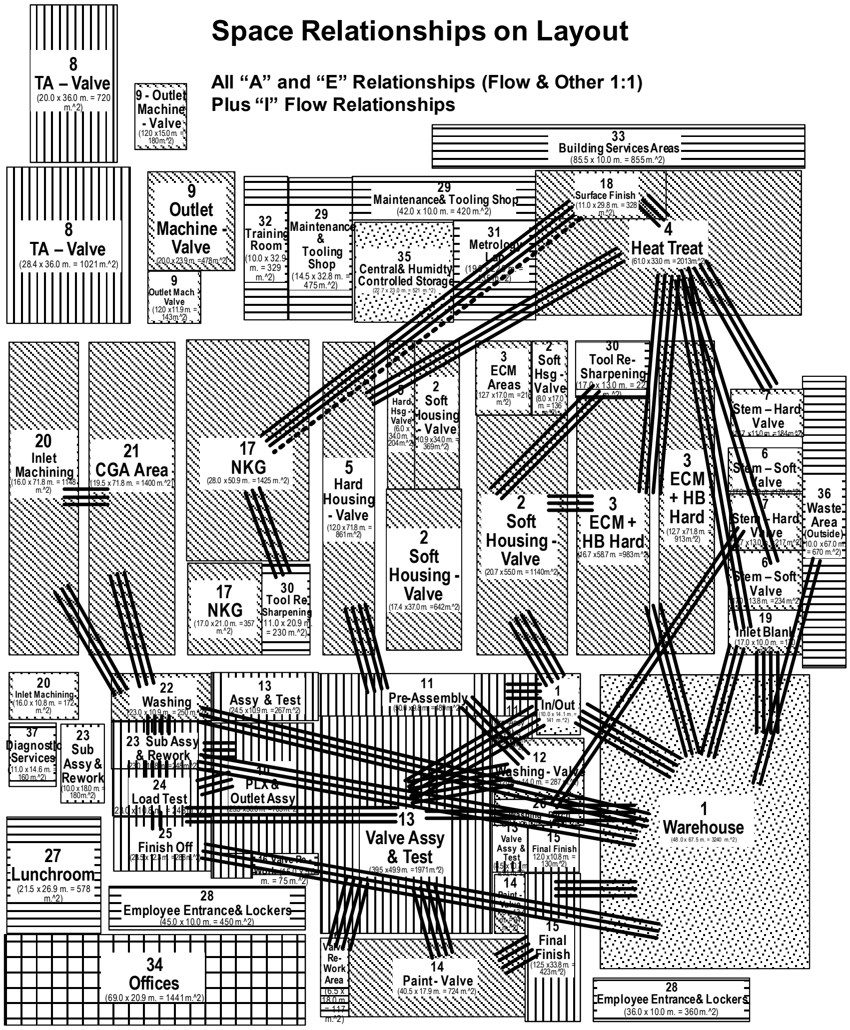


Figure 8-4. Space Relationship Diagram drawn as an overlay on a proposed layout. For clarity and speed, only the A, E and flow-related I relationships are shown. Drawn in this way, the diagram becomes a diagnostic tool for evaluating a layout and identifying potential improvements. In this example, the corner placements of the warehouse and heat treat result in long connecting lines. Existing layouts can be evaluated in the same manner.

When sketching on cross-section paper or grid sheet, it is fastest to convert all space requirements to number of squares before beginning the diagram.

Note that the Activity-Area and Features Sheet is the source document for all representation of space. Any mandatory or desired area shapes should be noted there and observed as squares are assigned and areas drawn in the space relationship diagram. In the absence of a shape requirement, areas should be roughly square or made rectangular. Some planners like to use the golden ratio, setting the long side equal to about 1.6 the short side, but this can be tedious and time consuming. But even somewhat irregular or "notched" shapes can be tolerated here, since each activity-area will be adjusted when it is placed into layout plans. Figure 8-5 shows a typical space relationship diagram.

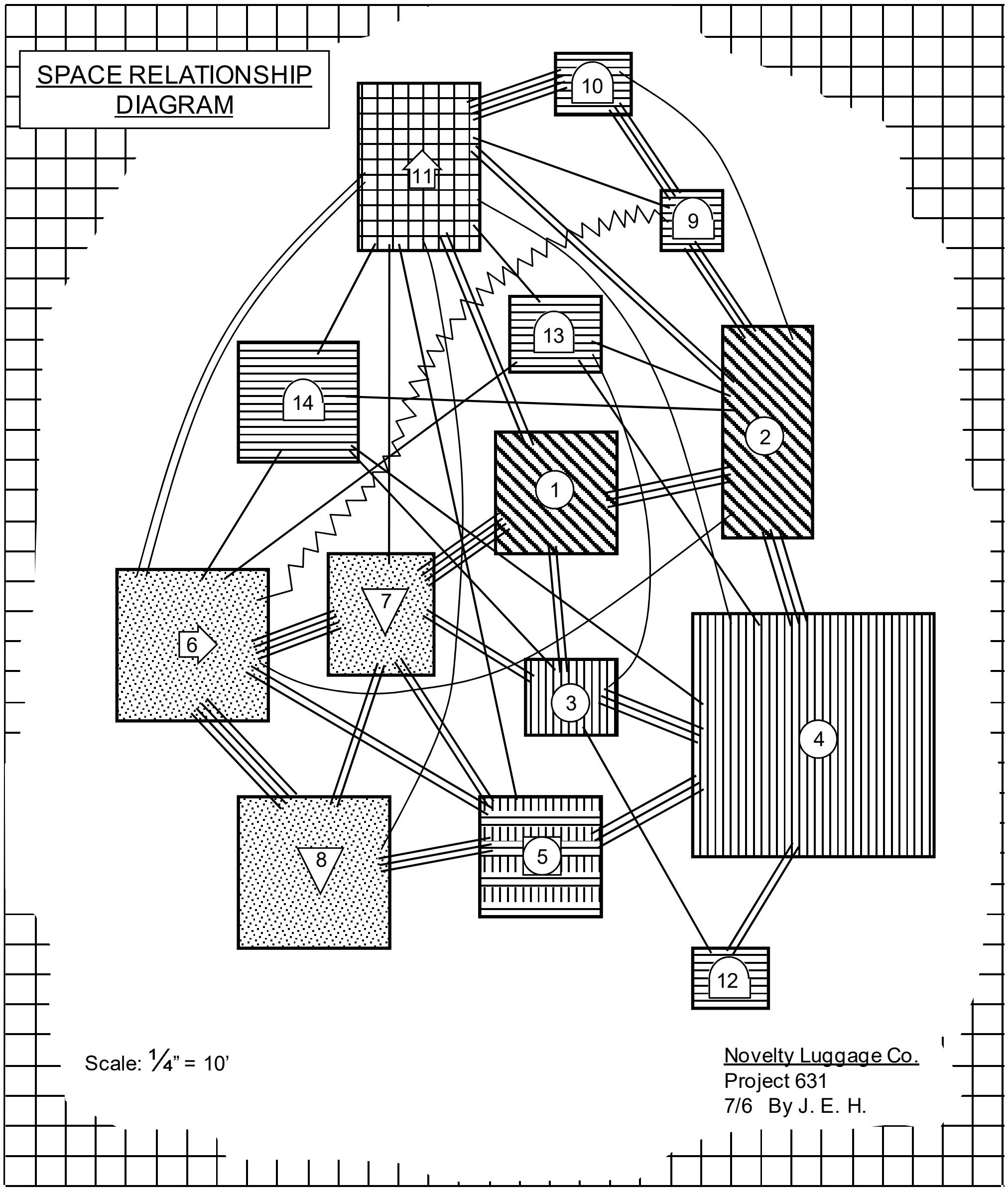


Figure 8-5. Typical Space Relationship Diagram for a plant producing monogrammed tote bags for conventions and promotional events, beach bags, tennis racket covers, and the like. The space for each activity-area is drawn to scale – generally compact. Activity 2 has a minimum length so is drawn elongated. One square of grid equals a convenient 100 square feet.

Colors or black-and-white shadings can be used to accentuate and further identify the general use of the space. Here, the SLP convention for black-and-white shading is used. This makes the areas stand-out and helps identify further the type of function in each activity. A colored version is shown on the inside back cover. Colors can be placed as an edge-of-area border or filled throughout the whole of each activity's space. Note that a combination of colors (or shading) is used for a combined activity. When no color printer or copier is available, it is best to represent the coloring as black-and-white shading patterns as shown above. This way the meanings are retained in black-and-white copies.

Whether working with pencil and paper or in an electronic drawing, generally apply the following:

1. Retain the same identifying symbols, numbers, and other conventions as used in prior charting and diagrams.
2. Retain the same geographical arrangement as the activity relationship diagram – impose the space on top of each symbol. (You will have time later to join, rotate, take the reverse image, or otherwise adjust.) .
3. Spread out the activities so the relationship lines can be drawn in. (You will find the diagram easier to read if you extend the relationship lines to run inside each block of space.)
4. Draw generally compact and rectangular blocks at first, except where shape is a requirement or an odd number-of-squares count makes it easier to distort the rectangle. (You will shape the areas as you fit them together later.)
5. Try to avoid letting relationship lines touch areas other than the ones they connect. This practice sometimes does lead to congestion of the lines, in which case, it is best to draw them straight through another area but as dotted lines.
6. If working with pencil and paper, work in black and white for both speed and fidelity in reproduction. When the diagram is complete, make the areas stand out by coloring them (in total or by edge-of-area border), or by shading with a black-and-white shading code. SLP incorporates the use of the MHMS-approved standard for color coding and indexed with it for black-and-white shading the tincture code of heraldry. (See Figure 6-5, Appendix V, and the Capsule Summary on the back cover.)
7. Effective electronic drawing tools include Microsoft ® Visio, PowerPoint and Excel. Each enables easy snapping of rectangles to a dimensioned grid. Visio is perhaps the most powerful but its text may become corrupted when pasted copies of a drawing are printed in Adobe ® PDF format. AutoCAD ® or any electronic drafting tool will also do.

Selecting a Scale

The planner should select a logical scale for the diagram. This scale may already be established on a site survey or drawings of existing buildings or floor areas. Where practical in Phase II block layout, the planner should make the diagram scale match the scale that will be used to plot the layouts.

If the choice of scale is open, pick one where the unit of area is a round number such as 1 inch equals 10 feet or 1 inch equals 50 feet (or such as 1 to 100 or 1 to 500 metric). A scale like one-sixteenth inch to the foot does not yield a round number for one marked-off square on the cross-section paper, and therefore, makes it more difficult to apportion and account for the various amounts of space. Where column spacings are regular, it is often practical on large layouts to use the area in one bay as the unit of space.

Later, in Phase III detailing, the diagram and layout planning should use the generally accepted scale of one quarter-inch or one-eighth inch to a foot (1 to 50 or 1 to 100 metric). But at this overall planning stage, the layout project should, as a practical matter, integrate with other overall drawings available.

Be aware that some engineers are in the habit of plotting electronic drawings simply to fit a sheet of paper. The resulting plots are at random scales and are difficult and tedious to measure with a pocket ruler. Since this is a universal need when reviewing diagrams and layouts with others, plots should always be made to a convenient physical measuring scale. At the very least, a few reference dimensions should always be included (large enough to be read) and a graphic scale added. That way the drawing can be sized to the available paper and printer without loss of information.

Showing Equipment Detail

Occasionally, it may be desirable to show machine outlines within an activity block on the space relationship diagram. In block layout planning, this practice should be confined to critical or unusual areas only – perhaps a paint line conveyor with specific in and out points, or a paint booth, oven, or autoclave. It is never necessary for general machinery and equipment areas, or office or warehouse space. The diagram will become much harder to read if such details are routinely shown. In detail planning during Phase III, such use of machine templates is more practical since each area is planned as a separate project and there are thus fewer details to display.

Making Templates for Block Layout Planning

Once the space relationship areas have been drawn and labeled, they can also be used to create templates for layout planning. This is especially easy if the diagram has been drawn at the scale to be used for the layouts themselves. Simply copy the diagram onto heavy paper or card stock, and cut out the areas. Or, draw and label a fresh set of the areas on printable pages, print and cut from there. One particularly useful feature of Visio is its ability to display the area of a rectangle dynamically as it is resized. See Figure 8-6. Once an initial activity is drawn with displayable dimensions and size, it can be copied, its text label edited, and it can be resized, re-shaped, and re-shaded or colored per the Activities Area and Features Sheet. In this way, an entire set of templates can be drawn in just a few minutes. They can then be plotted in color with an inexpensive ink-jet plotter.

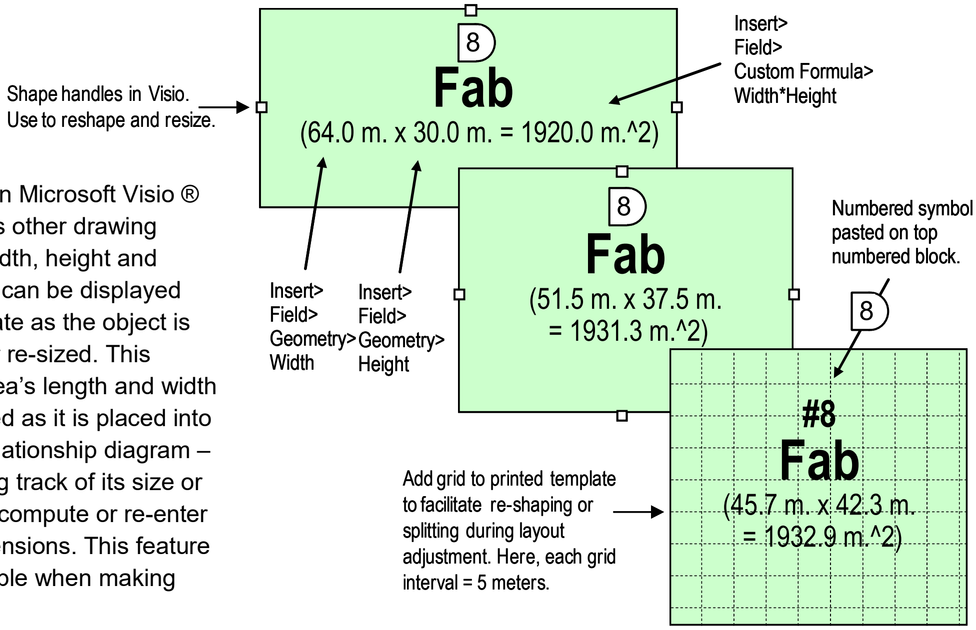


Figure 8-6. In Microsoft Visio ® (and perhaps other drawing software), width, height and width*height can be displayed and will update as the object is re-shaped or re-sized. This allows an area's length and width to be adjusted as it is placed into the space relationship diagram – without losing track of its size or having to re-compute or re-enter desired dimensions. This feature is also valuable when making layout plans.

When using paper templates for block layout, you will need to understand if the template's dimensions (length and width) represent required or minimum dimensions, or are merely a convenient way to display the area required. Do not let arbitrary template dimensions have undue influence on the layout. When developing your layouts, keep scissors handy to re-shape templates or even to split them into two or more sub-areas if needed. When re-shaping or splitting, take care not to lose pieces or forget to label them as to their activity name or number.

Superimposing a fine grid before printing or plotting your block templates will facilitate their adjustment into layouts. It allows the planners to quickly count squares and precisely fold or cut instead of having to scale the template before re-shaping or splitting.

Recognize that the finer the grid, the more flexible and precise will be your adjustments of areas into a layout. However, if the grid is too fine, planners may spend excessive time counting grid lines and adjusting their templates. This will distract from layout decisions themselves. Five divisions per inch is a useful grid, since it works well with engineering and metric scales and generally gives adequate precision for adjustment into block layouts

Recording the Alternatives

The space relationship diagram ties together Relationships and Space and serves as a bridge to Adjustment. Indeed it is often difficult for the planner, when preparing the diagram, to resist immediately making an Adjustment of it into a layout alternative. But it does not take much adjusting, before the planner becomes deeply involved with the many modifying considerations and practical limitations to be discussed in the next chapter.

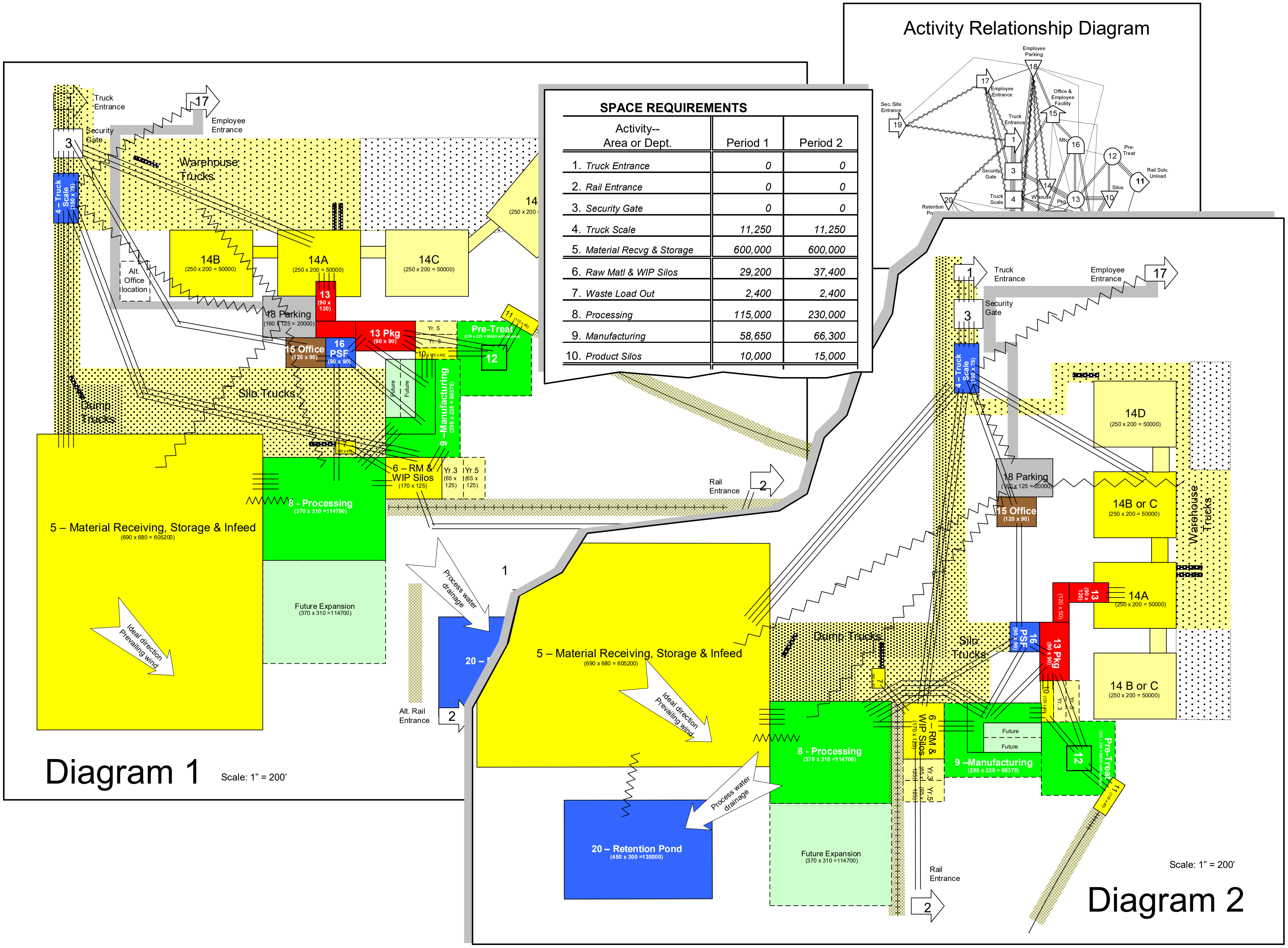
As the diagram is fitted and arranged, a record should be made of it and any significant alternative versions. These can then be compared side-by-side and used to develop alternative layouts in the next step of SLP. See Figure 8-7.

As might be expected, comparing various plans frequently results in combining the best features of each alternative and working out a new combination layout. The procedure is one of refining and weighing alternatives – usually with the aid of the operating department heads, service people, and others logically involved.

Figure 8-7. The Space Relationship Diagram translates relationships and space into adjusted arrangements that are almost layout plans. It thus serves to tie together the three basic fundamentals of every layout-planning project: Relationships, Space, and Adjustment.

Here, two different space relationship diagrams have been drawn for a new plant site. Each varies the entrance points for roads and rail, and the location and orientation of key areas to one another. As the space is diagramed, the number-of-lines coding is marked between the appropriate activity pair on the diagram. This ties the diagram to the charted relationships and reveals weaknesses in the arrangement of the activities when four-line or three-line relationships are lengthy, compared with the length of one-line and two-line relationships.

These diagrams were drawn in software and using color. Of course, colors and their meanings will be lost when printing in black and white unless they have been applied as black-and-white shadings.



SPACE REQUIREMENTS

Activity-- Area or Dept.	Period 1	Period 2
1. *Truck Entrance*	*0*	*0*
2. *Rail Entrance*	*0*	*0*
3. *Security Gate*	*0*	*0*
4. *Truck Scale*	*11,250*	*11,250*
5. *Material Recvg & Storage*	*600,000*	*600,000*
6. *Raw Matl & WIP Silos*	*29,200*	*37,400*
7. *Waste Load Out*	*2,400*	*2,400*
8. *Processing*	*115,000*	*230,000*
9. *Manufacturing*	*58,650*	*66,300*
10. *Product Silos*	*10,000*	*15,000*

Chapter 9

Adjusting into Plans

Up to this point in the SLP pattern (Sections 1, 2 and 3), efforts are largely directed to assembling data and following somewhat straightforward procedures. The space relationship diagram is practically a layout plan. It is derived directly from the best *Relationships* and *Space,* and therefore represents a theoretically ideal arrangement. But the theoretical ideal is seldom usable without *Adjustment* to incorporate a variety of modifications and practical limitations.

In terms of the SLP pattern, as soon as the diagram is put together in Section 3, the bottom drops out of it and the planners find themselves in Section 4 – adjusting, modifying, integrating, blending, and massaging the diagram to get an acceptable layout. This chapter deals with this really creative part of layout planning, where many modifying considerations and practical limitations stimulate adjustments of the diagram into a host of possible overall arrangements.

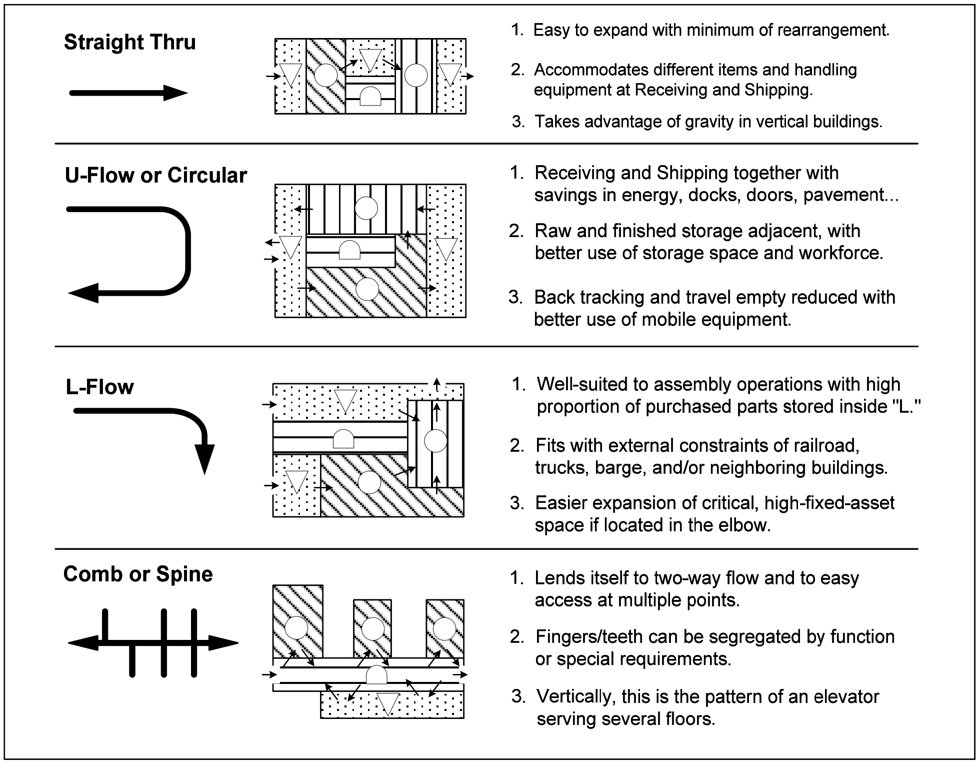
If they have not been participating all along, operating and service managers and personnel should be brought back into the project, now that there is something they can visualize. Furthermore, much of the adjustment will be made in response to their knowledge, observations, desires and practices.

In fact, the most effective approach is for the planner to involve and guide one or more teams of the appropriate personnel to develop their own layouts, using scaled templates and the space relationship diagram as their target; or, at the very least, as their starting point. After all, those who will work in the layout probably know more than anyone about what will work best. Appendix IX shows how to run layout planning as a team-based improvement (Kaizen) event.

Developing Alternative Layouts

The fastest way to develop alternatives is to create two or three small teams to work in parallel – perhaps in some friendly competition – and then compare their layouts. In this way, three to six alternatives can often be developed in the same time that a single person or team may use to arrive at just one or two. But to avoid duplication and redundant alternatives, the planners should think ahead and envision the alternatives that are most important or essential to develop – *before* starting to do so. Most major alternatives in layout planning result from the intentional desire to examine the following alternatives when adjusting the theoretical ideal:

1. Alternative *flow patterns* and *flow directions* through the layout: Straight-through, U-flow, L-flow, some variation or combination. The four basic flow patterns in plant layout appear in Figure 9-1. Even with a single flow pattern, alternatives may present themselves by varying the direction of flow.
2. Alternative *dock locations*, or input and output points. These are closely related to flow pattern but may lead to additional worthy alternatives. See Figure 9-2.



Straight Thru

1. Easy to expand with minimum of rearrangement.
2. Accommodates different items and handling equipment at Receiving and Shipping.
3. Takes advantage of gravity in vertical buildings.

U-Flow or Circular

1. Receiving and Shipping together with savings in energy, docks, doors, pavement...
2. Raw and finished storage adjacent, with better use of storage space and workforce.
3. Back tracking and travel empty reduced with better use of mobile equipment.

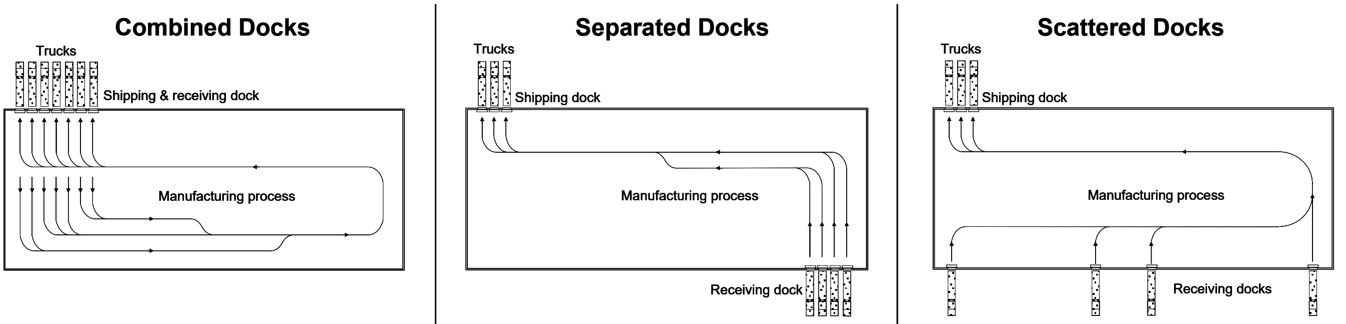
L-Flow

1. Well-suited to assembly operations with high proportion of purchased parts stored inside "L."
2. Fits with external constraints of railroad, trucks, barge, and/or neighboring buildings.
3. Easier expansion of critical, high-fixed-asset space if located in the elbow.

Comb or Spine

1. Lends itself to two-way flow and to easy access at multiple points.
2. Fingers/teeth can be segregated by function or special requirements.
3. Vertically, this is the pattern of an elevator serving several floors.

Figure 9-1. Basic flow patterns for plant and warehouse layouts. Straight-Thru and U-Flow are most common. Each has its benefits and appropriate uses. Most large facilities use a combination of flow patterns.



Combined Docks

1. Combined Docks is a good choice for smaller plants, where few goods are shipped or received. Otherwise congestion may result.
2. Advantages of combined docks include:
    a. Make the best use of loading dock personnel & equipment.
    b. Require less personnel involved in supervision & control.
    c. Facilitate truck check-in & loading bay assignment
    d. Security is easier to maintain.

Separated Docks

1. Separated Receiving & Shipping Docks are best in larger plants where the process begins in one part of the building and ends in another.
2. Reduction of material handling and traffic inside the plant can more than compensate for the issues of dock personnel & equipment efficiency, truck assignment and security.
3. Very effective in converting processes when raw and purchased material is delivered to front of the line and finished or packaged product flows into waiting trucks.

Scattered Docks

1. Scattered Docks are essential to many just-in-time, lean operating systems.
2. Materials can feed directly into the production line, most often without intermediate storage. Parked trailers become an extension of the building.
3. Extra positions may be required at each dock location to allow for trailer change-out.
4. Shipping docks at the end of the production line let goods flow immediately onto trucks.

Figure 9-2. Alternative dock concepts. When choice permits, locate docks to minimize in-plant traffic. This enhances safety, improves productivity and avoids material handling bottlenecks. More often, docks are a modifying consideration because they exist and are fixed or dictated by site conditions. (Sketches adapted from the Material Handling Education Foundation, Professional Material Handling Learning System, Vol. III.)

3. Layout and pattern of *main aisles*: number of, locations and orientations. Related of course to flow pattern and dock locations.
4. Keeping a highly-fixed area in place, or allowing it to move. In rearrangement projects, it is good practice to rate the *"fixity"* of activity-areas. The SLP vowel-code rating convention is well-suited to this purpose as shown in Figure 9-3.
5. Similarly, exploring alternative "*anchor locations*" for highly-fixed, critical or "highly-connected" activity-areas.
6. Alternative *key area assignments* to different bay, wings, floor levels or buildings, including off-site. Or to spaces that may soon be open in an existing layout.
7. *Varying the space available* – its configuration or location. Common examples involve the shape or location of building additions or use of mezzanines.
8. *Centralizing or decentralizing support areas* consistent with their relationships. Not combining perhaps, but "pushing them together" into a block or cluster.
9. *Combining or splitting* key activity-areas. "Changing the rules," since the areas were defined at the outset and used for relationships and space estimating. Still, good ideas may arise that involve some redefinition of the areas themselves, and perhaps even the underlying process. Common examples involve last minute definition of new manufacturing cells or mixed-model lines, or decentralization of batch processes, ovens and the like for treating, cleaning, painting, plating…
10. *Mirroring* or *rotating* an alternative within the space available.

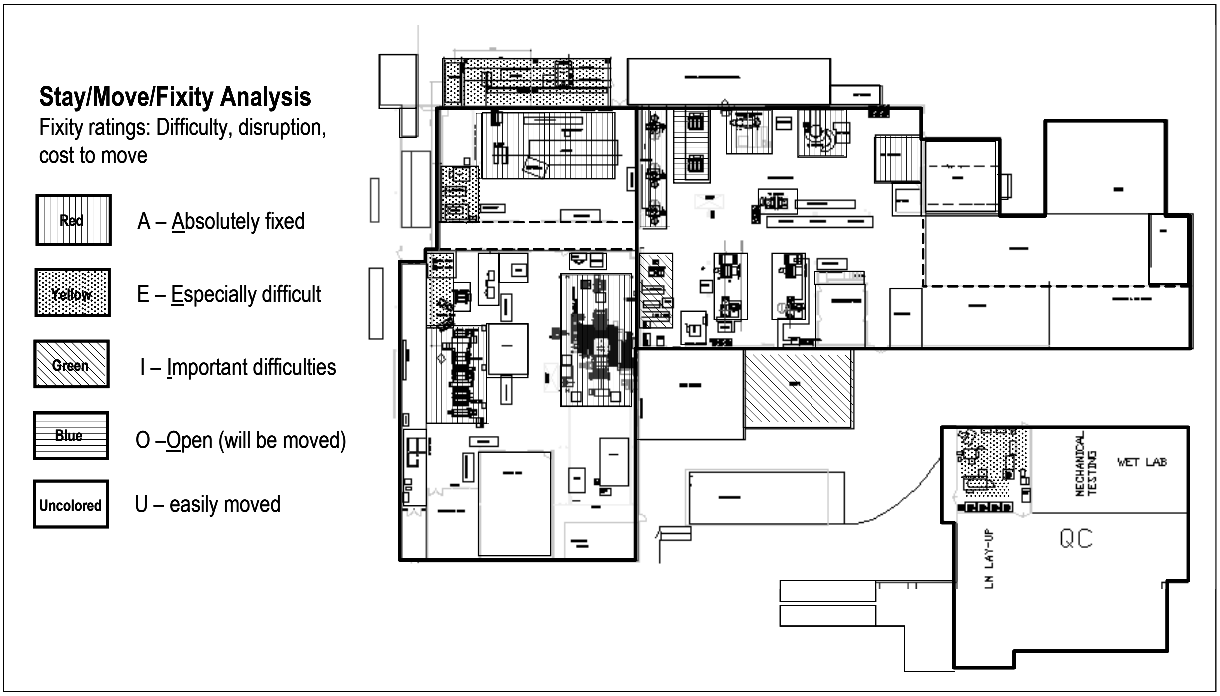


Figure 9-3. The "fixity" of machinery, equipment and building features often leads to modifications of an ideal arrangement. A good practice is to rate and highlight the ease or difficulty of moving equipment, areas or features. This is a good time to flag areas that must or will be moved by prior decision or plan. The SLP vowel-code and color conventions can be adapted for this purpose. In this aerospace components plant, moving some machines will require costly re-certification by the company's customers, in addition to the physical challenges themselves.

Modifying Considerations

No matter what ideal the team has in mind and intends to develop, the planning invariably encounters a number of Modifications that must be considered and force adjustments to the plan. Thus alternatives develop naturally from a single vision or ideal arrangement as embodied in the space relationship diagram. The most common modifying considerations are listed below. Many others could be added.

1. Handling methods, especially equipment
2. Storage facilities and equipment
3. Site conditions or surroundings
4. Building features
5. Utilities and auxiliaries
6. Personnel requirements
7. Operating policies, procedures and controls
8. Shape of detailed activities' layouts

Some major considerations may require much analysis and “adjustment time” – even a temporary delay in the layout planning – while others may be negligible and quickly disposed of. A good example of this is in warehouse layout, where the choice of handling and storage methods could cause a major rearrangement of the space relationship diagram. On the other hand, in office layout, these same considerations are unimportant compared to those of the personnel requirements or policies, procedures and control.

Materials Handling Consideration

In many plant layout projects the material handling methods are known and fixed. In others, the handling methods are open to change and become a dominant consideration in layout planning. SLP recognizes this with its early attention to flow of materials relationships and diagramming. In fact – if so desired – the planners may base their activity and space relationship diagrams entirely on flow of materials and related handling considerations. Refer to Figure 5-4 and see the illustration in Figure 6-2.

With sufficient knowledge of material handling methods and their cost patterns, the same flow intensities used to establish layout relationships can be used to select handling methods and develop material handling plans. It is not possible here to present a full discussion of materials handling analysis. However, note that handling analysis too can be broken down into four phases:

I. Integration with external transportation
II. General overall handling plan
III. Detailed handling plans
IV. Installation

Note the similarity to the four-phase framework of SLP. (See Figure 9-4.) The phases of handling analysis also are sequential and provide best results when they overlap. Their framework is central to a companion planning method Systematic Handling Analysis (SHA) a synopsis of which appears in Appendix X.

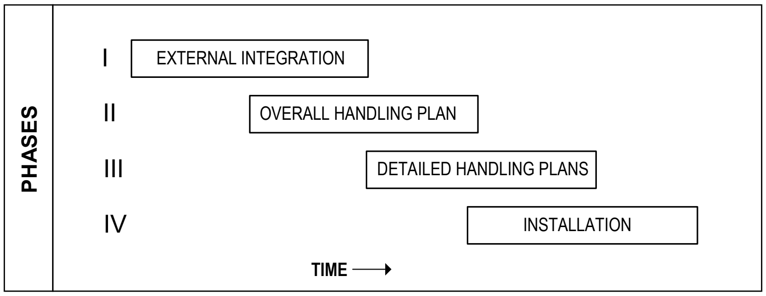


Figure 9-4. The four phases of materials handling analysis. With this approach, material handling methods can be planned in parallel and "locked together" with layout decisions in each phase.

First, make sure what external transportation facilities the internal handling plan must be coordinated with, noting any changes that may be practical. Then build a general overall handling plan to support and enable the general overall space relationship diagram. That is, concentrate on Phase II techniques of handling analysis – inter-department or inter-area moves. These are less detailed and less specific than those used later in Phase III. To be sure, overlap into detail handling analysis as necessary. For example, if an overhead traveling bridge crane looks like the general handling method to be used, and the moves this equipment make dominate the layout, then its capacity, space, speed, supporting-column spacing, and the like must be considered the overall handling plan and will determine much of the general overall layout. But the crane's use and clearances must be reviewed when the machines and equipment underneath it are laid out in detail.

As soon as the space relationship diagram is adjusted to a layout – even though it is but one possible arrangement and still unrefined – there are distances. That is, the layout establishes actual configurations and distances between the various activities. Therefore, a handling analysis can be based on the intensities of materials moved and the distances involved for each route. With those known, the planner can calculate transport work and can generally figure operating times for given methods of handling, and thereby estimate costs.

In discussing the flow diagram and/or space relationship diagram, we assumed that materials could always move from origin to destination over the shortest possible path. Now we must modify that assumption: the shortest distance is not always the most practical. Aisle locations, floor-load capacities, walls and partitions, all affect the actual distances.

Based on an analysis of materials and moves, the planner must decide on an overall method(s) of moving each material between each pair of activities. *Materials handling methods* consist of (1) a system or pattern of moves; (2) the equipment or actual transport vehicle; and (3) the transport unit (box, pallet, bundle, drum).

By system is meant the general way in which the different movements are tied together, both as to geography and physical movement. Basically, materials can move between different places in the three different systems below. These are illustrated and further explained in Figure 9-5.

1. Direct system
2. Channel (or Kanal) system
3. Central system

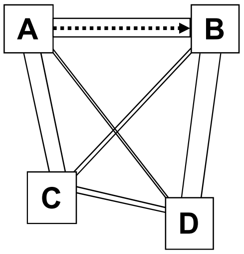
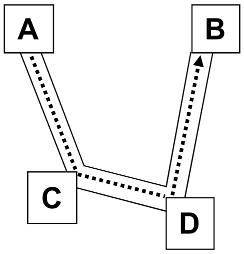
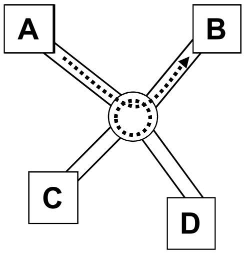
Direct	Indirect	
		
D - Direct	**K – Kanal (Channel)**	**C – Central**
Direct System Materials move from origin to destination over the shortest practical path. When the intensity of flow is high and the distance short or moderate, this system is generally the most economical to use – especially if the materials are special in some way(s) and time is urgent.	Kanal (Channel) System Materials move in a pre-established route and flow to destination together with other materials moving to or from other areas. When the intensity of flow is moderate or low and the distance moderate or long, this system is economical – especially if the layout is irregular or spread out.	Central System Materials move in a pre-established route from origin to a centralized sorting and/or dispatching area and then on to destination. When the intensity of flow is low and the distances moderate or long, this system quite often in economical – especially if the plant area is basically square and control is important.

Figure 9-5. The basic systems for movement of materials between departments or areas. Note that the shortest path is not always the best or most cost-effective way to move materials. There are many instances in which an indirect channel or route system is far more cost effective. Note that most mathematical algorithms and computer-based programs for layout planning assume that the shortest or shortest rectilinear path is best.

The planner must select the system or combination of systems to use and fit the equipment and containers (or transport units) to it. The whole “set” of handling methods should integrate into the space relationship diagram which the planner is adjusting into an acceptable layout.

The process charts discussed in Chapter 4 are essential in material handling analysis. So also are sources of flow data discussed in Appendix II, including the Route Chart and the Flow-In/Flow-Out Charts pictured there in Figures 4 and 5.

When setting material handling methods, the planner is interested in both the intensity of flow and the distance traveled. These are best visualized right on the space relationship diagram or the alternative layout as shown in Figure 9-6.

For each particular handling system (direct, channel, or central), determine the best handling method – the type of equipment and container (transport unit), best suited to that system. Establish the time and cost for that best method and the anticipated investment required. In the same way, the planner also considers combinations of the three systems and dual systems, for splits of product-material classes or different item groups. Combinations of methods become alternative handling plans and are evaluated in terms of time, cost, and investment in order to select the most suitable system and its methods. These can then be shown with symbols directly on the layout as in Figure 9-6.

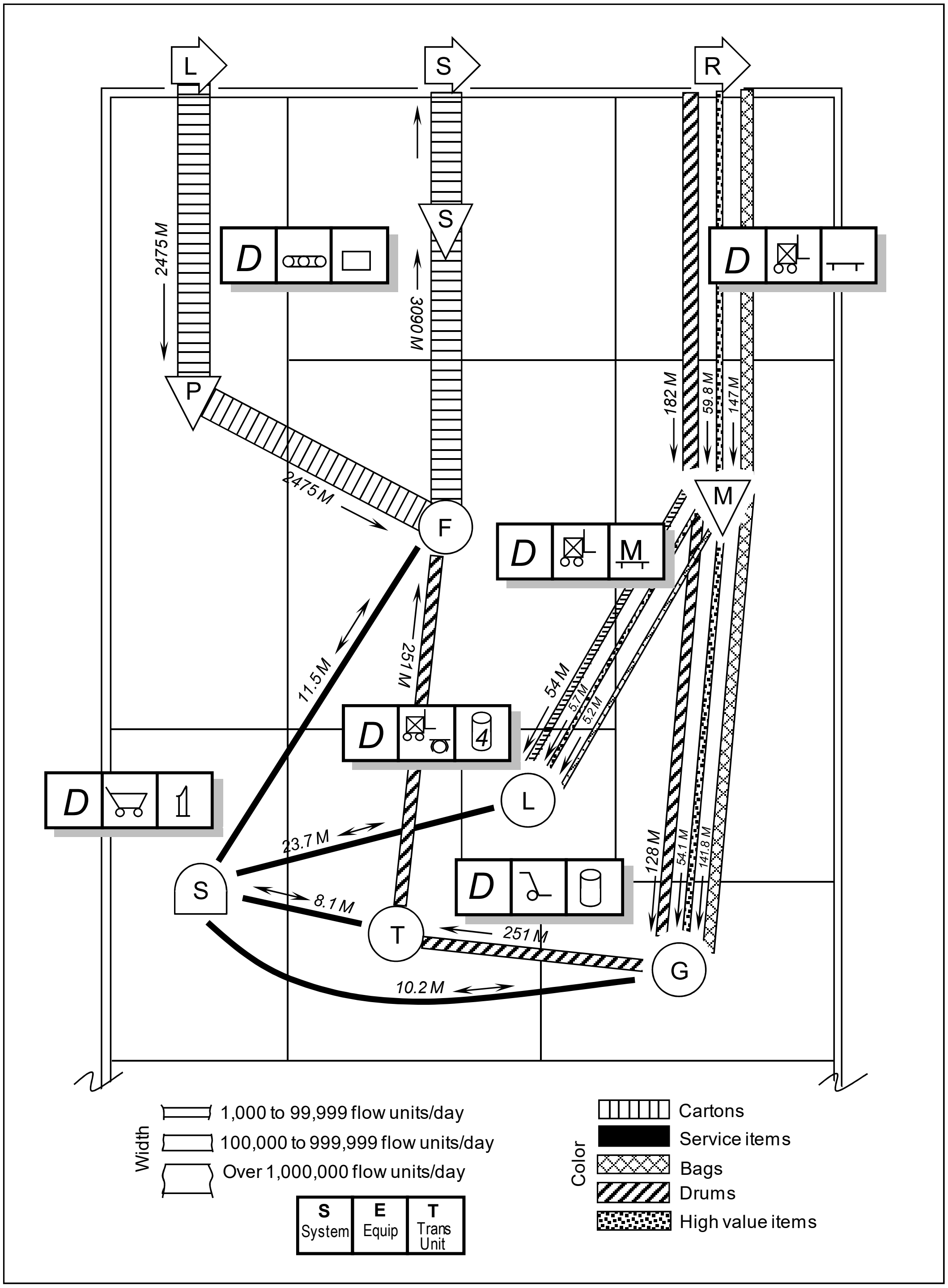


Figure 9-6. Flow diagramed to show the intensities of movement by class of material directly on the layout or space relationship diagram. This analysis was made to plan the overall handling system, equipment, and containers in a pharmaceutical plant. Bulk liquids are omitted. Symbols illustrate proposed (or existing) handling methods and can help the planner identify any layout modifications that these methods may require. To view the steps of the material handling analysis and a tabular summary of the symbols, see Figure 2 in Appendix X. Note that the Route Chart shown in Figure 4 of Appendix II would help to understand a route such as M to L where several items are moving. The Flow-In/Flow-Out Chart in Figure 5 would help to plan for areas such as M and S.

For the general type of equipment to be used, there is a host of possibilities. Appendix XI provides a list and graphic symbols like those in Figure 9-6. The evaluation form shown in Figure 9-7 provides the planner with a method of screening and selecting the general type of handling equipment. In all likelihood, this selection will be followed by or supported with more detailed and specific analysis. And in Phase III, Detail Layout Planning, the same kind of handling analyses is also used, though more detailed and limited to smaller areas.

Every handling method will have some impact on the layout, if only because of the space needed to operate. It follows that methods needing more or different kinds of space will have more impact. A method's direction of movement – one way, bi-directional – and the nature of its path – fixed or variable – can become modifying considerations in the overall layout plan.

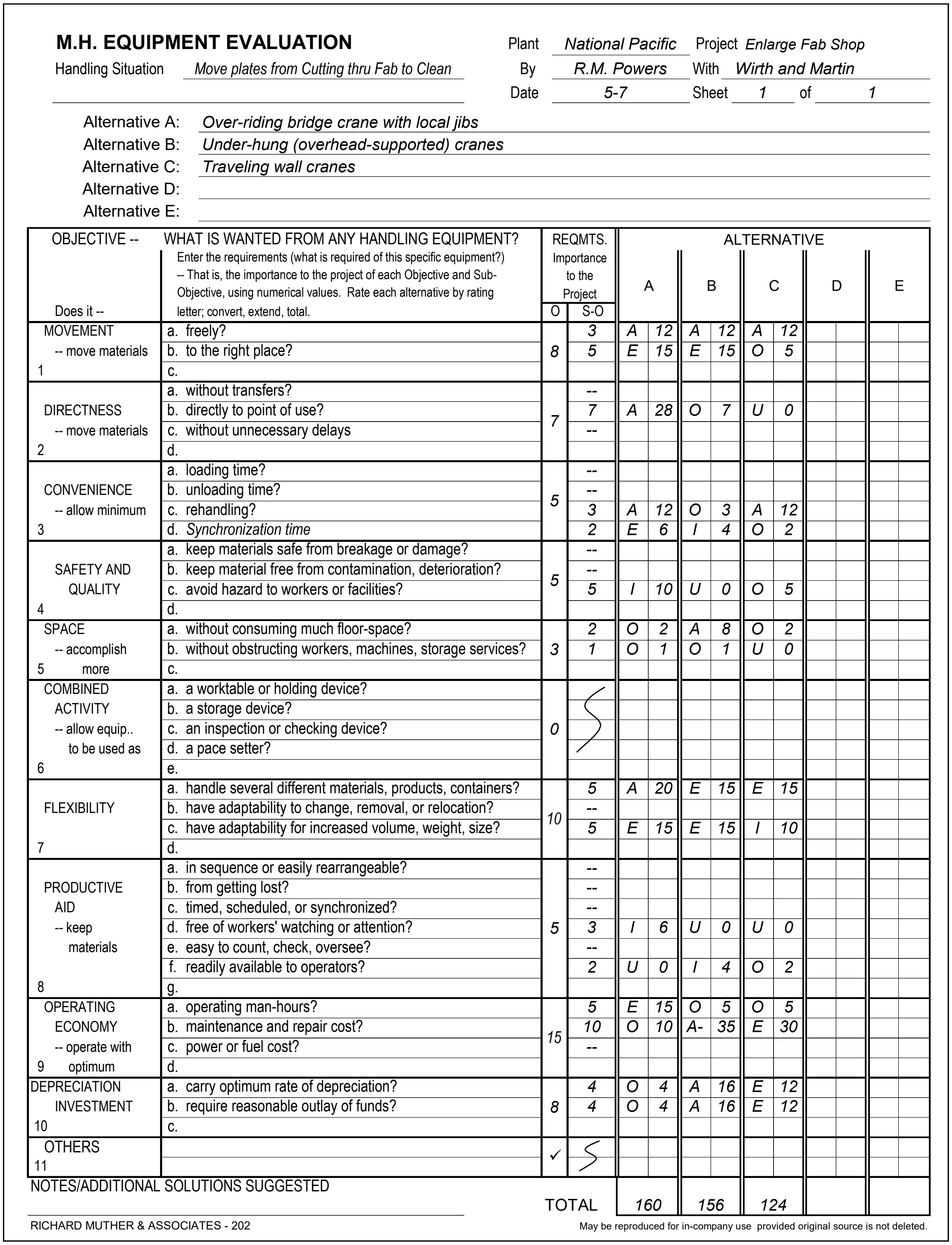
For example, the fork lift needs a certain aisle width and turning radius in which to operate. But it can use any suitable aisle and move in any direction with ease. In contrast, a tractor pulling a train of carts may need an area in which to load and unload and wider aisles for turning, and for turning around. In fact, it may be easier and save space to operate the train in one direction only. Dead-end aisles are a problem for both methods, but greater for the train. The combined impact of mobile handling devices can also affect the overall layout, most frequently by the amount of traffic that they may concentrate in one aisle or intersection. The "adjustment" may be to control the material handlers' routings, or it may be to disperse the traffic with layout modifications.

Conveyors at floor level need dedicated floor space within the areas that they serve. And they typically act as barriers to movement of people and mobile handling equipment. When supported from above their location may be dictated by the building's structure and by the need for safety underneath. Their noise may also be a factor in where to place them relative to people working nearby. And because of their investment cost, the planner will typically want to keep them as short as accumulation needs allow. Each of these conditions may become modifying considerations and lead to layout adjustments.

Overhead cranes pose their own set of modifying considerations, especially when movement between activity areas will require transfers between cranes or crane bays. The lifting capacities of cranes often vary – creating different "kinds of space" below. Here, the planner must adjust the layout so that the lifts do not exceed the capacities of cranes above the activity-areas.

Other Modifying Considerations

Arranging *storage facilities* is the heart of all warehouse layout projects. It is important to some extent in all industrial layouts, service-areas, offices, and retail store layouts as well. In fact, the storage of waiting materials, supplies, stationery, and other items is probably more common to every layout project than any other modifying consideration – though these may be detail layout problems, to be sure, in many instances.



M.H. EQUIPMENT EVALUATION

Handling Situation *Move plates from Cutting thru Fab to Clean*

Plant *National Pacific* Project *Enlarge Fab Shop*

By *R.M. Powers* With *Wirth and Martin*

Date *5-7* Sheet *1* of *1*

Alternative A: *Over-riding bridge crane with local jibs*

Alternative B: *Under-hung (overhead-supported) cranes*

Alternative C: *Traveling wall cranes*

Alternative D:

Alternative E:

OBJECTIVE -- Does it --	WHAT IS WANTED FROM ANY HANDLING EQUIPMENT? Enter the requirements (what is required of this specific equipment?) -- That is, the importance to the project of each Objective and Sub-Objective, using numerical values. Rate each alternative by rating letter; convert, extend, total.	REQMTS. Importance to the Project		ALTERNATIVE									
		O	S-O	A		B		C		D		E	
MOVEMENT -- move materials 1	a. freely?	*8*	*3*	*A*	*12*	*A*	*12*	*A*	*12*				
	b. to the right place?		*5*	*E*	*15*	*E*	*15*	*O*	*5*				
	c.												
DIRECTNESS -- move materials 2	a. without transfers?	*7*	*--*										
	b. directly to point of use?		*7*	*A*	*28*	*O*	*7*	*U*	*0*				
	c. without unnecessary delays		*--*										
	d.												
CONVENIENCE -- allow minimum 3	a. loading time?	*5*	*--*										
	b. unloading time?		*--*										
	c. rehandling?		*3*	*A*	*12*	*O*	*3*	*A*	*12*				
	d. *Synchronization time*		*2*	*E*	*6*	*I*	*4*	*O*	*2*				
SAFETY AND QUALITY 4	a. keep materials safe from breakage or damage?	*5*	*--*										
	b. keep material free from contamination, deterioration?		*--*										
	c. avoid hazard to workers or facilities?		*5*	*I*	*10*	*U*	*0*	*O*	*5*				
	d.												
SPACE -- accomplish 5 more	a. without consuming much floor-space?	*3*	*2*	*O*	*2*	*A*	*8*	*O*	*2*				
	b. without obstructing workers, machines, storage services?		*1*	*O*	*1*	*O*	*1*	*U*	*0*				
	c.												
COMBINED ACTIVITY -- allow equip.. to be used as 6	a. a worktable or holding device?	*0*											
	b. a storage device?												
	c. an inspection or checking device?												
	d. a pace setter?												
	e.												
FLEXIBILITY 7	a. handle several different materials, products, containers?	*10*	*5*	*A*	*20*	*E*	*15*	*E*	*15*				
	b. have adaptability to change, removal, or relocation?		*--*										
	c. have adaptability for increased volume, weight, size?		*5*	*E*	*15*	*E*	*15*	*I*	*10*				
	d.												
PRODUCTIVE AID -- keep materials 8	a. in sequence or easily rearrangeable?	*5*	*--*										
	b. from getting lost?		*--*										
	c. timed, scheduled, or synchronized?		*--*										
	d. free of workers' watching or attention?		*3*	*I*	*6*	*U*	*0*	*U*	*0*				
	e. easy to count, check, oversee?		*--*										
	f. readily available to operators?		*2*	*U*	*0*	*I*	*4*	*O*	*2*				
	g.												
OPERATING ECONOMY -- operate with 9 optimum	a. operating man-hours?	*15*	*5*	*E*	*15*	*O*	*5*	*O*	*5*				
	b. maintenance and repair cost?		*10*	*O*	*10*	*A-*	*35*	*E*	*30*				
	c. power or fuel cost?		*--*										
	d.												
DEPRECIATION INVESTMENT 10	a. carry optimum rate of depreciation?	*8*	*4*	*O*	*4*	*A*	*16*	*E*	*12*				
	b. require reasonable outlay of funds?		*4*	*O*	*4*	*A*	*16*	*E*	*12*				
	c.												
OTHERS 11		✓											
NOTES/ADDITIONAL SOLUTIONS SUGGESTED		TOTAL		*160*		*156*		*124*					

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Figure 9-7. Evaluation form for selecting the general type of materials handling equipment. This example evaluates three handling alternatives for the fabrication shop enlargement in a yard making small ships. The breakdown into objectives includes a list of features we would want from any piece of handling equipment on any project. Indicated in the requirements column is the importance of each objective, and sub-objective, to the situation at hand. The alternatives are rated for each sub-objective using the SLP vowel-letter rating. When the rating is complete, the letters are converted to numbers (see Figure 10-7) and multiplied by the S-O requirements weight. Totals indicate a weighted and rated value for each alternative.

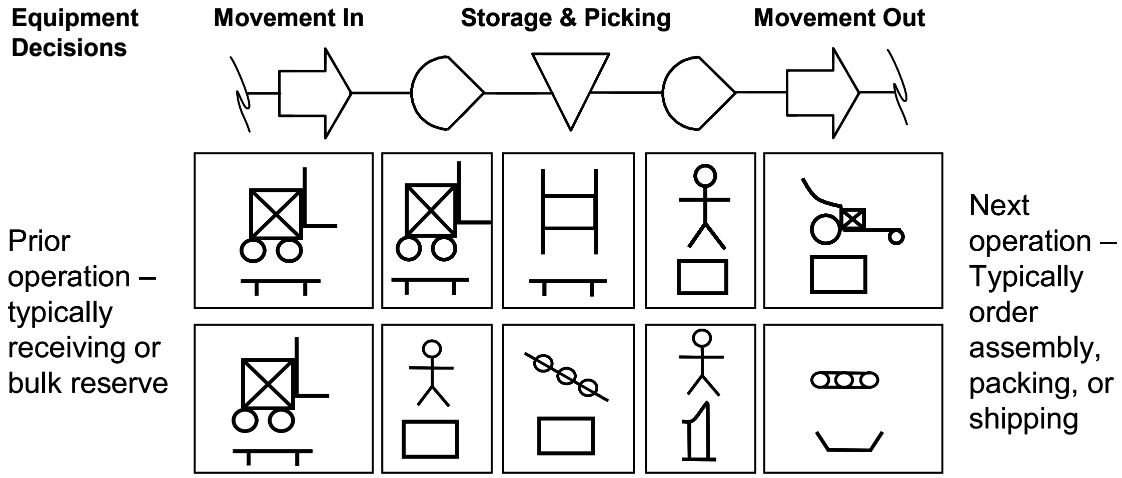

Figure 9-8. Two handling-and-storing methods, each with different space and layout considerations. These and additional symbols appear in Appendix XI and at www.RichardMuther.com > Downloads.

Perhaps the planner got a pretty good idea of how to store materials when establishing the storage areas' space requirements. Even if the methods were decided, they should now be re-examined in the light of the space relationship diagram and the other modifying considerations with which the storage must be integrated. As suggested in Figure 9-8, an area's storage methods must be compatible with the handling methods moving to and from it. In effect, the planner must set the appropriate *handling-and-storing method* and address its impact on the intended layout. In doing so, remember that storage is the area most easily and most commonly squeezed for space when planning new layouts – even if this squeeze requires a change of method.

The methods of stacking, racking, or supporting are many. Graphic symbols for a few of the more common types of equipment are included in Appendix XI. These can also be used to illustrate intended handling-and-storage methods on a block layout or space relationship diagram without having to decide on details or draw actual racks and equipment.

Site conditions or surroundings – the "larger" constraints imposed by location – can certainly influence how a layout is arranged. Thus, if the location has not yet been selected, then the overall layout very likely will "underlap" the Phase I decision. Such factors as slope of the land, prevailing wind, southern exposure, or North light are natural conditions which can influence the arrangement of the space. Manmade site conditions include dirt or fumes from adjacent plants, rail or waterway access, public regulations and property easements, and the effect of the company's own noise, hazards, and traffic on neighboring plants or homes. Within the plant, such considerations take such forms as the spread of contaminating materials, winter drafts from doors, glare from welding arcs, and vibrations from rapid or heavy-impact equipment. Modifying considerations like these must be identified – perhaps with photos and drawings as suggested in Figure 9-9 – and provided for during the adjustment into layout plans.

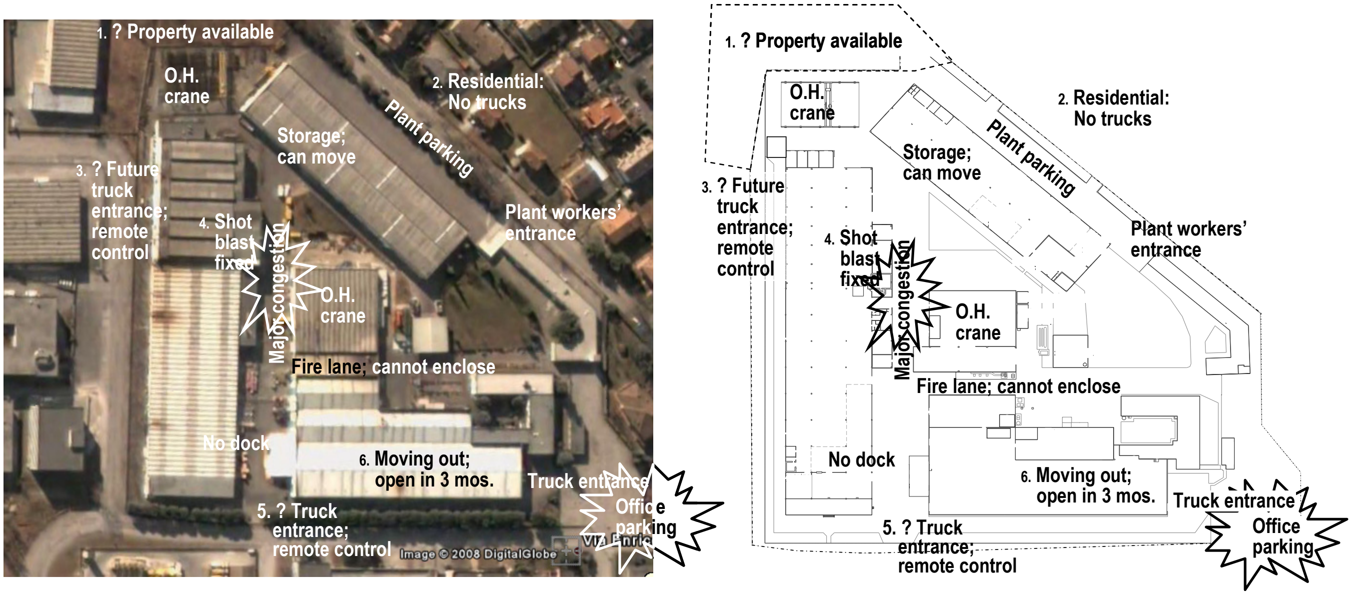

Figure 9-9. Site and surrounding conditions. When the layout is for an entire building or complex, it is helpful to mark up an aerial or satellite photo, or a drawing of the site to highlight modifying considerations and any limitations on the layout plan. Open or questionable issues and features can be given a reference number pointing to additional notes, discussion, problem-solving or action planning. Of course, close-up photos and detailed drawings of specific features may be useful. In this example, open conditions or issues are numbered for tracking and indexing of additional detail – close-up photos, detail drawings, and notes. Fixed conditions of interest are simply labeled, without a number.

Closely akin to site conditions are the *building features* themselves: ceiling height, floor load, column spacing, types of windows, walls, and doors. Common features were recorded and rated as "kind of space" requirements in Chapter 7 (See Figure 7-11). Where an existing structure is to be used, the availability of such features may already be determined. Some can be moved or changed, but they may still lead to modifications in the layout planning. Competent architectural advice can be very important here, especially if drawings of the original structure are not available. For choice of features not already recorded on the Activities Area and Features Sheet, the Industrial Building Features Guide in Figure 9-10 may be helpful when laying out industrial and service plants.

Modular arrangement of areas and buildings is a significant consideration when going onto a new site or into a new structure. Modular patterns offer many potential savings in real estate, construction costs, and the like. Among their advantages are:

1. Straightness of roads – of aisles
2. Regularity of building faces or column lines – of departmental areas, walls, or aisles
3. Length and installation cost of utility main lines – of distribution lines
4. Ease of layout planning, construction, installation
5. Ease of logical expansion and later rearrangement
6. Savings in maintenance and repair costs

INDUSTRIAL BUILDING FEATURES GUIDE

Use general-purpose or multipurpose building when the following are important or predominant:

- ☐ Initial cost
- ☐ Speed of getting the layout into production Probability of selling the building later for:
    - Profit
    - A better location
    - Foreclosure
- ☐ Frequency of changes in:
    - Products or materials
    - Processes or methods
    - Machinery and equipment
    - Volume or output

Use single-story construction, possibly including balconies and/or basement, when the following conditions exist:

- ☐ Product is large or heavy
- ☐ Weight of equipment causes heavy floor loads
- ☐ Large, more-or-less unobstructed space is needed
- ☐ Land value is low
- ☐ Land is available for expansion
- ☐ Product is not adapted to handling by gravity
- ☐ Erection time is limited
- ☐ Frequent changes in layout are anticipated

Use a relatively square building where there are:

- ☐ Frequent changes in product design
- ☐ Frequent improvements in process
- ☐ Frequent rearrangements of layout
- ☐ Restrictions on building material availability or substantial savings desired in amount of materials used

Use other shapes or separate buildings when there are:

- ☐ Limitations in physiography of the land
- ☐ Property lines at awkward angles
- ☐ Operations that cause dirt, odors, noise, vibration
- ☐ Operations not part of production
- ☐ Operations susceptible to fire, explosion, contamination

Use a basement if these features can be obtained

- ☐ Ample headroom
- ☐ Good ventilation
- ☐ Sound foundations
- ☐ Ample lighting
- ☐ Waterproofed walls
- ☐ Freedom from seepage or flooding

Use balconies for these typical situations:

- ☐ Light subassembly above final assembly on ground level
- ☐ Assembly operations with heavier forming machinery below
- ☐ Light-machine operations with heavier machines below
- ☐ Treating operations with forming operations and assembly of bulky units on ground level
- ☐ Supporting activities that can be kept off the production floor – storage, wash and locker rooms, production offices, packing, auxiliary equipment, and the like
- ☐ Operating or servicing upper parts of tall, high machinery
- ☐ Liquid or bulk material storage and preparation areas, involving mixing, aging, blending, and the like

Use <u>no windows</u> generally in cases when:

- ☐ Plant is underground
- ☐ Work is affected by changes in temperature, humidity, light
- ☐ Work is subject to dust, dirt, contamination
- ☐ Workers or work are affected by external noise
- ☐ Artificial light and power is inexpensive
- ☐ Seeing things outside is not necessary
- ☐ Windows could get dirty fast

Use these desired <u>floor characteristics</u> where practical:

- ☐ Floors of various buildings at same level
- ☐ Strong enough to carry machines and equipment
- ☐ Made from inexpensive materials
- ☐ Not too expensive to install
- ☐ Ready for use quickly after laying down
- ☐ Easily and quickly repaired, removed, and replaced
- ☐ Resistant to shock, abrasion, heat, vibration
- ☐ Not slippery under any condition
- ☐ Noiseless and sound absorbing
- ☐ Attractive to eye and with numerous colors available
- ☐ Unaffected by changes in temperature and humidity, or by oils, acids, alkalis, salts, solvents, or water
- ☐ Odorless and sanitary
- ☐ Resilient enough to seem soft underfoot and to minimize damage to articles dropped on it
- ☐ Easy to fasten machines and equipment to
- ☐ Will dissipate static electricity and not cause sparks
- ☐ Easily kept clean

Use these <u>roof and ceiling features</u> when applicable:

- ☐ Overhead space and height clearance for:
  - Production machines
  - Process equipment – treating vats, drying ovens, etc.
  - Handling equipment – cranes, conveyors, etc.
  - Elevated traffic ways
  - Sprinkler (with code-required clearance underneath)
  - Electrical distribution
  - Heating and ventilating systems
  - Air circulation
  - Washroom and toilets, service and storage areas built off the production floor
- ☐ Strength for underside (or above) support of:
  - Machinery and process equipment
  - Handling equipment for material or machinery
  - Heating and ventilating systems
  - Elevated traffic ways, storage or service areas
- ☐ Light:
  - Roof lighting independent of walls or expansion plans
- ☐ Heat conductor for:
  - Heat losses in winter
  - Effect on personnel in summer
- ☐ False ceiling:
  - Dust accumulation and dust drop-off
  - Appearance

Figure 9-10. General guide for industrial building features.

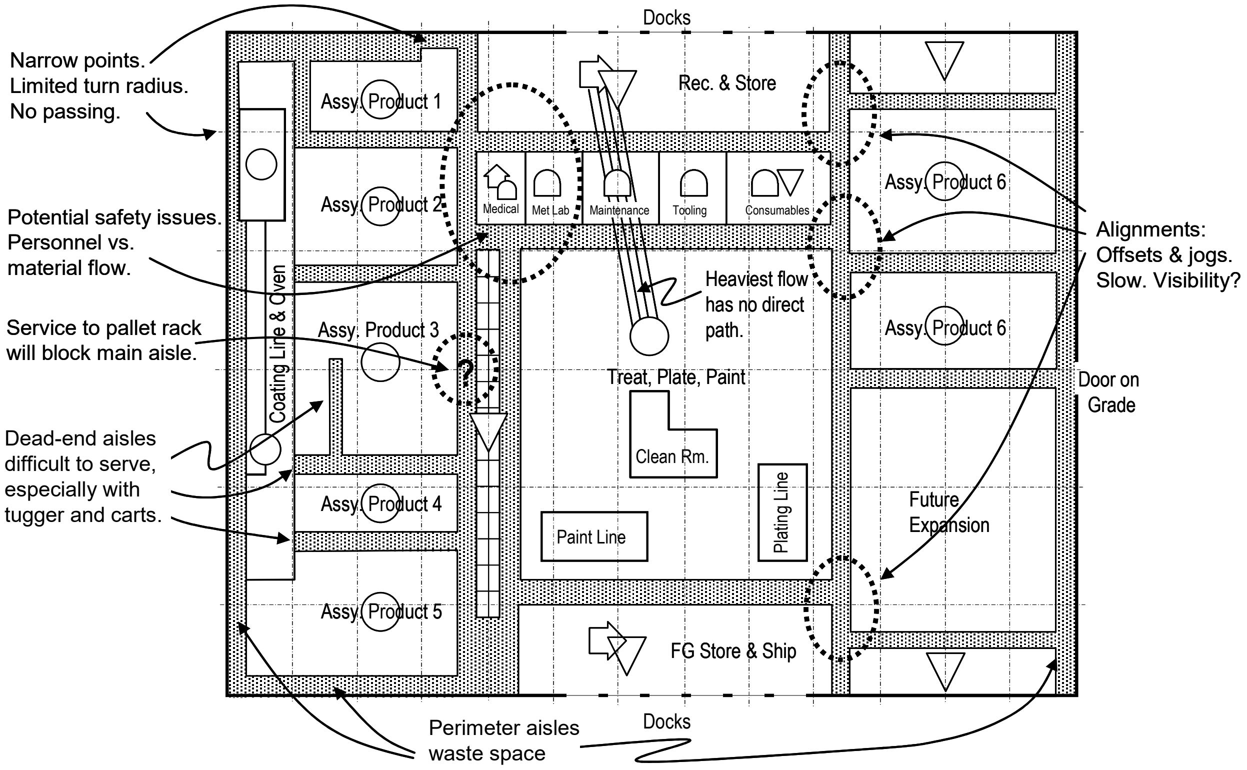

Figure 9-11. Adjusting the layout for effective aisles. This proposed layout keeps aisles free of columns but suffers from other potential problems. The highest flow path from Receiving & Storage to the center Treat, Plate, Paint area must go around the block of small service areas. This creates a safety issue since personnel traffic will be heavy around the service areas. Accessing the pallet rack will block the main aisle in front of it. Dead-end aisles may preclude the use of tuggers and carts since they cannot back up. Misaligned aisle intersections will slow traffic and impair visibility. The perimeter aisles waste space. Further adjustment will improve these conditions.

While use of a space or building module may mean a little additional initial investment, its advantages, from the standpoint of construction and maintenance, of installing and servicing the utilities and auxiliary lines and equipment, and of integrating buildings or departmental areas with each other, usually outweigh the disadvantages.

In any event, building features must be integrated with the layout plan as the planner adjusts the space. Certainly, for new construction, the architect-engineer should be available for consultation as the general overall plan takes shape, for his or her preliminary drawings should be integrated with and approved at the same time as the overall layout.

Locations, widths and alignments of *main aisles* are important in every layout. See Figure 9-11. Strive for long, straight main aisles that bisect the layout, with sufficient width for any necessary turns, turning around or passing. Try to align at least one door on grade with a main aisle for bringing in and removing large equipment. For safety, pay attention to separation of personnel and materials movement. Avoid offsets at intersections since they increase turns, aisle congestion and collision risk. Avoid dead-end aisles since they are harder to service with handling equipment. For maximum space utilization, aisles should always serve both sides. Perimeter aisles do not.

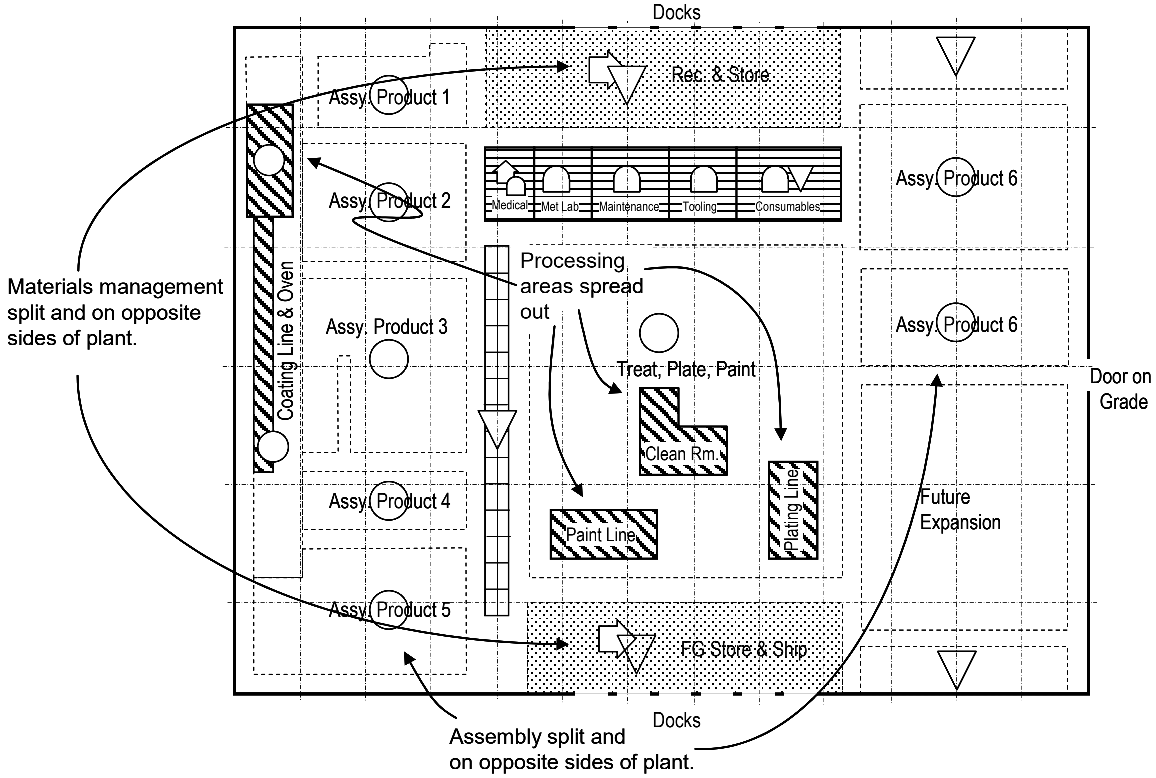

Figure 9-12. Adjusting for kinds of space. This is the same proposed layout as Figure 9-11. The plan does a good job of keeping the walled service areas as a block. However, processing areas are spread out. If these need special electrification, piping, drainage, spill retention, special ventilation, roof stacks and the like, costs may be reduced and maintenance made easier by adjusting into closer proximity and alignment. Note that both assembly and materials management areas are on opposite sides of the layout. This prevents sharing of docks and fork trucks, and makes it harder to supervise and share personnel in both functions. Presumably any relationships pulling these areas together were captured in the relationship chart and diagram. But if they were overlooked, or the layout has been based on flow of materials alone, any important other-than-flow relationships must be considered now.

Good layouts always consider the effective distribution of *utilities*. Layout adjustments are often necessary to accommodate piping, wiring, ventilation, and various forms of waste recovery. The location of *maintenance* must also be considered. Adequate space must be provided for the maintenance or repair department itself. Additionally, employees of the maintenance department need access, for themselves and their equipment, through the areas and around the building structures involved. In detail layout planning, access around individual pieces of machinery and equipment must be provided.

Adjusting the layout to keep *like kinds of space* together generally leads to lower installation and rearrangement costs. Distribution runs for utilities are shorter. Humidity, temperature, and air pressure control are less costly to install and operate and easier to maintain in contiguous areas. Enclosures for special kinds of space – offices and labs, clean rooms, support areas – can share common walls and environmental controls. Special forms of fire protection, security, curbs and spill retention are all less costly when the areas needing them are contiguous. Figure 9-12 illustrates these issues and modifying considerations. Note that the relationship chart can capture these plant engineering and architectural considerations as other-than-flow relationships between activity-areas.

Personnel requirements include questions of centralized versus decentralized plant entrances, of locker rooms, food service, and the like. Whether to put restrooms on the ground floor, on a mezzanine, or in a basement, must be decided.

Safety considerations, convenience of employee access, and questions of communicating systems may all be involved in the project and should be considered as the general overall layout takes shape. Even housekeeping and appearance considerations can modify layout plans.

Placement of minor support activities is another modifying consideration. For example, an exhaustive analysis (in connection with the relationship chart) may have been made to determine the closeness of the credit union to all of the other activities. Or it may have been considered too minor an activity and so kept off the relationship chart, to be picked up as a modifying consideration. In either case, when the planner adjusts the space relationship diagram into a layout, the space and features required for the credit union may be fitted in with all of the other activities involved. That is, the relationship between all *major* activities is determined in making the relationship chart. Less important activities are picked up as modifying considerations. The less important activities or features therefore adjust, rather than determine, the space relationship diagram. This is always true when the relationships are based on flow of materials only.

Another area of major consideration is operating *procedures* and *controls*. Any arrangement of space can have its advantages completely offset if practical operating procedures cannot be followed. The production planning and control system, the inventory paperwork, the scheduling system, the time-keeping routine, the methods of controlling quality, the manner of keeping track of rework or scrap, and a host of other operating procedures and their supporting paperwork are important to the performance which the installed layout actually can give.

For example, the layout shown earlier in Figure 3-4 can only be made to work a certain way. The slow-movers – made to order daily – are collected first, and then the in-stock items picked from their finished-goods shelving. In order to make this layout work, a revised system of releasing orders to the plant also had to be worked out. Furthermore, in order to make an effective incentive system for the operators producing fast-mover items, a system of counting and controlling the work of each operator had to be planned into the layout.

It is easy for staff analysts, and especially for engineers, to overlook these practical operating procedures. They are a most important part of layout planning. The planner should lean over backwards not to neglect them.

Details within activity-areas are a final source of modifying considerations. As the planner develops the overall layout, critical details within activity-areas need to be understood. These influence both the area's configuration and its relationship to main aisles and other areas nearby. Thus, overlapping into Phase III is a significant part of adjusting the Phase II layout. Common considerations include: entrance and exit points and internal flow of materials; also the placement or orientation of highly-fixed or oversized equipment, and any enclosures that may be tied-in with others nearby.

Practical Limitations

Considerations which are open for development, design, or decision, we call modifying considerations; those which impose constraints on our planning are called *practical limitations.* The latter include such restrictions as may be built into an existing building, existing handling methods, or a not-to-be-changed production-control-and-dispatching system. Company policy, building codes, labor union contract, and community regulations on waste disposal can all affect the layout; and, as noted earlier, the physical characteristics of the location – a Phase I decision – always exert limitations on the layout. Even a need for straight aisles of adequate width imposes requirements, for main aisles are part of any overall layout plan. Certainly one of the most important limitations is the question of cost savings and available investment money.

As the planner works through the modifying considerations already discussed, various practical limitations will come into play and lead to additional changes and layout adjustments. For example, in a certain project, the layout may benefit from use of a highly synchronized, fully automatic conveying system. But practical limitations of the budget or placing too great a dependence on one piece of equipment, or the conveyor’s obstruction to cross-traffic may rule out its use.

When perceived limitations involve external codes and government regulations, the planner must either assume what is permitted, or take the time to find out. Some codes will be clear. Others will be ambiguous and subject to interpretation. Here, it may be impossible to get a timely answer as to the practicality of a specific approach or layout feature. When this happens, the planner must decide whether to carry the alternative layout or feature forward into evaluation, or change them to what he believes may be permitted – typically taking a conservative point of view.

Many smaller, less dramatic constraints and limitations abound in layout planning. For example, one company’s manufacturing policy requires that all small parts be fed to assembly lines from one side, while large parts are fed from the other. Layouts violating this rule will not be approved by the current management.

For each good idea, there is a set of practical limitations which must be weighed against it. As the pros and cons of each consideration are weighed, the obviously poor or weak possibilities are abandoned and the seemingly worthwhile ideas retained. These are incorporated into the various adjustments of the space relationship diagram – each to help the planner develop a more satisfactory layout.

Essentially, the process is making compromises, the planner striving for an arrangement of activities which will give the most practical overall compromise of all considerations.

As you work through the many considerations involved, keep a record by making a drawing or a photograph of the various alternative plans. Eventually, relatively few good alternatives remain. Very seldom is there only one clear-cut obvious arrangement. Rather, the alternatives sometimes comprise as many as six or eight possibilities. But if the alternatives haven't boiled down at least to this few, then the planner has not finished exploring the modifying considerations and their practical limitations.

The Mechanics of Adjustment and Layout Development

In Phase II, overall layouts are typically prepared in one of the following ways:

1. Drawing the activity-areas, line by line:
   a. in an electronic drawing or
   b. with pencil on paper.
2. Arranging scaled block templates, representing the activity-areas:
   a. in an electronic drawing
   b. in paper or card stock form, then photographing the result and/or using it to guide a line drawing.
3. One or more teams arrange scaled or block templates. These are typically photographed and/or the taped template arrangements saved. But line drawings are only made (later) for the top one or two plans – the winners in subsequent evaluation.

To be sure, there are other approaches, such as working with a digital projector on a large screen, with a group guiding the planner's template placement in an electronic drawing.[1]

Which method to use depends upon the project's situation. Line drawings are precise but take time to prepare, plot, review and revise. Templates of the block variety can be quickly placed, reviewed and revised, but the result is only approximate. Some time must always be spent later if a line drawing version is needed. The pros and cons of various kinds of drawings, templates, models and electronic tools are discussed in greater depth in Chapter 13.

The most important choice when developing a Phase II overall or block layout is whether to have one or perhaps two planners prepare the alternatives – by whatever physical means – and then present them to a team of "reviewers." Or, to equip a team with templates and let the team members place them as a group activity. (Since line-drawing is never a group activity, that approach is not an option).

The team approach typically considers more alternatives in less time. If two or more teams are working, they can develop and sort through many alternatives in a very short time. And the evaluation of alternatives in the next Section 5 of the SLP pattern goes faster since the participants are more familiar with the plans. In the team approach, the layout planner's (or project leader's) job is to:

1. Provide a comfortable place for the team to work – typically for a day or two.
2. Staff the teams with the right mix of personalities and knowledge (so that one person doesn't end up doing all the work, or take over all the work).

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[1] 1. We are intentionally leaving out the use of mathematical models and the algorithms used to apply them. Here the planner enters relationships and space into a computer program and it generates the layout. There are many mathematical approaches – quadratic, graph-theoretic, exact, heuristic, linear, non-linear, integer, mixed integer... These can be found in any college text on facilities planning and design. A brief discussion and two references appear in Chapter 13. In our experience, the use of such programs in industry is rare.

3. Provide each team with the Relationship Chart and diagrams for reference and guidance.
4. Set an appropriate scale – not too small or one person will end up placing all the templates, and not too large because the ergonomics become poor – bending and reaching over a large work area – and the finished layout becomes too unwieldy.
5. Provide enough “base sheets” or plots of the space available at the selected scale.
6. Make sets of templates for the expected alternatives, plus one for quick development of a potential “better idea,” after the expected alternatives have been evaluated. Ideally, the templates will be made in color on card stock and will be gridded at a meaningful scale for quick re-shaping by the teams.
7. Always check to make sure the templates and base sheets are at the same scale.
8. In Phase II Overall Layout, make sure that the planners understand which block template dimensions are fixed or minimums and which can be adjusted to fit their plans. Provide the Activity Areas and Features Sheet for reference. In Phase III Detail Layout, templates should reflect the actual shapes and footprints of the equipment to be placed. Block templates will be imprecise.
9. Think ahead about the specific alternatives that must be developed, versus those that are only “nice to develop, time permitting.”
10. Assure that two or more teams are not duplicating each others’ plans.
11. Circulate and help answer questions about modifications and limitations, or clarify meanings and data on forms, charts and diagrams.
12. Provide refreshments.

Some finer points on the team approach are presented in Appendix IX. Photos of “adjustment in action” appear below in Figures 9-13 and on the next page in Figure 9-14.

a

b

Figure 9-13. When there is no team, the planner will develop the layouts alone, making electronic drawings (a), or perhaps placing colored paper templates on a plot of area to be planned (b), or even drawing by hand with pencil and paper. When working alone, make and save frequent copies and photos of template arrangements. Otherwise you may find it difficult to “back out” of a “dead end” idea. To the extent practical, bring others in to review the alternatives as they develop. In addition to being helpful, their input now will save time later in revision, refinement, and evaluation.

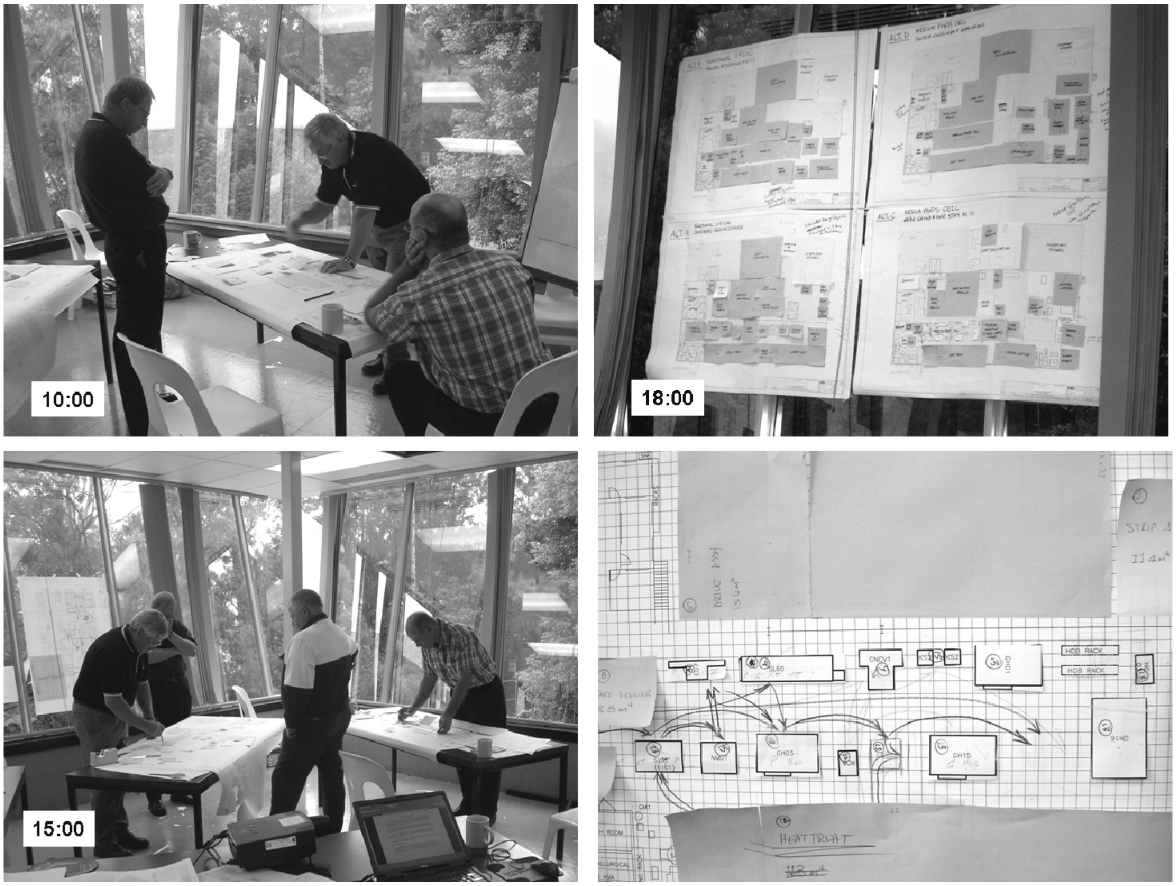


Figure 9-14. A day of layout development. Here a small team naturally subdivides in midday to explore two layouts in parallel. Another team worked down the hall. By evening, four alternatives were ready to compare. By working on a scaled grid of the plant, one team was even able to prepare a rough layout for a new manufacturing cell. The overall plan templates were blocks; the cell templates were machine outlines.

Working with Templates

Working with paper templates at a comfortable scale is often less tiring than working with the same templates in electronic form. Even when the final arrangement must be captured in electronic form, the total time is often shorter. In any electronic drawing the temptation is always present to add precision, even to alternatives that will be discarded. While imprecise, placement of paper templates permits rapid exploration of alternatives. The paste-ups are easier to show to others and often save lost time waiting on plots for this purpose. Greater precision can be added when the template layout is converted to a drawing and further refined.

Be sure to understand which templates may be adjusted by cutting and fitting, and which may not due to shape or configuration requirements or minimum dimensions. Remember, you are free to change the shape of an initial template within or up to known dimensional limits of its area or equipment. If templates have been cut into pieces for re-shaping, make sure that the pieces did not get lost or mislabeled. Take care that all templates are accounted for and placed.

Problem-Solving Procedures

As layouts are developed, and indeed throughout the planning project, various open issues emerge that cannot be immediately resolved. These are sometimes simply questions needing an answer; or choices needing a decision, or assumptions needing verification. But others are more significant and become research, planning or problem-solving projects in their own right.

To keep moving on the layout, the planners will need an organized way to list, document, track and ultimately dispose of their open issues. The list will typically be long at first, but it should be very short by the time alternatives are ready for evaluation.

Along the way, all manner of specialized and specific analytical techniques may be needed. From the perspective of project management, a standard or general way of proceeding may also be helpful. One of these is the 6-step *universal problem-solving procedure* below and illustrated in Figure 9-15.

1. State the Problem
2. Get the Facts
3. Restate the Problem
4. Analyze and Decide
5. Take Action – What, Who, When
6. Follow-Up

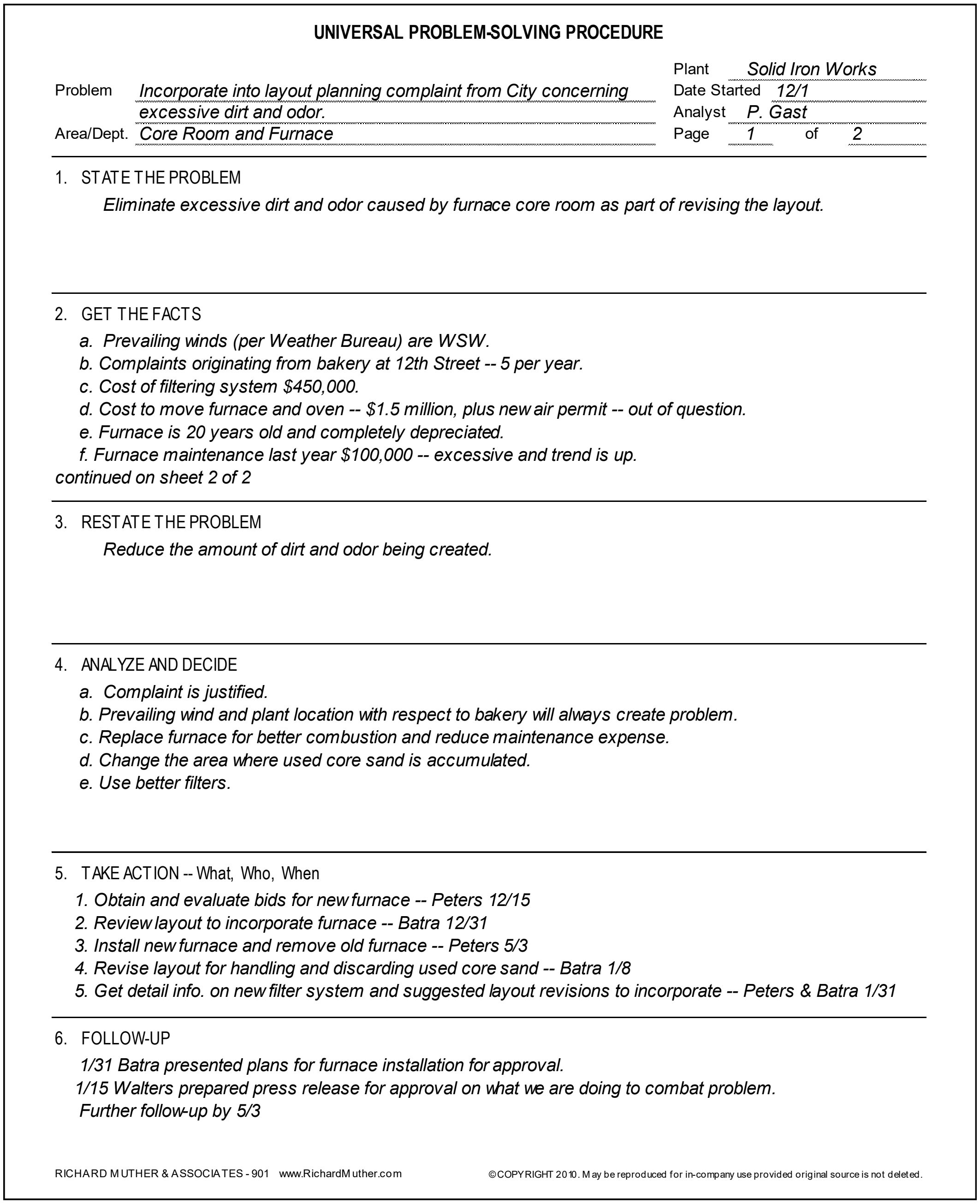
To be sure, it is hardly detailed or specific enough for any complex problem, but it is a simple, basic method of solving everyday problems that arise during layout planning. It can help deal with the many considerations in an organized way.

Toyota's recently popularized A3 report gives a similar task list: I. Background, II. Current Conditions, III. Goals/Targets, IV. Analysis, V. Proposed Countermeasures, VI. Plan, VII. Follow-up. Six Sigma's Define, Measure, Analyze, Improve, Control provides is another popular task structure. The point is to have one and use it when problems arise. Note also that various tools, techniques and methods from continuous improvement (Kaizen) programs and from quality improvement are also useful here.

Problems that cannot be resolved within the allowed time frame to develop the layout will have to be carried forward as open issues and related assumptions. Their existence and status should be documented and decision-makers made aware during evaluation and approval.

Plans X, Y and Z

From the ideal arrangement in the space relationship diagram, our planning has progressed though modifying considerations and practical limitations. Good ideas and adjustments have been kept; not-so-good and impractical ones discarded. At this point, the planner should end up with generally two to five alternative plans – called Plan X, Plan Y, and Plan Z, in the SLP pattern. Any one of them can be made to work. The next problem is to decide which layout alternative to adopt. In the next chapter we discuss how to evaluate these alternatives.



UNIVERSAL PROBLEM-SOLVING PROCEDURE

Problem *Incorporate into layout planning complaint from City concerning excessive dirt and odor.*
Area/Dept. *Core Room and Furnace*
Plant *Solid Iron Works*
Date Started *12/1*
Analyst *P. Gast*
Page *1* of *2*

1. STATE THE PROBLEM

Eliminate excessive dirt and odor caused by furnace core room as part of revising the layout.

2. GET THE FACTS

a. Prevailing winds (per Weather Bureau) are WSW.
b. Complaints originating from bakery at 12th Street -- 5 per year.
c. Cost of filtering system $450,000.
d. Cost to move furnace and oven -- $1.5 million, plus new air permit -- out of question.
e. Furnace is 20 years old and completely depreciated.
f. Furnace maintenance last year $100,000 -- excessive and trend is up.

continued on sheet 2 of 2

3. RESTATE THE PROBLEM

Reduce the amount of dirt and odor being created.

4. ANALYZE AND DECIDE

a. Complaint is justified.
b. Prevailing wind and plant location with respect to bakery will always create problem.
c. Replace furnace for better combustion and reduce maintenance expense.
d. Change the area where used core sand is accumulated.
e. Use better filters.

5. TAKE ACTION -- What, Who, When

1. Obtain and evaluate bids for new furnace -- Peters 12/15
2. Review layout to incorporate furnace -- Batra 12/31
3. Install new furnace and remove old furnace -- Peters 5/3
4. Revise layout for handling and discarding used core sand -- Batra 1/8
5. Get detail info. on new filter system and suggested layout revisions to incorporate -- Peters & Batra 1/31

6. FOLLOW-UP

1/31 Batra presented plans for furnace installation for approval.
1/15 Walters prepared press release for approval on what we are doing to combat problem.
Further follow-up by 5/3

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Figure 9-15. This general, six-step procedure for solving problems has been around for many years. It provides an organized way of attacking the many modifying considerations bound to crop up in almost every layout project. The problem illustrated here is a typical one. The form guides the planners in using this generally recognized industrial engineering procedure. Graphs, cartoons or diagrams can be used with or in lieu of text for those who prefer a more visual approach, or need a captivating presentation to others not directly involved.

Chapter 10

Selecting the Layout

We are now at a point where we have a relatively few alternative layouts. The SLP pattern refers to them as Plans X, Y, and Z. Any one of these plans will do the job. Any of them can be made to work satisfactorily. However, each has its own peculiar set of advantages and disadvantages. The problem is to decide which of the alternative plans to select. In SLP, this evaluation and subsequent approval take place in Section 5 of the pattern using three basic methods:

1. Balancing advantages against disadvantages
2. Factor analysis rating, supported where practical by measured comparison
3. Cost comparison and justification

Clear Presentation

Before attempting any selection of one plan over another, each plan should be clearly represented. Usually this involves "dressing up" the alternative layouts. Get a clear replica of each plan. And, recognize that others whom we may invite to participate in this selection process are not familiar with the codes, symbols, and activity designations used to do the planning. The replicas or reproductions should leave no doubt about how various arrangements of features and space are meant to work.

If templates were colored with the SLP code, the alternative layouts are already colored. If not, then use this color code to highlight major differences among the plans. Recall that SLP uses only 5 to 7 colors to show differences in types of space. Thus, it is easy to find the warehouse, the dock areas, the office, the assembly floor, the machine shop, support areas… and to see how these differ among the plans. Such comprehension is next to impossible if a dozen or more colors – with no inherent meanings – are randomly applied in a misguided attempt to differentiate each area, or simply to “spice up” the presentation.

Label areas using the familiar company names, and clearly designate main aisleways, walls, craneways, and the like. Remove activity-area symbols and identifiers if these will confuse.

When comparing general overall (block) layouts in Phase II, do not show machinery and equipment except where these are critical to understanding the overall plan. Typically this will be limited to a handful of very large and highly-fixed machines or equipment, production lines, or conveyors.

Showing detailed equipment during block evaluations is generally bad practice since it clutters up the layout, distracts from and obscures “big picture” differences among the plans. Figure 10-1 illustrates this point.

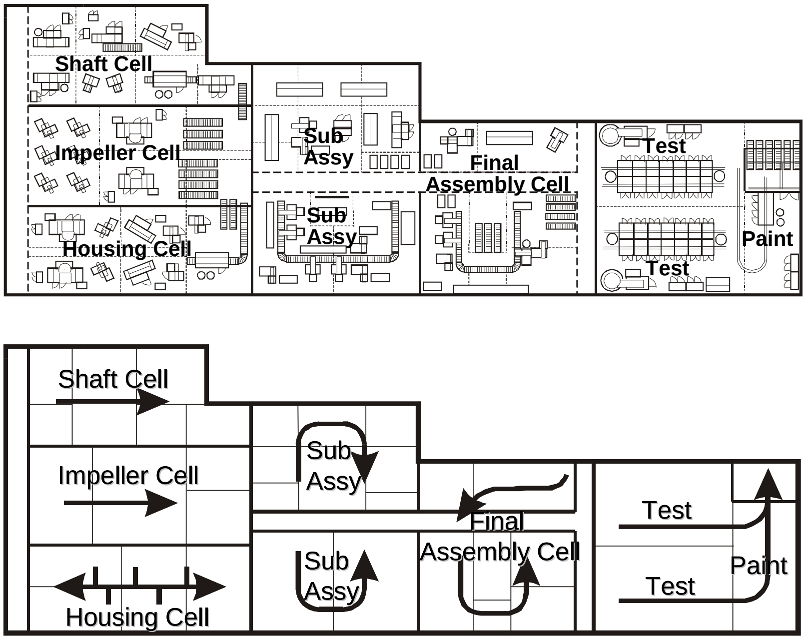


Figure 10-1. Avoid unnecessary details when selecting overall (block) layouts in Phase II. Excessive detail distracts, obscures and confuses. It also invites premature evaluation of equipment arrangements.

Investment in clear presentation typically depends upon several factors:

1. *The evaluators and approvers and their expectations* – typically the higher in the organization, the higher the expectations; unless the approvers are hands-on owners or managers, in which case they may not want the time or expense of elaborate presentations.
2. *Their familiarity with the facility and the alternatives* – shop people may need little help in understanding the plans, especially if they have been involved in the planning. Others not based in the facility may need help.
3. *Stage of the decision* – screening alternatives to get the best two is usually accomplished with whatever the layout team(s) prepared. This could be little more than paper templates taped to a site drawing. At the other extreme, a major capital request at corporate headquarters will require some re-drawing and dressing up in order to sell the plan.
4. *Availability of resources* – electronic drawings, renderings, displaying and plotting – perhaps even graphic animation – require technical support: proficiency plus software, projecting and plotting capabilities.
5. *Time pressures and decision date* – the fancier the presentation, the more time needed to prepare it – perhaps more than the planning itself. For quick selection, make do with simple yet clear presentation.

Examples of Phase II overall layout presentation appear in Figures 10-2, 10-3 and 10-4. Computer graphic renderings and animations are not shown but may be useful at times.

Experience has shown that each plan should be clearly labeled. We prefer to use letters as identification, to avoid any unintentional implication of preference which numbers tend to give. Additionally, a title or brief description of each plan, small enough to be written on the plan and on the evaluation sheet, helps eliminate any mix-ups and reduces reference conversation both during and following the evaluation.

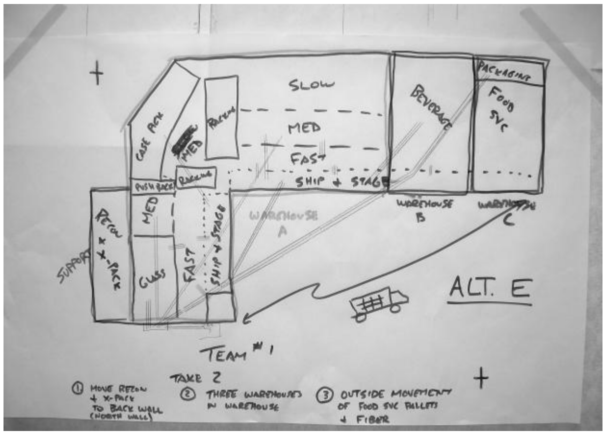


Figure 10-2. Marker-pen drawing on flip-chart paper. One of five alternatives for 80,000 square meters of food and beverage distribution. Even roughly-drawn sketches such as this may be sufficiently clear for evaluation and selection when the planners are also the raters and decision-makers. When such sketches are drawn to a scale on gridded flip chart paper, they can be reasonably precise.

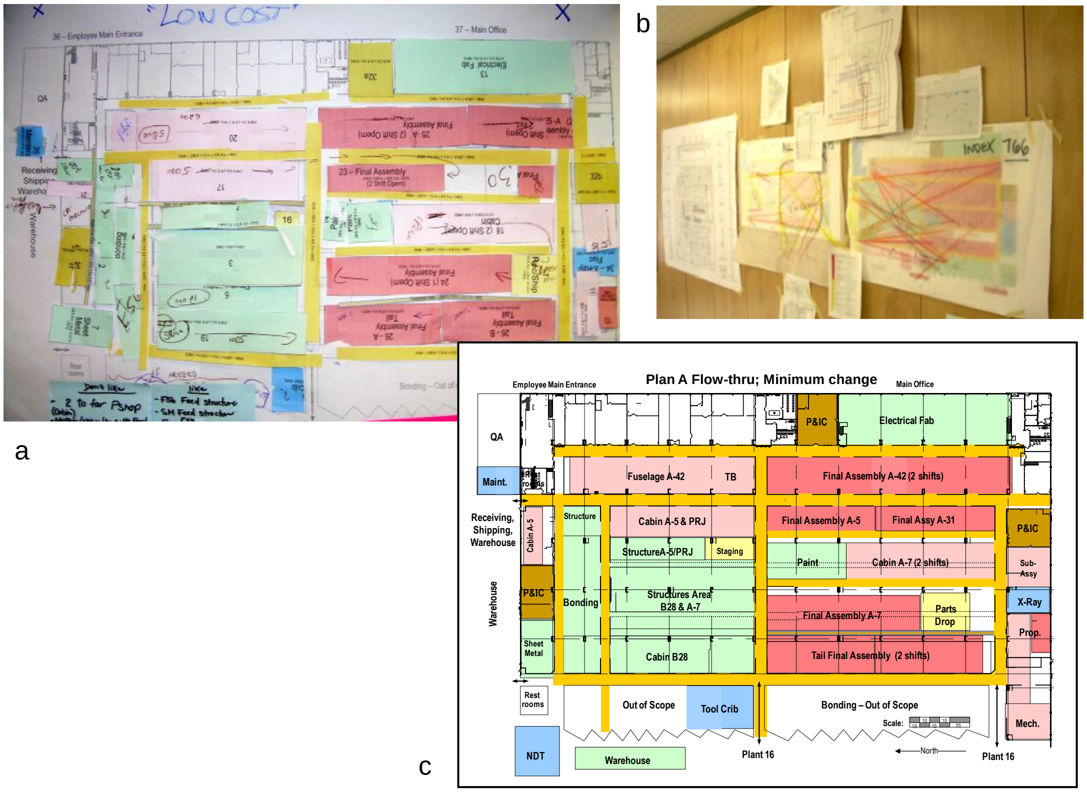


Figure 10-3. When the planning team is familiar enough with the alternatives, selection can be made from evaluation of paper-template layouts (a), without waiting to dress them up. Supporting charts and diagrams from SLP should be posted nearby for ready reference (b). For presentations to management and others not directly involved, each layout should be clarified in an electronic drawing (c).

Also, be careful to make each layout exactly as it is intended to be. Prepare replicas of the actual layout to be evaluated. Evaluate the *actual* plan, not what could be done with a few changes. To evaluate plans other than those actually before us, is to reduce the accuracy of the evaluation. The time involved becomes significantly longer.

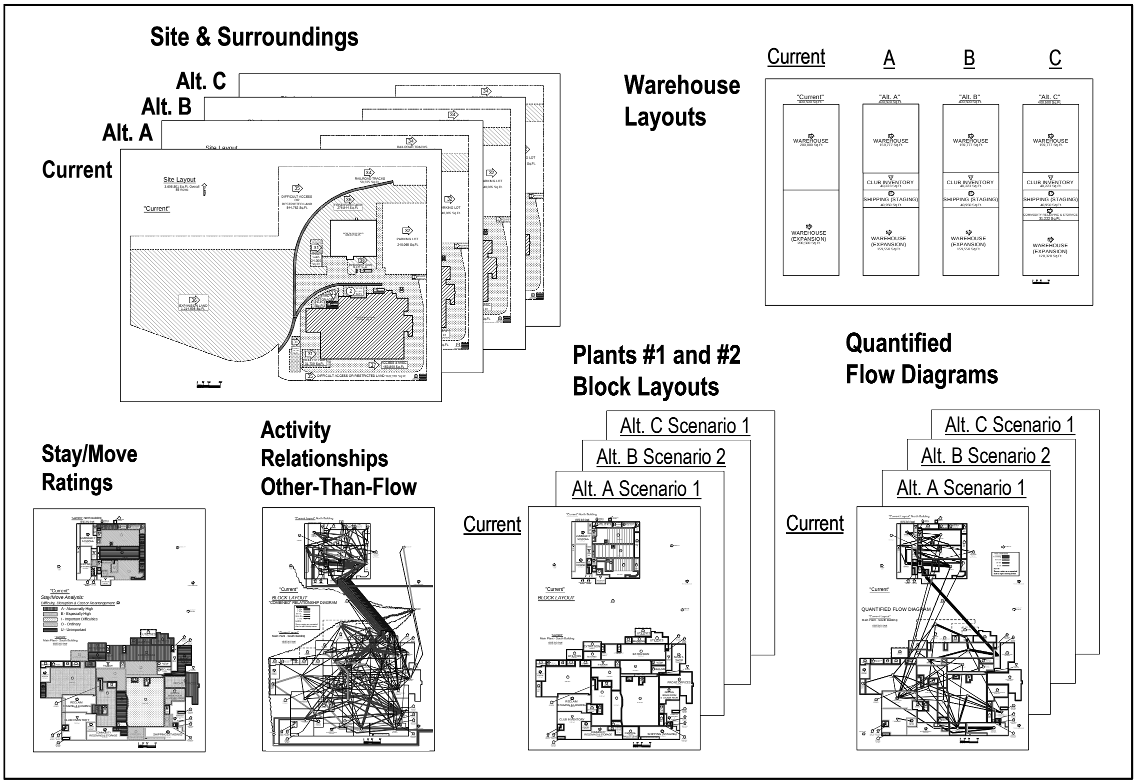


Figure 10-4. Set of electronic drawings for a major plant expansion and overall layout selection. Clear presentation was essential since the evaluators did not develop the plans. The top manager was from a distant location and not familiar with the specifics of the layout. Preparing and checking such drawings, and incorporating them into a presentation with other SLP documents can take several days.

This is not to say that changes in the plans cannot be made. Actually, the very process of evaluating layouts frequently brings new ideas to light. As a result, the end product is often a new combination of two alternatives or a further modification of one of the alternatives. But the point here is that if and when there are changes, the layout should be redrawn or the replica prepared anew so the new layout plan can be evaluated. In other words, always have before you as you make the selection, the true replica of each layout being evaluated.

In this connection, and for convenient reference, it is well for the planner to clean up and organize his work sheets and diagrams. Clearly understood documentation of relationships and space provide others with a quick appreciation of what has been planned. Consider plotting these documents at a large size and hanging them on the wall for reference and as a storyboard of the planning work to this point.

Probably the best results are gained when the choice is between alternative plans, each of them sound, but each significantly different. Plans which are all essentially the same offer little choice or possibility for further improvement.

Advantages versus Disadvantages

Probably the easiest of the three evaluation methods mentioned is that of listing *advantages* and *disadvantages* – the pro's and con's system. It is also the least accurate. Therefore, it is used more for preliminary screening of rough alternatives, or in Phases I and II where data is not so specific and not so readily available. See Figure 10-5.

Alternative C **Building Expansion**
Add One Furnace

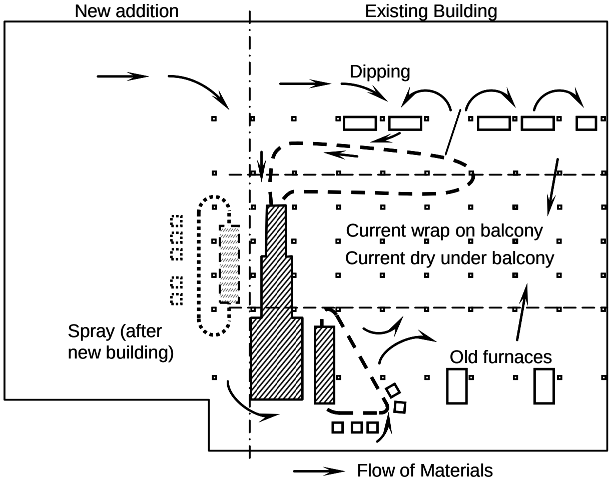
Alternative B **Building Expansion**
Add Two Furnaces
(2 Shift Operation)

Step

Adva

Disac

Alternative A **Building Expansion**
Add One Furnace
(2 Shift Dipping and Burning)



Installation Sequence

Step 1. Tear out one section of balcony wall and floor
2. Tear out furnace no. 4 and build continuous furnace
3. Move one set of dryers (3)
4. Begin 2-shift operation and continuous furnace
* 5. Install spray dryer between old and continuous furnace
6. Rebuild old section of building
7. Move spray department to new building: extend chain and dipping area: and use under-balcony-area for wrapping

Advantages of this Layout:

1. Have opportunity to make use of new building in most effective way – including use of this furnace
2. Economy in burning tools and chain (short length)
3. No blocking of changes or dipping expansion in future
4. Could reconvert to one shift easily if forced to
5. Have ample room for storage of sprayed items before burning in case you cannot burn them with catalogue-ware
6. A minimum of cross-traffic

Disadvantages:

1. Must tear out 1 section of balcony (Est. $10,000)
2. Must tear out furnace no. 4
3. Must relocate spray department after new building is complete (Est. $25,000)
4. Must move one section of vertical dryers (Est. $12,500)

* Layout shown – step 5

Figure 10-5. Evaluating alternative layouts by listing advantages and disadvantages is a simple and often very effective way of selecting the best of several plans – especially in rough or early screening stages of evaluating

The pro's-and-con's system is merely listing in columns or on adjacent sheets all the advantages of each alternative. Below them are listed the disadvantages. This simple comparison is surprisingly effective and certainly not a time-consuming procedure.

The same method of weighing pro's and con's can be made more accurate by rating the significance of each advantage and seriousness of each disadvantage, as shown in Figure 10-6. The same vowel-letter rating used throughout the SLP procedures now is given a numerical value scale, as explained in Figure 10-7.

ADVANTAGES					
Plan A – Receive at Rear: Flow up and through.			Plan B – Receive at Side; Figure-eight flow.		
1.	Can use basement for raw material storage.	A-	1.	Tool and Die Shop near Engineering Office	E
2.	Can receive by rail	I	2.	Majority of workers near parking lot	I-
3.	Can use present Shop Office without disruption.	O	3.	Expansion for new process will be	I

Figure 10-6. A rating scale can be used in conjunction with the list of advantages and disadvantages to give a value to each one. Here the simple SLP vowel-letter rating was used. Disadvantages are rated with a negative vowel and converted into a negative value. Note that A– (“A minus”) and I– are ratings of half a degree less than A and I respectively.

RATING CODE AND VALUES		
Vowel Coding	Description of Rate	Numerical Value
A	Almost Perfect -- (Excellent)	4
E	Especially Good -- (Very Good)	3
I	Important Results Obtained -- (Good)	2
O	Ordinary Results Provided -- (Fair)	1
U	Unimportant Results -- (Poor)	0
X	Not Acceptable -- (Not Satisfactory)	?

Figure 10-7. The simple vowel-letter coding used throughout the SLP procedure is used as above for assigning values to ratings. "A" is still equivalent to four – just as it was in the number-of-lines scale when we diagramed relationships. This gives a 25% spread between letters, or 12½% when minus ratings (or half degrees) are used. Although letters are readily converted to numbers, evaluating in letters is preferred because of the unintentional implied accuracy of numerical ratings and because it is too easy, and tempting, to add up numbers before the rating is done and thus see how the various plans are coming out.

Weighted Factor Analysis

Every layout plan has intangible costs which for several practical reasons cannot be measured in terms of dollars and cents. Moreover, a comparative cost analysis of alternatives sometimes doesn't aid in the decision-making, no one plan having a clear-cut financial advantage over the other. As a result, perhaps the most effective general method of evaluating layout alternatives is that termed *factor analysis.*

The factor analysis method follows the engineering concept of breaking down the problem into its elements and analyzing each one. This makes it more objective. Essentially, the procedure is as follows:

1. List all of the factors which are considered important or significant to deciding which layout to select.
2. Weigh the relative importance of each of these factors to each other.
3. Rate the alternative plans against one factor at a time.
4. Extend the weighted, rated values, and compare the total value of the various plans.

The procedure is set forth in Figures 10-8 and 10-9. An example of it is shown in Figure 10-10. The factor analysis method is highly flexible, yet it is precise, even though its accuracy is based on a series of judgments or estimates of probability.

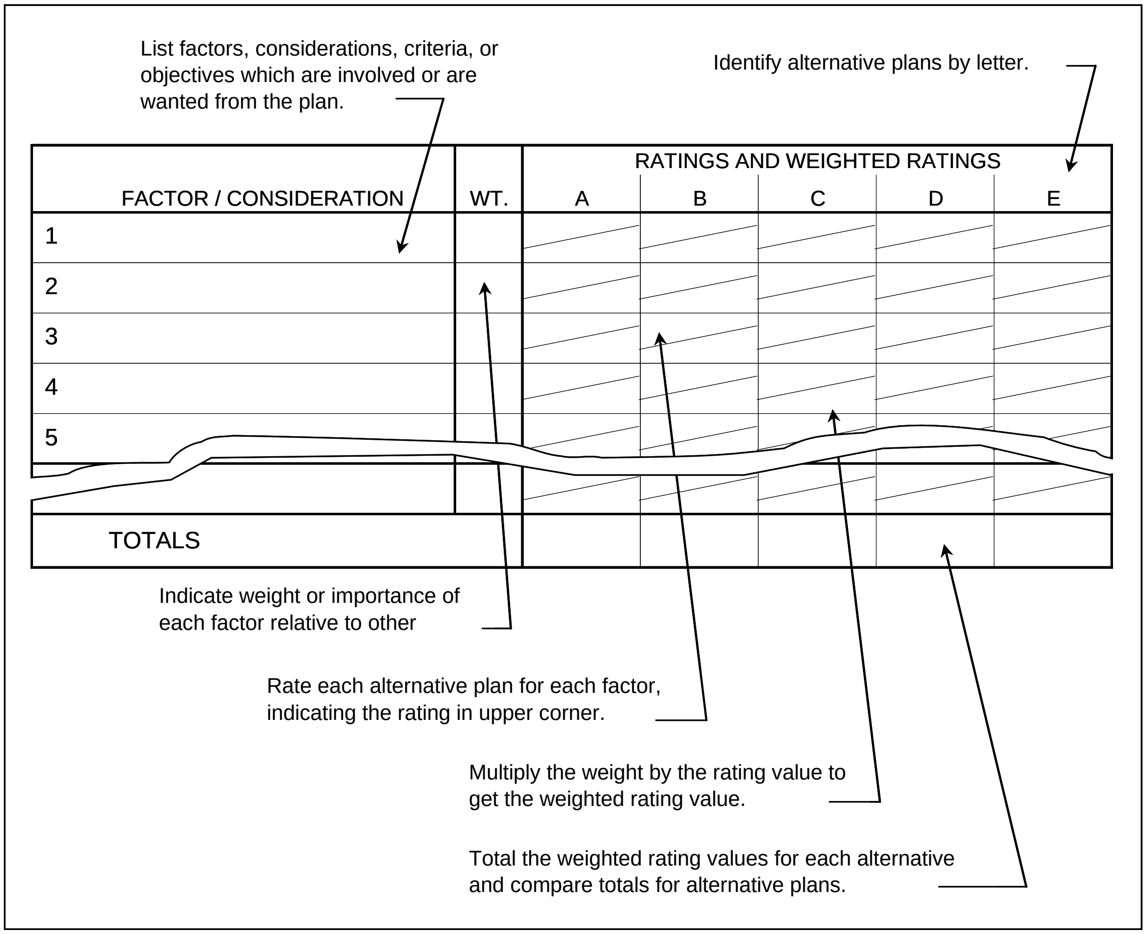
The overall objectives of the layout planning are broken down into so-called factors or considerations – the things that are important for the layout to achieve. Ideally, these and perhaps their relative importance will have been stated at the outset of the planning and used to guide the development of alternatives. But if not, the point is to establish objectives or criteria and assign a weight to each.

This is most expediently done by one or two people in the form of a list with definitions of what is meant by each factor. The list and any tentative weights should then be reviewed with those who will ultimately approve the selected plan. This may be the planners themselves, but more often it will be a manager higher in the organization. Even if a list of objectives was prepared earlier on, it should now be scrutinized, modified as necessary, and increased by any factors overlooked.

In listing the factors, be certain they are clearly defined, easily clearly understood. Fuzziness or duplication can be as serious as omissions. To list "flow of materials," "progressive routing," "smooth feed-in of materials" all as separate factors only causes confusion.

Often “safety” must appear as a factor and carry the highest weight, even if no unsafe layout will be accepted and all will receive high ratings. Recognize that the presence of highly weighted and commonly rated factors reduces the differentiation of the method.

Avoid lengthy factor lists. Typically, the best layout can easily be identified with 10 factors or less. If the ratings are to be made by a team or committee, they will tire after more than 10 factors, especially when rating more than three or four alternatives. Minor factors can be held in reserve as potential tie-breakers.



List factors, considerations, criteria, or objectives which are involved or are wanted from the plan.

Identify alternative plans by letter.

Indicate weight or importance of each factor relative to other

Rate each alternative plan for each factor, indicating the rating in upper corner.

Multiply the weight by the rating value to get the weighted rating value.

Total the weighted rating values for each alternative and compare totals for alternative plans.

Figure 10-8. Mechanics of factor analysis method of evaluation. SLP recommends a range of 1 to 10 for weights and the vowel-letter code with its equivalent values for the ratings.

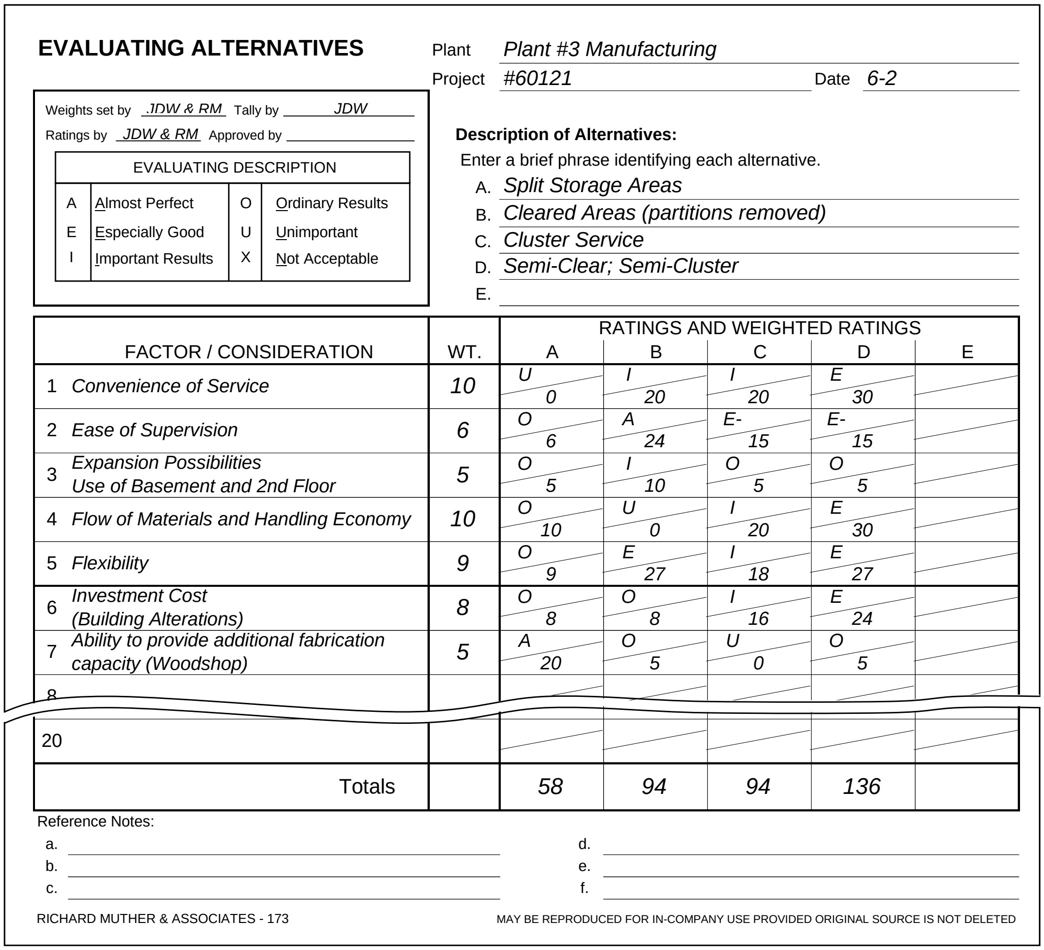
A list of the factors or considerations most commonly involved follows – not in the order of importance. (See Appendix XII for explanations of these factors.)

1. Ease of future expansion
2. Adaptability and versatility
3. Flexibility of layout
4. Flow of materials effectiveness
5. Materials handling effectiveness
6. Storage effectiveness
7. Space utilization
8. Effectiveness of supporting-service integration
9. Safety and housekeeping
10. Working conditions and employee satisfaction
11. Ease of supervision and control
12. Appearance, promotional value, public or community relations
13. Quality of product
14. Maintenance problems
15. Fit with company organization structure
16. Equipment utilization
17. Utilization of natural conditions or surroundings
18. Ability to meet capacity or requirements
19. Plant security and pilferage
20. Compatibility with long-range company plans

PROCEDURE FOR EVALUATING ALTERNATIVES BY FACTOR ANALYSIS

1. Identify the Plans to be Evaluated
    a. Select the layout plans that are to be evaluated.
    b. Have a visual plan or sketch of each layout in front of each rater, and clearly understood by all, during the evaluation process.
    c. Identify each visual plan by letter--A, B, C, etc. Also give it a brief three-to-five word description.
2. Establish the Factors or Considerations
    a. Establish what factors, considerations, criteria, or objectives are involved or are wanted from the layout.
    b. Define the factors so they are clearly understood. Avoid duplication between terms and confusion as to meaning.
3. Arrange a Rating Sheet
    a. List the factors or considerations vertically on lines of one sheet of paper or pre-printed form or use electronic spreadsheet.
    b. Array the identification letter for each alternative plan horizontally in columns across the same sheet.
    c. Leave room for adequate reference notes.
4. Determine the Relative Importance of Each Factor
    a. Determine a weight or importance value of each factor relative to the other factors.
    b. Record by whom the weight values were determined.
5. Rate Each Factor for Alternative Plans
    a. Establish a rating code or system.
    b. Rate each alternative on the extent to which it achieves or affords the ends represented by the factor in question – rating each layout exactly as it is planned.
    c. Rate all plans for one factor; then take next factor.
    d. Enter rating symbol above slant line on rating sheet.
    e. Record by whom the rating(s) was (were) made.
6. Calculate Weighted Values and Total
    a. Translate the rating symbols into numerical values and multiply the weight value by each rating number.
    b. Total the weighted rating values for each alternative plan by adding the respective columns.
    c. Record by whom the extension and tally were made.
    d. Take action as appropriate, based on totals.

Figure 10-9. Procedure for factor analysis method of evaluation.



EVALUATING ALTERNATIVES

Plant *Plant #3 Manufacturing*

Project *#60121* Date *6-2*

Weights set by *JDW & RM* Tally by *JDW*

Ratings by *JDW & RM* Approved by

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. *Split Storage Areas*

B. *Cleared Areas (partitions removed)*

C. *Cluster Service*

D. *Semi-Clear; Semi-Cluster*

E.

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS				
		A	B	C	D	E
1 *Convenience of Service*	*10*	*U* *0*	*I* *20*	*I* *20*	*E* *30*	
2 *Ease of Supervision*	*6*	*O* *6*	*A* *24*	*E-* *15*	*E-* *15*	
3 *Expansion Possibilities Use of Basement and 2nd Floor*	*5*	*O* *5*	*I* *10*	*O* *5*	*O* *5*	
4 *Flow of Materials and Handling Economy*	*10*	*O* *10*	*U* *0*	*I* *20*	*E* *30*	
5 *Flexibility*	*9*	*O* *9*	*E* *27*	*I* *18*	*E* *27*	
6 *Investment Cost (Building Alterations)*	*8*	*O* *8*	*O* *8*	*I* *16*	*E* *24*	
7 *Ability to provide additional fabrication capacity (Woodshop)*	*5*	*A* *20*	*O* *5*	*U* *0*	*O* *5*	
8						
20						
Totals		*58*	*94*	*94*	*136*	

Reference Notes:

a.

b.

c.

d.

e.

f.

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MAY BE REPRODUCED FOR IN-COMPANY USE PROVIDED ORIGINAL SOURCE IS NOT DELETED

Figure 10-10. Example of evaluating alternative layouts by the factor analysis method. Vowel-letter values are those shown in Figure 10-7. Here, one alternative stands out as best. More often, the decision is not so clear and further appraisal is necessary.

Establishing the *weight values* for each factor is usually a joint effort, often involving fairly important members of management. Perhaps the most effective way of setting weight values is to pick out that factor which is considered the most important and give it a value of 10. Then relate the weight of each of the other factors to 10. Get approval of these values before going ahead, especially from those who will approve the layout.

In rating each plan, use the SLP vowel-letter rating code, modified as in Figure 10-7. It is easy to remember, significant in definition, refinable (by adding a minus sign), and yet does not imply the accuracy of a number system.

Always *rate across* the form, considering each of the plans for one factor at a time, to maintain a constant interpretation of each factor for the various plans. This is important for it is easier to keep one factor in mind for several plans than the reverse, especially since there are usually more than five factors but seldom more than five plans.

Moreover, rating one plan at a time vertically tempts the planner to see how the results are beginning to shape up. And regardless of how objective one tries to be, there is always the tendency to preference one plan over another. By rating across and by using letters rather than numbers during the rating process, the planner helps himself and others avoid this temptation.

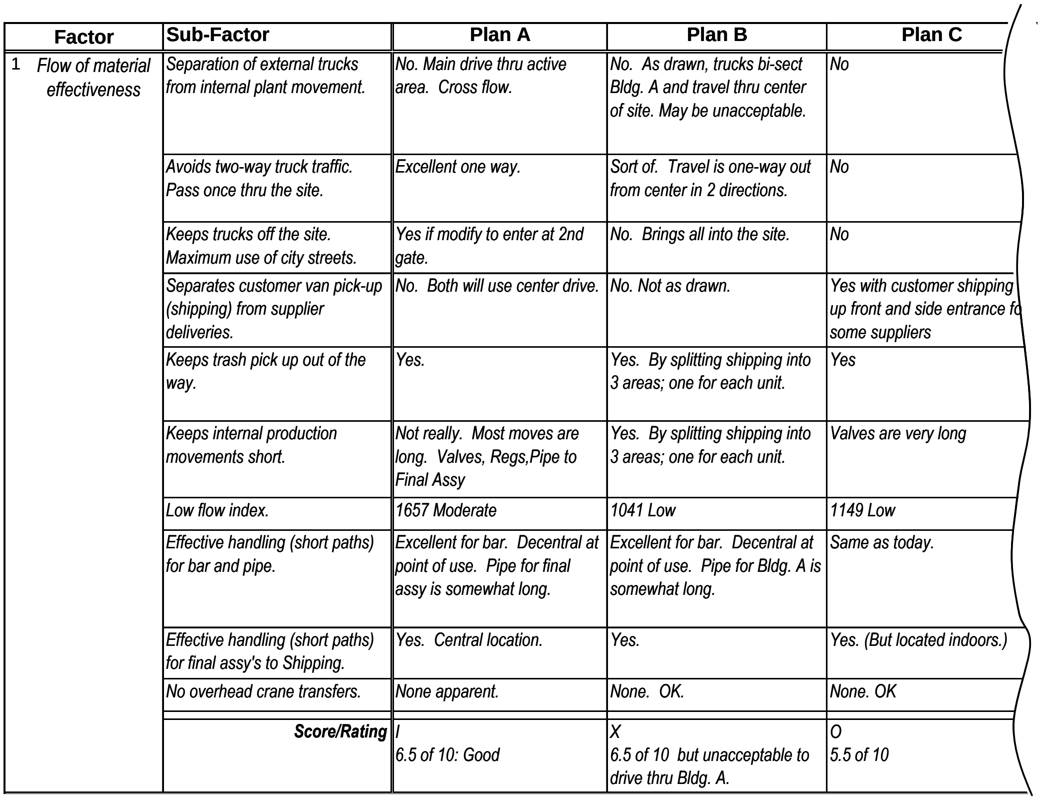
After rating all factors for all plans, convert the letter rating to a numerical value. Do this by multiplying the weight factor by the numerical value of the letter rating. After the numbers have been extended, the numerical values are totaled for each plan. Ordinarily the result is one of the following:

1. One plan clearly stands out head and shoulders above the others and can be accepted as the best logical compromise. (Twenty percent higher value total than its closest competitor generally signifies a winner.)
2. Two plans come out very close. In this case, reevaluation of the two plans, involving more factors, closer scrutiny of the weighting and rating, or inviting more people to share in the weighting and rating process should be undertaken.
3. The planner (and/or other "evaluators") will see possible improvements in one or more of the alternatives. For example, the planner may see where the two or three best alternatives rated lowest. The U's and O's act as red flags. By concentrating on these particular weaknesses of the respective plans, each layout may be further improved.
4. During the rating process, it is discovered that a combination of two or more of the plans can be worked out. A replica of that combination layout must be made. By adding another column to the form (or another sheet), the planner rates the new combination plan on the same basis as the others.

Note that at the top of the evaluation form, provision is made for several important records. Not only should the plan be at hand during the evaluation, but a brief description of each alternative plan should be provided. Additionally, those who establish the weighting should be listed; those who do the rating should be listed; and the person who actually enters the figures, makes the extensions, and totals the columns should be recorded in the "tally by" space, even if just entering into an electronic spreadsheet.

The rating itself can be done by the layout planner alone, or it can be done *in conjunction with others*. When the people most interested are asked to participate in the evaluating, several advantages are gained. If general agreement is reached by those participating, the layout has, in essence, sold itself; there is no problem of going back and convincing or trying to convince these people as to the advantages and disadvantages of one layout over another. Participation helps focus the minds of several people on the layout, balancing their own personal preferences for any one plan. Participation at this stage, like participation at the stages of establishing relationships and determining space, brings in for consultation and discussion the people who have to make the layout work.

When the joint-participation method is used for evaluating alternatives, ratings can be done in two ways: (a) by individuals, then compared, or (b) by joint discussion. It is generally better to do the former. Comparisons of individual ratings usually show better than half of the ratings to be the same, and so discussion can be limited to only those areas where differences occur.



Factor	Sub-Factor	Plan A	Plan B	Plan C
1 *Flow of material effectiveness*	*Separation of external trucks from internal plant movement.*	*No. Main drive thru active area. Cross flow.*	*No. As drawn, trucks bi-sect Bldg. A and travel thru center of site. May be unacceptable.*	*No*
	Avoids two-way truck traffic. Pass once thru the site.	*Excellent one way.*	*Sort of. Travel is one-way out from center in 2 directions.*	*No*
	Keeps trucks off the site. Maximum use of city streets.	*Yes if modify to enter at 2nd gate.*	*No. Brings all into the site.*	*No*
	Separates customer van pick-up (shipping) from supplier deliveries.	*No. Both will use center drive.*	*No. Not as drawn.*	*Yes with customer shipping up front and side entrance fo some suppliers*
	Keeps trash pick up out of the way.	*Yes.*	*Yes. By splitting shipping into 3 areas; one for each unit.*	*Yes*
	Keeps internal production movements short.	*Not really. Most moves are long. Valves, Regs,Pipe to Final Assy*	*Yes. By splitting shipping into 3 areas; one for each unit.*	*Valves are very long*
	Low flow index.	*1657 Moderate*	*1041 Low*	*1149 Low*
	Effective handling (short paths) for bar and pipe.	*Excellent for bar. Decentral at point of use. Pipe for final assy is somewhat long.*	*Excellent for bar. Decentral at point of use. Pipe for Bldg. A is somewhat long.*	*Same as today.*
	Effective handling (short paths) for final assy's to Shipping.	*Yes. Central location.*	*Yes.*	*Yes. (But located indoors.)*
	No overhead crane transfers.	*None apparent.*	*None. OK.*	*None. OK*
	Score/Rating	*I* *6.5 of 10: Good*	*X* *6.5 of 10 but unacceptable to drive thru Bldg. A.*	*O* *5.5 of 10*

Figure 10-11. Sub-factors for flow of materials effectiveness. Tables like this one may be helpful when the evaluation factors are broadly defined and have several aspects. In this project, "Flow of material effectiveness" related to several types of movement on a large site. It was broken out into 10 sub-factors and the overall rating for each alternative was based on a count of its positive sub-factor ratings.

If several people are interpreting the factors in different ways, the planner can set up tables of sub-factors like that shown in Figure 10-11. This allows general factors to be made situation-specific and insures that all aspects of a factor receive attention by each rater. This approach doubles or triples the rating time, but can lead to a clearer decision and greater consensus on which plan is best and why.

Factor analysis makes a systematic evaluation out of many otherwise subjective views, and it is, therefore, particularly adaptable where investment costs or savings between plans are not accurately measurable or significant. The procedure is especially suitable, too, for projects where the degree of opinion is high in relation to measurable economic considerations. The procedure is especially appropriate for general overall layouts, service areas, and offices – less so for detailed layouts of production machinery where more tangible or specific factors may prevail. Relative or estimated costs and savings can be added to the sheet and rated. But it is usually better to keep these economic factors separate. In this way, the factor analysis indicates the intangible benefits of each plan while the economic analysis determines if these benefits are worth their cost.

The planner should not overlook the genuine psychological benefits of this technique. It affords a convenient, organized way to involve both those who must make the layout work (in the rating) and those who must approve the expenditure of funds (in setting the factors and/or the weight values). Most important, it provides a way for the planner to get his or her relative sense of values coordinated with the thinking of management and operating people before recommending a specific plan.

Flow Index, Transport Work and Material Handling Cost

In manufacturing and distribution center layouts, flow of materials is typically the most important selection factor after initial investment. As suggested in Figure 10-11, "flow of materials" may have several specific meanings or aspects. Some such as potential congestion, or degree of traffic separation, or avoidance of certain kinds of move are largely subjective and should be rated during factor analysis.

But the travel distances of flow routes can be measured. If a flow analysis and from-to chart were prepared in Section 2 of SLP, the two-way flow intensity on each route can now be applied to its distance in each alternative layout. In this way, the route and total material flows can be computed for each layout and compared with numerical values. These comparisons can take three forms:

1. Flow Index
2. Transport Work
3. Estimate of actual material handling cost

For a quick but crude *flow index* of material handling effort, draw your earlier *flow relationships* (A, E, I, O) onto the layout using the SLP number-of-lines convention – 4, 3, 2, 1. Draw the lines center-to-center or edge-to-edge for each activity pair, but be consistent for all. Now measure the distance (length) of each flow relationship line (actual as drawn, or converted to scale units) and multiply it by the number of lines. See Figure 10-12. Add the results for all flow relationships to get a total for the layout.

Transport work is a more precise and meaningful computation. Transport work is defined as Intensity times Distance and is typically a good indicator of *relative* material handling cost – without the time and effort needed to estimate *actual* handling cost. Draw the same flow lines as above and measure their distances *at scale*. Multiply the distance between each activity pair by the two-way flow between the pair, as given on the From-To Chart. Then sum for all pairs, which is to say for all flow routes. See Figure 10-13.

Even more refinement is achieved by measuring the lengths of the expected travel paths. But each refinement takes more time and may not add insight. Remember, you are trying to compare relative flows among the alternative plans in order to select the best. This typically does not require precise estimates of actual travel. What you are trying to see is which layout minimizes the total area enclosed under the flow lines, which is to say the sum of widths times lengths, where width can be in number of lines or units of flow intensity.

To estimate actual material handling cost, first convert flow intensities to trips or moves with the planned handling method (system, equipment and transport unit). Establish the terminal (pick-up and set-down) and the travel cost for each type of equipment. For each move and/or route, determine its travel path and distance. Apply the costs to the moves and their distances and total for each layout. This is the most precise way to compare the material flow aspects of alternative layout plans. However, this method requires definition of the move system (direct, indirect) and estimates of terminal and travel cost for each type of equipment. If costs are not already available, this exercise will quickly turn into a research project that may delay the layout planning. This approach is made easier and more practical with specialized software like that shown in Figure 10-14.

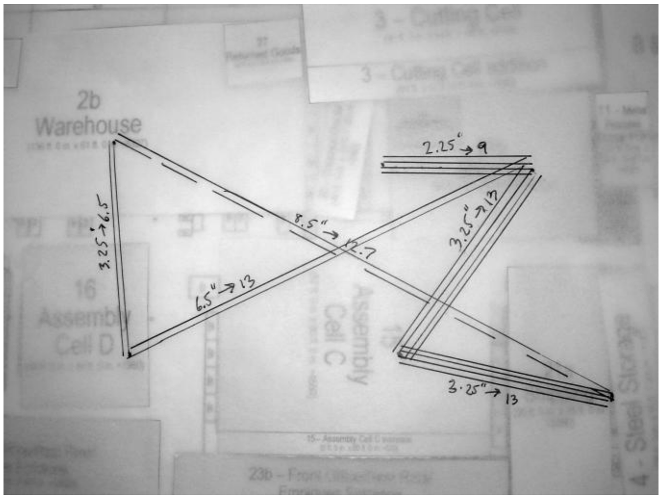
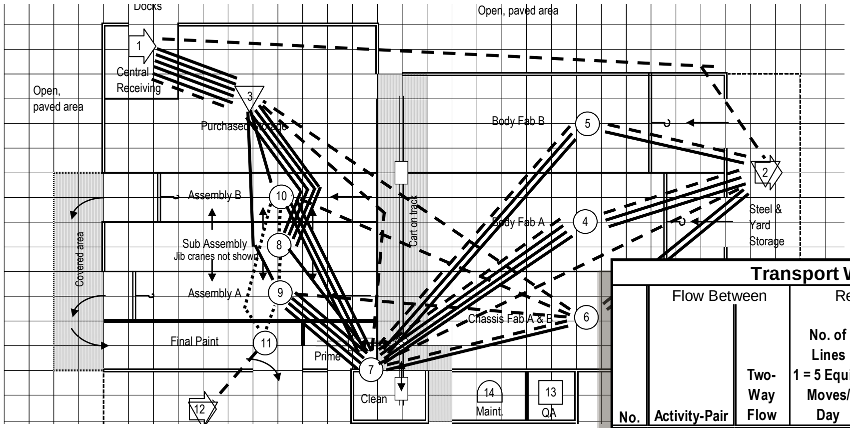


Figure 10-12. The fastest way to compare material handling effort is to draw and measure the length of flow lines – from pick-up point to set down – on an overlay of the layout or template arrangement. Here, the templates can faintly be seen through the glare on the tracing paper. Lengths in inches are multiplied by the number of flow lines, with a dotted line worth 0.5. The resulting *flow index* for the 8.5" line is 12.7. The total flow index for all routes shown is 67.2 and can be compared to other alternatives.



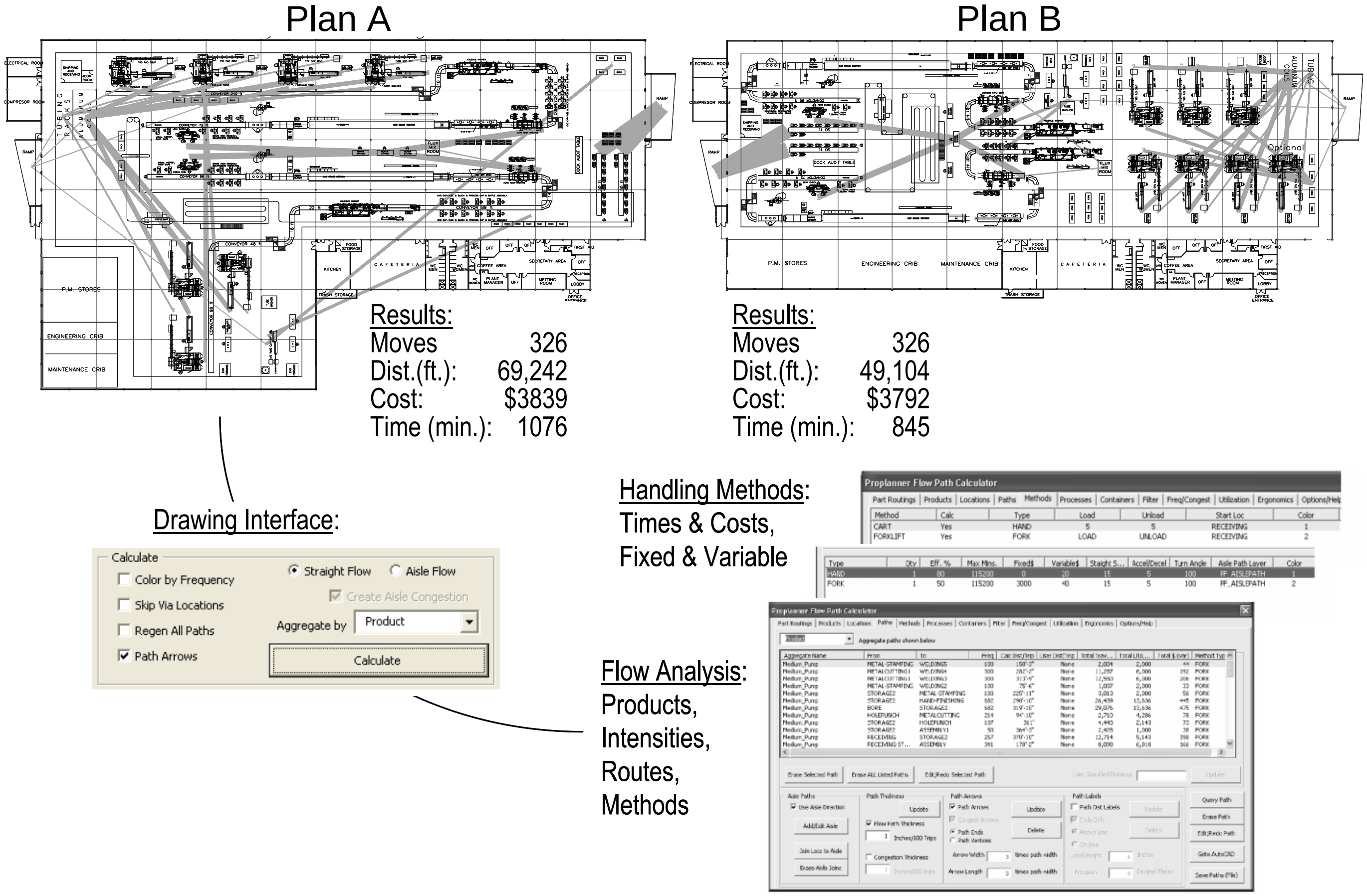
Transport Work Calculation

No.	Flow Between Activity-Pair		Two-Way Flow	Represenation No. of Lines 1 = 5 Equiv. Moves/ Day	Vowel Rating	SLP # of lines convention	Distance in Meters Center to Center Straight Line	Transport Work: Two-Way Flow Intensity x Distance
1	1	3	31.5	6	A	4	20	620
2	3	8	21.6	4	E	3	24	510
3	7	9	21.6	4	E	3	20	425
4	4	7	18.0	3.5	E	3	47	850
5	7	10	14.4	3	I	2	35	510
6	2	4	12.0	2.5	I	2	31	378
7	5	7	12.0	2.5	I	2	63	756
8	2	6	10.0	2	I	2	39	394
9	2	5	8.0	1.5	I	2	31	252
10	6	7	6.0	1.5	I	2	39	236
11	3	9	4.5	1	O	1	35	159
12	3	10	4.5	1	O	1	16	71
13	3	6	3.0	0.5	O	1	79	236
14	11	12	2.5	0.5	O	1	16	39
15	8	9	2.2	0.5	O	1	4	9
16	3	7	2.1	0.5	O	1	63	132
17	6	9	2.1	0.5	O	1	55	116
18	1	2	2.0	0.5	O	1	134	268
19	2	7	2.0	0.5	O	1	87	173
20	8	10	1.4	0.5	O	1	4	6
21	6	10	1.4	0.5	O	1	63	88
22	9	11	1.0	0.5	O	1	4	4
23	7	8	0.9	0.5	O	1	24	21
24	10	11	0.7	0.5	O	1	24	16
25							Total T.W.	6270

Figure 10-13. Transport Work calculation for a plant layout. This example uses straight-line distance center to center as scaled directly on the drawing. Rectilinear distance would be more precise and easily obtained by counting the grid lines which are 5 meters apart. Or, actual paths could be traced.

Flow intensity on each route was established by flow analysis in Figure 4-20. Since the base unit is a truck body, Transport Work is actually equivalent truck-body-meters per day, or equivalent move-meters per day.

One solid line represents 5 equivalent moves; with a dashed line (0.5 lines) used for rounding-off. The same worksheet could calculate a less precise "flow index" using the number of flow lines drawn instead of two-way flow. The SLP number-of-lines convention could also be used but would be even less precise.



Calculate

- ☐ Color by Frequency
- ☐ Skip Via Locations
- ☐ Regen All Paths
- ☑ Path Arrows
- ● Straight Flow ○ Aisle Flow
- ☑ Create Aisle Congestion
- Aggregate by: Product

Method	Calc	Type	Load	Unload	Start Loc	Color
CART	Yes	HAND	5	5	RECEIVING	1
FORKLIFT	Yes	FORK	LOAD	UNLOAD	RECEIVING	2

Type	Qty	Eff. %	Max Mins.	Fixed$	Variable$	Staight S...	Accel/Decel	Turn Angle	Aisle Path Layer	Color
HAND	1	80	115200	0	20	15	5	100	FF_AISLEPATH	1
FORK	1	50	115200	3000	40	15	5	100	FF_AISLEPATH	2

Product — Aggregate paths shown below

Aggregate Name	From	To	Freq	Calc Dist/Trip	User Dist/Trip	Total Trav...	Total L/U...	Total $ (var)	Method Typ
Medium_Pump	METAL-STAMPING	WELDING5	100	150'-3"	None	2,004	2,000	44	FORK
Medium_Pump	METALCUTTING1	WELDING4	300	282'-2"	None	11,287	6,000	192	FORK
Medium_Pump	METALCUTTING1	WELDING3	300	313'-9"	None	12,550	6,000	206	FORK
Medium_Pump	METAL-STAMPING	WELDING2	100	75'-6"	None	1,007	2,000	33	FORK
Medium_Pump	STORAGE2	METAL-STAMPING	100	225'-11"	None	3,013	2,000	56	FORK
Medium_Pump	STORAGE2	HAND-FINISHING	682	290'-10"	None	26,439	13,636	445	FORK
Medium_Pump	BORE	STORAGE2	682	319'-10"	None	29,076	13,636	475	FORK
Medium_Pump	HOLEPUNCH	METALCUTTING	214	94'-10"	None	2,710	4,286	78	FORK
Medium_Pump	STORAGE2	HOLEPUNCH	107	311'	None	4,443	2,143	73	FORK
Medium_Pump	STORAGE2	ASSEMBLY1	50	364'-3"	None	2,428	1,000	38	FORK
Medium_Pump	RECEIVING	STORAGE2	257	370'-10"	None	12,714	5,143	198	FORK
Medium_Pump	RECEIVING-ST...	ASSEMBLY	341	178'-2"	None	8,090	6,818	166	FORK

Aisle Paths
- ☑ Use Aisle Direction
- Add/Edit Aisle
- Join Locs to Aisle
- Erase Aisle Joins

Path Thickness
- ☑ Flow Path Thickness
- 1 Inches/100 Trips
- ☐ Congestion Thickness

Path Arrows
- ☑ Path Arrows
- ☑ Congest Arrows
- ● Path Ends
- ○ Path Vertices
- Arrow Width 3 times path width
- Arrow Length 3 times path width

Path Labels
- ☐ Path Dist Labels
- ☑ Ends Only
- ● Above line
- ○ On line

Figure 10-14. The Flow Planner software from Proplanner^{TM} is a useful tool for diagramming and costing material flow when the layout is drawn in AutoCAD. The planner inputs product-material routings, their movements and planned handling methods. Standard terminal and travel times and their costs are established for each method, as well as its fixed cost of ownership. Distances are extracted from the AutoCAD drawing and applied to movements and their methods. In this way, Flow Planner calculates total distance; fixed, variable and total handling cost, and total material handling time. These are then used to compare alternative plans.

The illustration above is instructive in several ways. Note that Plan B's total distance is about 30% less than Plan A while its handling time is only 20% less. As a rule, this happens because the number of moves and their terminal handling times are independent of distance and overall layout.

Note that the handling costs are virtually identical. Their 2% difference ($3792 vs. $3839) is within the error of the flow estimates. This is typically because terminal costs are a significant element of total cost and do not change. And also because for each unit of a method that is required – say a truck or crane – its fixed cost remains, even though its travel time and costs are reduced by better layout. Note also that Plan B uses somewhat less space than Plan A. This difference may be worth more than the very minor savings in estimated handling cost.

Finally, note that the flow paths and costs are measured between individual machines rather than between activity-areas. This additional precision takes time to establish but is generally not needed to see which overall plan is best. In Phase II layout, the planner will be faster by using blocks of space for the activity-areas. Then use the grouping and aggregation features of AutoCAD and Flow Planner to "roll up" the costs and statistics to the level of activity-areas. (Illustration courtesy of Proplanner^{TM} www.Proplanner.com)

Cost Comparison

The method of evaluating layouts which has the most substance is some form of cost comparison or financial analysis. In most cases, if cost analysis is not the chief basis for decision, it is used to supplement other evaluation methods.

There are two entirely different reasons for making a cost analysis, although the data used in both cases may be identical. In the first case, the purpose will be to *justify* a particular project – to find out whether it is economically feasible. In the second case, the problem is to *compare* alternative proposals with each other, and/or to an existing operation, assuming each to be adequately justified. The layout planner is usually concerned with the second case, though frequently with the justification as well.

Effective cost comparisons can often be made with far less detail than needed for justification and capital appropriation – since we only need to differentiate their *relative* costs. Therefore, simple comparisons often precede justification, narrowing the alternatives to a manageable few for detailed analysis.

There are basically two approaches to preparing a cost analysis. Either consider the *total costs* involved or consider *only those costs that will be affected by the project* under consideration. If alternative proposals for an entirely new layout are being compared, total costs must be used. With a relayout, it is often simpler, and just as effective, to deal only with the changes in costs reflected in the various proposals under consideration.

The size of the project also must be considered in deciding what kind of comparison to make. If the project is extensive and complex, it should be evaluated for its effect on the total operation of the company. A relatively small relayout project, on the other hand, can be evaluated and alternatives compared simply by calculating the change in contribution to profit.

Before making any computations, the layout planner should be thoroughly familiar with the accounting and financial policies of the company. There is usually competition for available funds among different areas of the company, and proposals must be subject to a rule of measure common to all. Additionally, it is most important that the layout planner know what decision management is planning to make on the basis of the data furnished to them. Company policy on treatment of depreciation, tax considerations, cost distribution procedures, and the assignment of costs to specific accounts are areas for potential error unless clearly understood.

There are also several methods of figuring the practicality of an investment in a new layout. Return on investment, return on capital employed, and payout period are all methods that can be used, and there is no uniform agreement as to which is best. Our rule is to *use that method which your own financial officer recommends or will accept.*

Before starting to collect data for an analysis, the layout planner, or analyst, must recognize that there are two forms of expenditures: *capital expenditures* and *operating expenses*. Improper or inconsistent classification of these expenditures can lead to serious errors. Questions of proper classification should be resolved with the accountants before the analysis is begun.

With these considerations in mind, the planner needs a systematic way of classifying cost elements and accumulating cost figures in such a manner that any of the methods of analysis can be used to measure the performance expected. We recommend the following procedure:

1. Prepare a work sheet(s) that picks up *investment* requirements for each alternative.
2. Prepare a work sheet that establishes *operating* cost estimates.
3. Make *calculations* to compare or justify expenditures for alternative plans.

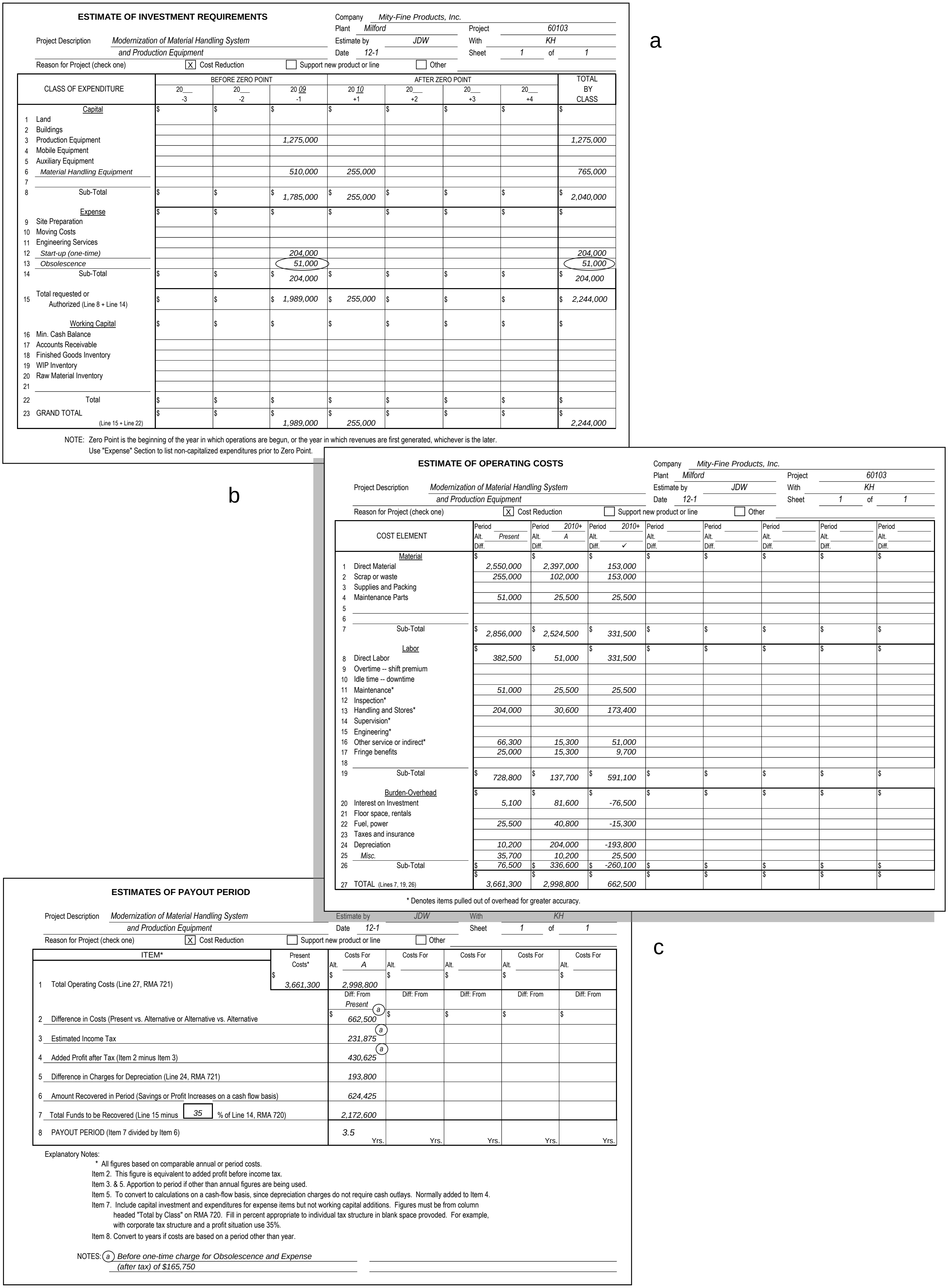
Figure 10-15a, the Estimate of Investment Requirements, is a form that provides adequate space for recording the various kinds of investment expenditures, and relates those expenditures to the period in which they occur. Most of the items or classes of expenditures necessary are listed down the left side of the sheet, with several blank spaces provided for special items. We have included space for the expense items that occur prior to the start of operations, because they are often overlooked. Remember that any items listed in this category are carried forward to an expense account and are not to be capitalized. However, some of the items listed as expense, such as site preparation and engineering services, may well be handled as capital expenditures depending upon the circumstances under which they occur.

A section of the form is provided for working capital – again because it is frequently omitted from calculations, where it belongs. The vertical columns are identified at the top by the year in which a given expenditure is to be made. The time value of money is important, and it is easy to forget that certain funds may be spent well in advance of the beginning of operations. For example, if $2,000,000 is paid for land three years before operations start rather than one year before, the difference in total cost at a simple interest rate of 6% per year for two years is $240,000. This kind of expenditure is easy to miss unless space for "before" expenditures is provided on the form being used.

Sometimes after operations begin, additional capital investments will be made. For example, a warehouse may be added to a plant some time after full production is reached. The form provides a reminder that such things are to be ferreted out and included. All entries on this form should be supported by appropriate engineering estimates or financial forecasts. One sheet of this form is generally prepared for each alternative plan.

The same general format is used on the worksheet for recording *operating cost* data. A sample worksheet, the Estimate of Operating Costs, is shown in Figure 10-15b. Again the cost elements are listed down the left side of the sheet. The vertical columns may be used for recording the cost amounts either by period or by alternative, or in combination. The form can therefore be used to compute differences between alternatives, total period costs, or combinations of both. All entries should be supported by detailed cost analysis sheets.

The breakdown of cost elements may seem unusually detailed, but it is deliberately so. It is far too easy to miss some of the less common elements; and this listing is helpful as a check to ensure that all applicable costs are included in the calculations.



a

ESTIMATE OF INVESTMENT REQUIREMENTS

Company *Mity-Fine Products, Inc.*
Plant *Milford* Project *60103*
Project Description *Modernization of Material Handling System and Production Equipment*
Estimate by *JDW* With *KH*
Date *12-1* Sheet *1* of *1*
Reason for Project (check one) ☒ Cost Reduction ☐ Support new product or line ☐ Other

	CLASS OF EXPENDITURE	BEFORE ZERO POINT			AFTER ZERO POINT				TOTAL BY CLASS
		20__ -3	20__ -2	20 *09* -1	20 *10* +1	20__ +2	20__ +3	20__ +4	
	Capital	$	$	$	$	$	$	$	$
1	Land								
2	Buildings								
3	Production Equipment			*1,275,000*					*1,275,000*
4	Mobile Equipment								
5	Auxiliary Equipment								
6	*Material Handling Equipment*			*510,000*	*255,000*				*765,000*
7									
8	Sub-Total	$	$	$ *1,785,000*	$ *255,000*	$	$	$	$ *2,040,000*
	Expense	$	$	$	$	$	$	$	$
9	Site Preparation								
10	Moving Costs								
11	Engineering Services								
12	*Start-up (one-time)*			*204,000*					*204,000*
13	*Obsolescence*			*51,000*					*51,000*
14	Sub-Total	$	$	$ *204,000*	$	$	$	$	$ *204,000*
15	Total requested or Authorized (Line 8 + Line 14)	$	$	$ *1,989,000*	$ *255,000*	$	$	$	$ *2,244,000*
	Working Capital	$	$	$	$	$	$	$	$
16	Min. Cash Balance								
17	Accounts Receivable								
18	Finished Goods Inventory								
19	WIP Inventory								
20	Raw Material Inventory								
21									
22	Total	$	$	$	$	$	$	$	$
23	GRAND TOTAL (Line 15 + Line 22)	$	$	$ *1,989,000*	*255,000*	$	$	$	$ *2,244,000*

NOTE: Zero Point is the beginning of the year in which operations are begun, or the year in which revenues are first generated, whichever is the later.
Use "Expense" Section to list non-capitalized expenditures prior to Zero Point.

b

ESTIMATE OF OPERATING COSTS

Company *Mity-Fine Products, Inc.*
Plant *Milford* Project *60103*
Project Description *Modernization of Material Handling System and Production Equipment*
Estimate by *JDW* With *KH*
Date *12-1* Sheet *1* of *1*
Reason for Project (check one) ☒ Cost Reduction ☐ Support new product or line ☐ Other

	COST ELEMENT	Period ___ Alt. *Present* Diff.	Period *2010+* Alt. *A* Diff.	Period *2010+* Alt. Diff. ✓	Period Alt. Diff.	Period Alt. Diff.	Period Alt. Diff.	Period Alt. Diff.	Period Alt. Diff.
	Material	$	$	$	$	$	$	$	$
1	Direct Material	*2,550,000*	*2,397,000*	*153,000*					
2	Scrap or waste	*255,000*	*102,000*	*153,000*					
3	Supplies and Packing								
4	Maintenance Parts	*51,000*	*25,500*	*25,500*					
5									
6									
7	Sub-Total	$ *2,856,000*	$ *2,524,500*	$ *331,500*	$	$	$	$	$
	Labor	$	$	$	$	$	$	$	$
8	Direct Labor	*382,500*	*51,000*	*331,500*					
9	Overtime -- shift premium								
10	Idle time -- downtime								
11	Maintenance*	*51,000*	*25,500*	*25,500*					
12	Inspection*								
13	Handling and Stores*	*204,000*	*30,600*	*173,400*					
14	Supervision*								
15	Engineering*								
16	Other service or indirect*	*66,300*	*15,300*	*51,000*					
17	Fringe benefits	*25,000*	*15,300*	*9,700*					
18									
19	Sub-Total	$ *728,800*	$ *137,700*	$ *591,100*	$	$	$	$	$
	Burden-Overhead	$	$	$	$	$	$	$	$
20	Interest on Investment	*5,100*	*81,600*	*-76,500*					
21	Floor space, rentals								
22	Fuel, power	*25,500*	*40,800*	*-15,300*					
23	Taxes and insurance								
24	Depreciation	*10,200*	*204,000*	*-193,800*					
25	*Misc.*	*35,700*	*10,200*	*25,500*					
26	Sub-Total	$ *76,500*	$ *336,600*	$ *-260,100*	$	$	$	$	$
27	TOTAL (Lines 7, 19, 26)	$ *3,661,300*	$ *2,998,800*	$ *662,500*	$	$	$	$	$

* Denotes items pulled out of overhead for greater accuracy.

c

ESTIMATES OF PAYOUT PERIOD

Project Description *Modernization of Material Handling System and Production Equipment*
Estimate by *JDW* With *KH*
Date *12-1* Sheet *1* of *1*
Reason for Project (check one) ☒ Cost Reduction ☐ Support new product or line ☐ Other

	ITEM*	Present Costs*	Costs For Alt. *A*	Costs For Alt.	Costs For Alt.	Costs For Alt.	Costs For Alt.
1	Total Operating Costs (Line 27, RMA 721)	$ *3,661,300*	$ *2,998,800*	$	$	$	$
			Diff: From *Present*	Diff: From	Diff: From	Diff: From	Diff: From
2	Difference in Costs (Present vs. Alternative or Alternative vs. Alternative		$ *662,500* ⓐ	$	$	$	$
3	Estimated Income Tax		*231,875* ⓐ				
4	Added Profit after Tax (Item 2 minus Item 3)		*430,625* ⓐ				
5	Difference in Charges for Depreciation (Line 24, RMA 721)		*193,800*				
6	Amount Recovered in Period (Savings or Profit Increases on a cash flow basis)		*624,425*				
7	Total Funds to be Recovered (Line 15 minus *35* % of Line 14, RMA 720)		*2,172,600*				
8	PAYOUT PERIOD (Item 7 divided by Item 6)		*3.5* Yrs.	Yrs.	Yrs.	Yrs.	Yrs.

Explanatory Notes:
* All figures based on comparable annual or period costs.
Item 2. This figure is equivalent to added profit before income tax.
Item 3. & 5. Apportion to period if other than annual figures are being used.
Item 5. To convert to calculations on a cash-flow basis, since depreciation charges do not require cash outlays. Normally added to Item 4.
Item 7. Include capital investment and expenditures for expense items but not working capital additions. Figures must be from column headed "Total by Class" on RMA 720. Fill in percent appropriate to individual tax structure in blank space provoded. For example, with corporate tax structure and a profit situation use 35%.
Item 8. Convert to years if costs are based on a period other than year.

NOTES: ⓐ *Before one-time charge for Obsolescence and Expense (after tax) of $165,750*

Both forms can be used on any project, regardless of complexity, by making entries only where appropriate.

Completing these two forms for a given project furnishes the data needed to calculate a solution. Now the planner must decide what kind of analysis to make of the data accumulated. Often, the analyst is restricted by company policy to a given method of evaluation; even so, familiarity with the theory and the inherent assumptions on which that method is based is recommended.

Space does not permit a detailed discussion of the various methods of analysis. A wealth of information is available in current literature on the subject, although all authorities do not agree on which is actually the best method to use.

Figure 10-15. Examples of cost comparisons. Figure "a" shows Estimate of Investment Requirements for the modernization of the material handling system and production equipment. This form provides space for classifying and listing the funds needed to get the project underway. In the example, a third of the material handling equipment will not be purchased until next year. The periods before and after zero point can be any increment of time that is convenient to use; whether we use calendar years, fiscal years, quarters, or months does not matter.

The expense columns can be used after the zero point, but only if they are expenses other than normal operating expenses and are incurred as part of getting the project fully underway. If there is a one-time charge for obsolescence, as there is in this example, it should be entered in the expense section, but the amount should be circled and not included in the totals.

Any entry in the Working Capital Section should show added working capital required to support this project. When comparing alternate proposals involving differences in investment, a separate sheet of this form should be used for each alternative proposal.

Figure "b' shows an Estimate of Operating Costs. Here comparative operating cost figures for both the existing method and a proposed method (Alternative A), and the differences between the two, have been entered. In the example shown, we have compared the average costs of the present method with the average costs of Alternative A, and have calculated the difference in the costs for each element and for the total amounts.

In the column of figures farthest to the right, the entry on Line 27 represents an average reduction in annual costs, or added profits before tax, of $662,500 that would be the result of making the expenditures listed in Figure "a".

Figure "c" shows an Estimate of Payout Period. This was used to compute the payout period using dollar amounts from Figures "a" and "b". Any working capital requirement is excluded from payout period calculations, for we assume that the entire amount of added working capital will be recovered when the installation is terminated or abandoned. We should remember that the total funds requested, the total capital investment to be authorized, and the total funds to be recovered during the payout period will frequently be different amounts. For convenience in computing the payout period, any one-time charge for obsolescence and/or start-up expense is ordinarily excluded from the cost figures, unless it is appreciably different for given alternatives.

We suggest use of the discounted-cash-flow method or internal rate-of-return method for justification studies and/or comparison between alternatives for the following cases:

1. A major relayout project
2. Any layout project that involves increments of investment in successive years
3. Any layout project that involves a number of assets with large differences in useful lives
4. Any layout project in which the pattern of revenues and/or costs varies extensively as time progresses
5. When the project under consideration has to compete with projects from other divisions or areas for a limited amount of funds

Most layout projects do not require such extensive analysis, and a less complex method is adequate. Many layouts do not involve large investments, but are rearrangements of equipment already on hand. In such cases, most of the costs to be recovered are those incurred in planning and moving. Extensive analysis is also usually unnecessary for relayout projects where proposed alternatives can be compared with existing operations; for projects that affect only a small part of a total operation; or for "necessity" projects that must be done to keep a larger operation functioning properly. In such cases, the calculation and comparison of payout periods is adequate for a proper decision. But a word of warning: Do not use payout period as a crutch to avoid using a more detailed and accurate method when it would be more appropriate.

Inasmuch as all methods of analysis depend on essentially the same expenditure and cost data, it is often helpful to evaluate by a simple method, such as payout period or average return, and then go on to more precise calculations if a clear advantage is not apparent.

In Figure 10-15c, the data from 10-15 a & b have been used to calculate the payout period. Here, with changes in costs between an existing method and a proposed method, the savings in cost (profit increase on a cash-flow basis) are compared with the total funds to be recovered in order to determine the payout period.

This example of payout is included because it is a popular method of cost justification and comparison; but, we have warned of its limitations. Especially, it is not advisable to depend on payout period calculations if the useful life of the project is considerably longer than the payout period.

Costs are not the only element to be evaluated in choosing among proposed layouts. The intangibles evaluated by the factor analysis method are frequently more significant than cost justification and comparison. In any event, the planner can well afford to apply both methods to many if not most projects.

Request for Approval

Although the method of getting the layout approved depends upon the nature of the project, the company, and what kind of approval is required, generally speaking, it involves the following:

1. As a check on your layout, review it with the other people most involved – including operating and service personnel. Others gain a feeling of participation, and the review helps to pre-sell the layout. Others understand better what is planned. They help catch errors which may have been made. All this allows presentation to higher authorities with the support of those who are involved.
2. Prepare a clear and accurate "picture" of what is proposed. Clear visualization helps others understand quickly what they are being asked to approve. Use present-and-proposed illustrations, with explanatory drawings or models, and clear plans showing recommended and alternative solutions.
3. Provide a recap or synopsis of how the recommended plan was developed. The SLP methodology serves here beautifully, for its pure logic and plain orderliness command respect. And, if both the relationships and space have been signed off as approved earlier, the submission for final approval can be highly convincing.
4. Prepare a presentation for approval, either oral or as a written report. The specific request should be just that – a specific request for approval and allocation of funds. It should include a summary statement indicating the investment funds required; when the money will be spent; what the returns will be, and when; a breakdown of how the money will be spent; as well as intangible advantages and disadvantages. And, it should answer the questions which people most often have in mind when asked to give their approval, namely:
    a. What do we stand to *gain* from this layout?
    b. What do we *risk* with this layout?
    c. How does this layout *affect me* personally and the group I represent?

Recognizing Approval

When approval is given to the overall or block layout plan, the SLP pattern of procedures is complete. Having reached this point, the planner can move aggressively into the detailed planning phase of the project. It is important, therefore, to draw up, duplicate, or otherwise reproduce the approved plan so that all further planning will be integrated with what has generally been approved. This helps ensure coordination and avoids some groups' misdirecting their efforts by working to non-approved plans.

Overlapping Considerations

Planning the general overall layout is discussed, in the eight chapters of Part Two, as one straightforward sequence. Keep in mind, however, that Phase II is overlapped by Phase I and itself overlaps Phase III. Frequently important Phase III details of critical sub-areas are considered in the work on the general overall layout. Moreover, it often means making a preliminary general overall plan. This approved Phase II is then submitted to others for study, comment, and rework. The home office, architectural engineers, layout consultants, and others are frequently involved here, if they have not already participated during integration of the modifying considerations or evaluating of alternatives.

Tentative plans on the Phase III details can now move forward without much likelihood that major changes in the general overall layout will cancel any detail planning. Still, it is wasteful of man-hours and engineering talent to go too far into Phase II details without having general agreement on the major physical features (column spacing, walls, main aisleways, utility distribution, and the like) that are part of, or approved with, the overall layout.

Part Three

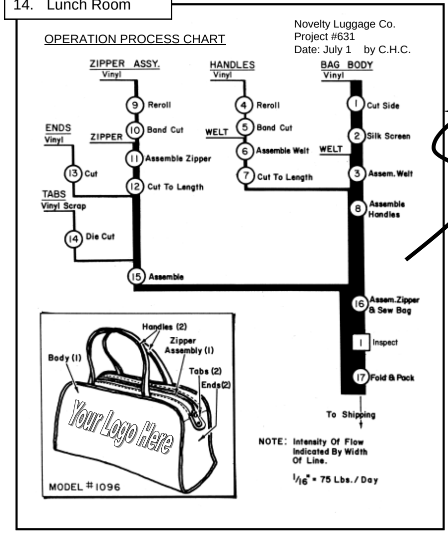
EXAMPLE OF SYSTEMATIC LAYOUT PLANNING, PHASE II

Key Input Data: P, Q, R, S, T

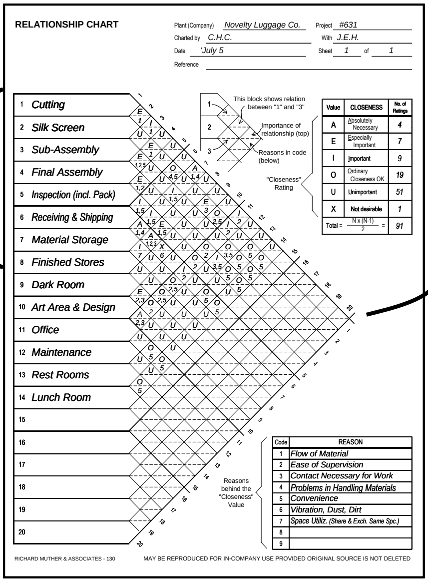
List of Activity Areas
1. Cutting
2. Silk Screen
3. Sub-Assembly
4. Final Assembly

14. Lunch Room

1. Activity-Areas



2. Flow of Materials



RELATIONSHIP CHART

Plant (Company) *Novelty Luggage Co.* Project *#631*
Charted by *C.H.C.* With *J.E.H.*
Date *'July 5* Sheet *1* of *1*
Reference

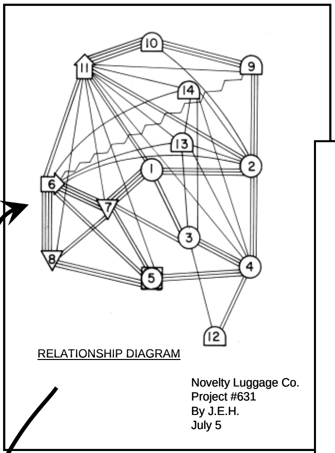
1 Cutting
2 Silk Screen
3 Sub-Assembly
4 Final Assembly
5 Inspection (incl. Pack)
6 Receiving & Shipping
7 Material Storage
8 Finished Stores
9 Dark Room
10 Art Area & Design
11 Office
12 Maintenance
13 Rest Rooms
14 Lunch Room
15
16
17
18
19
20

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	4
E	Especially Important	7
I	Important	9
O	Ordinary Closeness OK	19
U	Unimportant	51
X	Not desirable	1
Total = $\frac{N \times (N-1)}{2}$ =		91

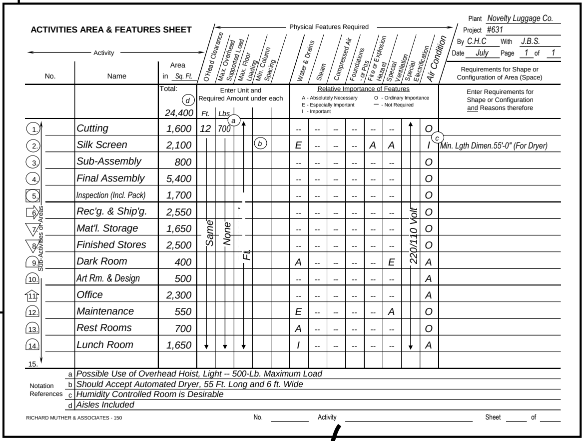
Code	REASON
1	Flow of Material
2	Ease of Supervision
3	Contact Necessary for Work
4	Problems in Handling Materials
5	Convenience
6	Vibration, Dust, Dirt
7	Space Utiliz. (Share & Exch. Same Spc.)
8	
9	

RICHARD MUTHER & ASSOCIATES - 130 MAY BE REPRODUCED FOR IN-COMPANY USE PROVIDED ORIGINAL SOURCE IS NOT DELETED

2. Relationship Chart
(Flow & Other Activity Relationships)



2. Relationship Diagram



ACTIVITIES AREA & FEATURES SHEET

Plant *Novelty Luggage Co.*
Project *#631*
By *C.H.C* With *J.B.S.*
Date *July* Page *1* of *1*

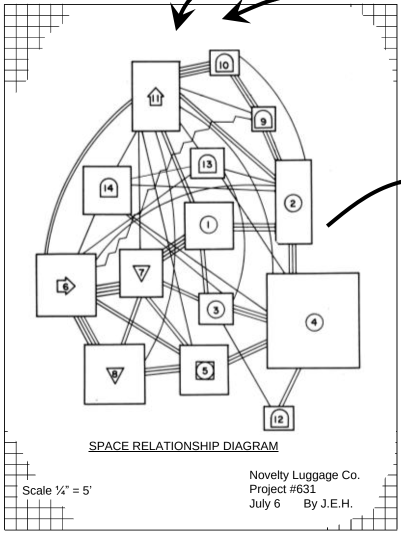
No.	Name	Area in Sq. Ft.	O'Head Clearance	Max. Overhead Supported Load	Max. Floor Loading	Min. Column Spacing		Water & Drains	Steam	Compressed Air	Foundations or Pits	Fire or Explosion Hazard	Special Ventilation	Special Electrification	Air Condition	Requirements for Shape or Configuration of Area (Space)
		Total: (d) 24,400	Ft.	Lbs.												Enter Requirements for Shape or Configuration and Reasons therefore
1.	Cutting	1,600	12	700 (a)	↑			--	--	--	--	--	--	↑	O	
2.	Silk Screen	2,100				(b)		E	--	--	--	A	A		I (c)	Min. Lgth Dimen.55'-0" (For Dryer)
3.	Sub-Assembly	800						--	--	--	--	--	--		O	
4.	Final Assembly	5,400						--	--	--	--	--	--		O	
5.	Inspection (Incl. Pack)	1,700						--	--	--	--	--	--		O	
6.	Rec'g. & Ship'g.	2,550						--	--	--	--	--	--		O	
7.	Mat'l. Storage	1,650	Same	None	Ft.			--	--	--	--	--	--	220/110 Volt	O	
8.	Finished Stores	2,500						--	--	--	--	--	--		O	
9.	Dark Room	400						A	--	--	--	--	E		A	
10.	Art Rm. & Design	500						--	--	--	--	--	--		A	
11.	Office	2,300						--	--	--	--	--	--		A	
12.	Maintenance	550						E	--	--	--	--	A		O	
13.	Rest Rooms	700						A	--	--	--	--	--		O	
14.	Lunch Room	1,650	↓	↓	↓			I	--	--	--	--	--	↓	A	
15.																

Activity ← → ; Physical Features Required ← → ; Enter Unit and Required Amount under each; Relative Importance of Features: A - Absolutely Necessary, E - Especially Important, I - Important, O - Ordinary Importance, — - Not Required; Sub-Activities or Areas

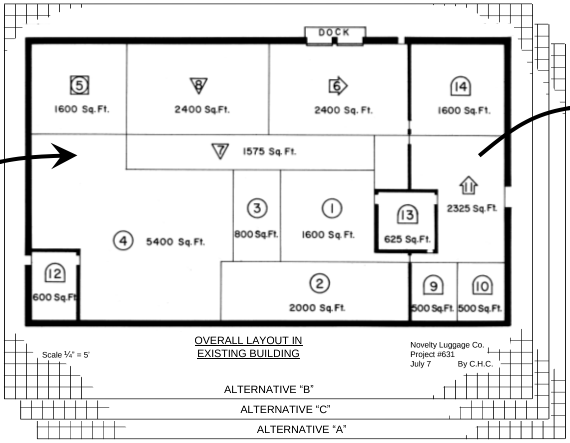
Notation References
a Possible Use of Overhead Hoist, Light -- 500-Lb. Maximum Load
b Should Accept Automated Dryer, 55 Ft. Long and 6 ft. Wide
c Humidity Controlled Room is Desirable
d Aisles Included

RICHARD MUTHER & ASSOCIATES - 150 No. ______ Activity ______ Sheet ____ of ____

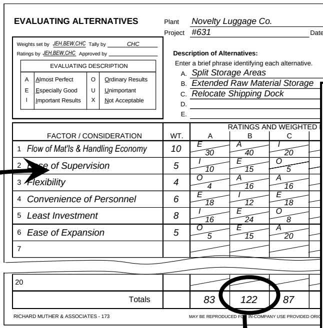
3. Space Requirements



3. Space Relationship Diagram



4. Alternative Layouts
based on Modifying Considerations and Practical Limitations



EVALUATING ALTERNATIVES

Plant *Novelty Luggage Co.*
Project *#631* Date *July 8*

Weights set by *JEH,BEW,CHC* Tally by *CHC*
Ratings by *JEH,BEW,CHC* Approved by ______

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:
Enter a brief phrase identifying each alternative.
A. Split Storage Areas
B. Extended Raw Material Storage
C. Relocate Shipping Dock
D.
E.

	FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED A	 B	 C
1	Flow of Mat'ls & Handling Economy	10	E 30	A 40	I 20
2	Ease of Supervision	5	I 10	E 15	O 5
3	Flexibility	4	O 4	A 16	A 16
4	Convenience of Personnel	6	E 18	I 12	E 18
5	Least Investment	8	I 16	E 24	O 8
6	Ease of Expansion	5	O 5	E 15	A 20
7					
20					
	Totals		83	122	87

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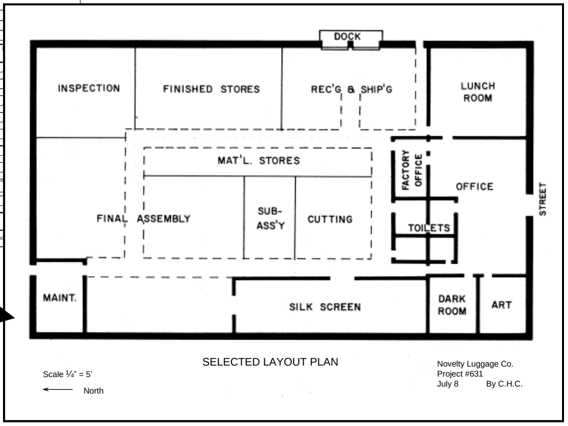
5. Evaluation



5. Selected Layout Plan
Phase II – Overall Block Layout

Introduction to Part Three

Part Three covers planning detailed layouts, Phase III of the SLP framework. It involves arranging the location of each individual machine, piece of equipment, employee working space, storage rack of material, and supporting features.

As we have pointed out, the phases are sequential and, for best results, should overlap. Also, we have stated that the SLP pattern of procedures is essentially the same for both Phases II and III. The pattern merely repeats itself in more detail for each of the sub-areas to be laid out.

Perhaps Part Two is best summarized by an example. The Figure *accompanying this introduction illustrates each step of the Phase II sequence. It represents the planning for a new factory, of about 25,000 square feet, to produce monogrammed tote bags for conventions and promotional events, beach bags, tennis racket covers, and the like.*

Each step is numbered below its illustration. The complete sequence represents the pattern as followed for this particular example.

An example of detail layout planning, Phase III, for Activity Number 2 (Silk Screen Department) is shown later on as Figure 11-14. It follows the SLP pattern of procedures – with the same outputs and key documents – for one area in the overall plan.

By now you recognize that SLP is a step-by-step system of planning, with defined outputs and key documents for each step. Here are the outputs and key documents that you will need to complete your detailed layouts in Phase III.

Pattern of Procedures Section Number	*Key Document(s); Must do*	*Other potentially useful documents; Do if helpful*	*Output*
1 Activities	*P-Q Analysis*	• *Operation process chart* • *Flow process chart* • *Line balance* • *Multi-product process chart*	*List of Activity-Areas*
2 Relationships	*Relationship Chart*	• *Line-feeding flow chart*	*Activity Relationship or Flow Diagram or both*
3 Space	*Activity Areas and Features Sheet*	• *Machinery & Equipment Area & Features Sheet* • *Office Layout Requirements Data*	*Space Relationship Diagram*
4 Adjustment	*Equipment Layout Drawings*	• *Scaled equipment templates* • *Models and renderings* • *Elevation drawings*	*Alternative Layouts*
5 Evaluation	*Evaluation of Alternatives*	• *Cost estimates and comparisons*	*Selected Detail Layout(s)*

Chapter 11

Detail Layout Planning

Chapters 3 through 10 were each devoted to one section of the SLP pattern using overall or block layout planning for illustrations and discussion. This chapter covers all of Phase III Detailed Layouts. Since all 5 sections of the SLP Pattern are repeated in Phase III, we should in theory re-cover all the material in Chapters 3 – 10. And it is true that all of the steps, techniques, charts, diagrams and forms that we have presented can and will be used in Phase III. But since we have discussed them in previous chapters, we will rely here on Figures to illustrate their application in detail planning. This will allow us to focus our discussion on the differences between Phases II and III and what they mean for the planning. Chief among them are:

1. *Equipment layout*. The purpose of detail layout is to locate each individual machine and piece of equipment in an area. This requires more specific and more granular data, dimensions, and techniques of analysis.
2. *One area at a time*. Scope is limited to one activity-area within the overall block layout. While we may need to detail the entire facility, SLP does so one activity-area at a time. This is essential to keeping track of progress, delegating to and involving the right people on a productive basis. (SLP treats the planning of individual workplaces as part of Phase III layout. Additional procedures for workstation layout are covered in Chapter 12).
3. *Within the confines (or constraints) of an overall layout*. Another significant difference is that detail planning is relatively constrained. Space Available, for example, is pretty well established; the limits of area and configuration are set when the General Overall Layout is approved; column spacing, floor loading, and other building features are also fixed; the interdepartmental handling system is agreed upon; scheduling, inventory, and timekeeping policies and procedures are now set.
4. *At a slower pace*. It is essential to get the overall (generally inter-area) questions resolved before tackling the details, for detail layout planning requires considerable time. This is not to say detail planning is more important or requires more skill and experience. On the contrary, Phase II is where major and costly layout decisions are made. But Phase III requires more planning time per unit of area laid out.
5. *By different people*. It is usually possible and desirable, especially on large projects, to delegate detail layout planning to those at an echelon of responsibility one level below those who have been intimately concerned with planning the overall layout. In overall planning, the participation and approval of division officers or departmental managers is obtained. In detail layout planning, the opinions of those who will be directly responsible for the operation of each department or sub-area being planned are solicited. This involves supervisors, operators and supporting-service group or section leaders. Failure to include in the planning the people who are actually involved and vitally interested is a serious error, one that can lead to a completely impractical layout or an installation that does not function effectively.

Degrees of Facilities Planning

Because detail planning does take considerable time, and every layout project has its practical time limit, it is well to set a schedule for each area to be laid out. Coordinate the times for adjacent areas so their effect on each other can be worked out. The schedule stimulates improved performance on the part of those planning the layouts. And, in general, the schedule better coordinates the overall project. Discriminative scheduling of each area is in order. By this we mean: Recognize and designate ahead of time differences in degree, kind, or emphasis of the layout planning to be done. One area may involve entirely new equipment; a second area will be moved "as is," with all but the barest necessary detail planning postponed until later. To accomplish this planning in various degrees, again use the vowel-rating conventions. See Figure 11-1.

This A-to-U rating, when assigned to each area, designates to subordinates and operating personnel where the planning time is to be spent and which areas are to remain "about the same." Areas designated A are those involving new processes completely unfamiliar to the company. U-designated areas are to be left essentially as is; or to the discretion of the department supervisor. In either event, no layout planning time is scheduled.

This system of rating layout planning effort or attention is termed *Degree of Facilities Planning.* Generally, degree of facilities planning indicates, in addition to the degree of layout planning, the extent of financial investment as well. It is logical, therefore, that this rating method should be applied broadly and not limited to scheduling the detailed layout-planning effort.

The SLP Pattern Repeated

Apply the SLP pattern to the layout of each detail area. In Section 1, establish the products or materials involved and how many of each for each area. Analyze the other input data for each area, reorganize them into a finer breakdown, and establish the activities for the area (actually, the sub-activities within the earlier designated activity). In detailed manufacturing layouts, the “activities” will typically include machines, equipment and stations or groupings thereof, and perhaps local building features.

A – Absolutely necessary to do extensive layout planning at this time.

E – Especially important to do extensive layout planning at this time.

I – Important to do extensive layout planning at this time.

O – Ordinary layout planning is OK.

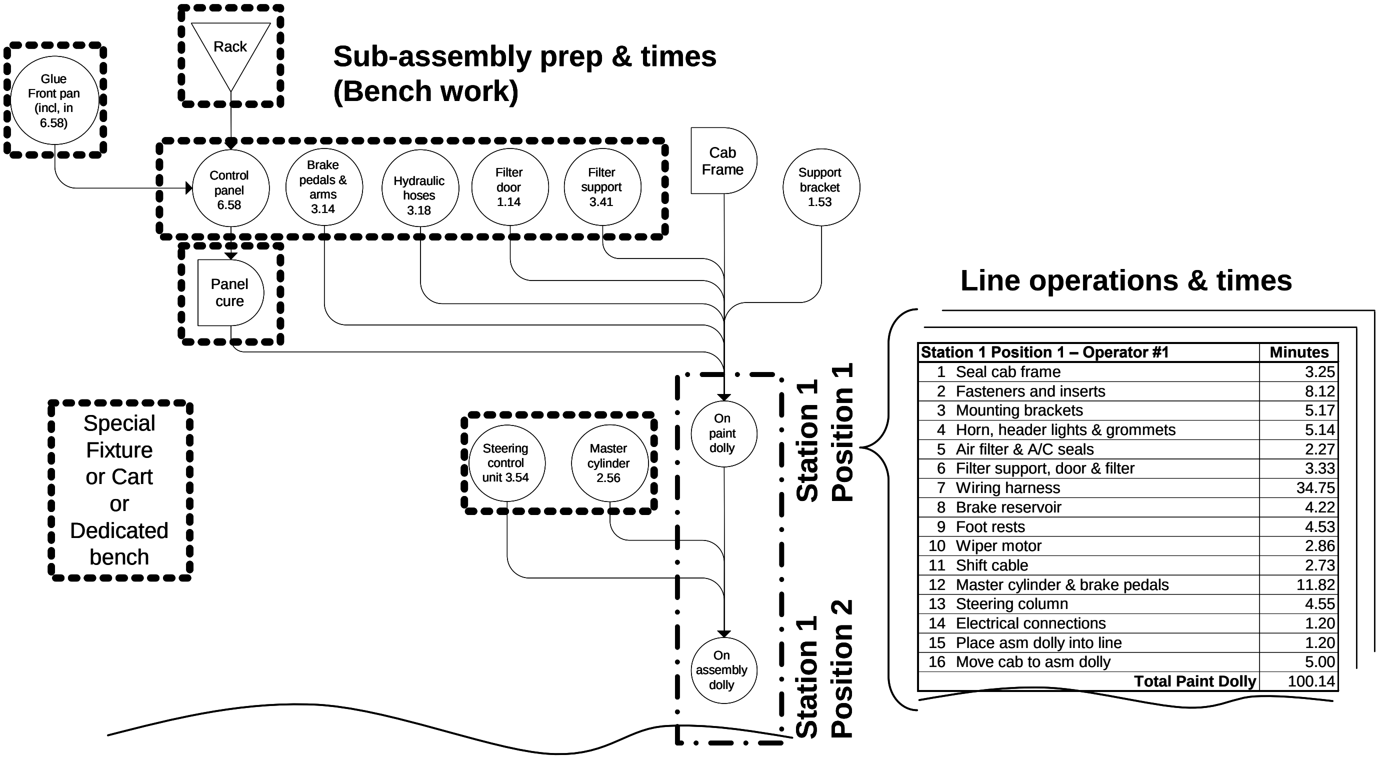
U – Unimportant – don’t spend any time on layout planning now.

Figure 11-1. Rating designations for Degree of Facilities Planning. This is a systematic way of indicating the degree of layout attention each area can justify in the light of the total project schedule.

Choice of layout type – by fixed position, process, or product, or a combination – will likely have already been made in the overall plan. But if not, or if the choice should be reviewed, a P-Q analysis should be performed *for the area being planned*. This will also help clarify the nature and significance of material flow and how to analyze it.

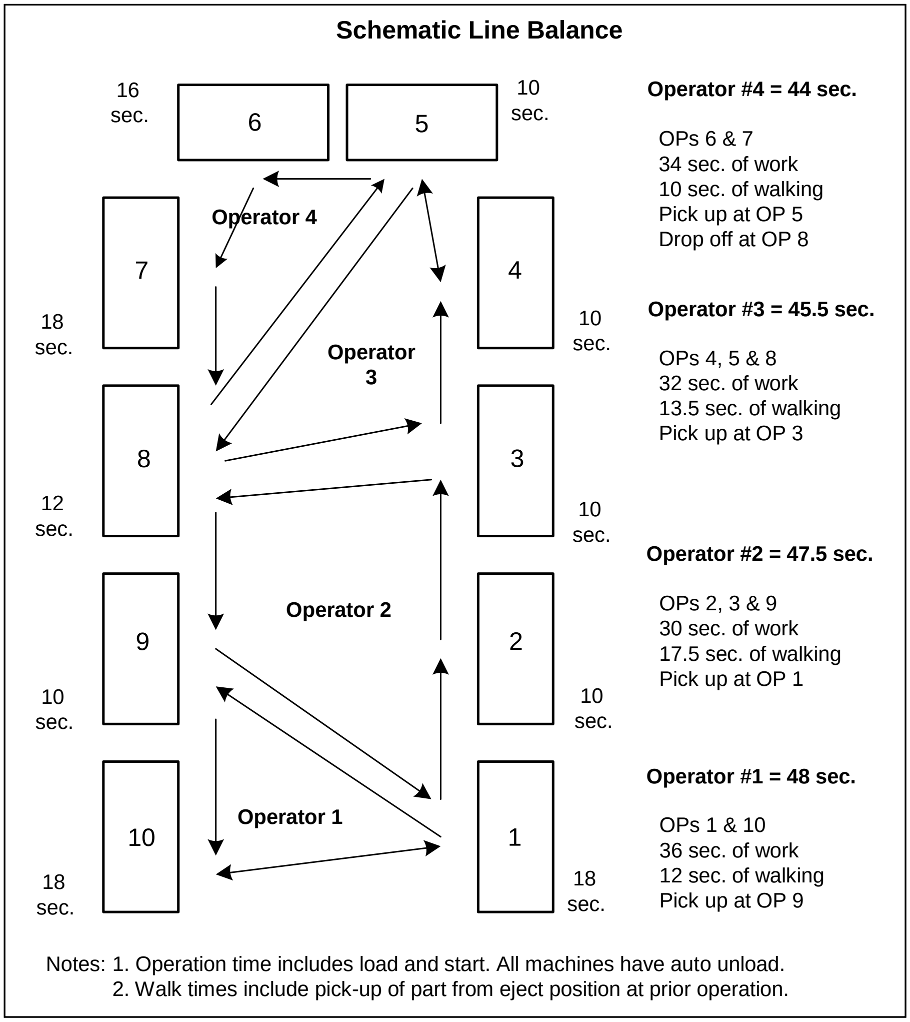
The output of Section 1 is a list of activity-areas. But in detail planning, making this list requires understanding of the individual processing steps (routing) and their times. In assembly areas and multi-operator cells, line balancing techniques may be needed to establish the number of stations, the operations performed at each, and how the operators will be assigned. In this way, Phase III layout planning is often more closely interrelated with process planning than in overall or block layout. Two illustrations appear in Figures 11-2 and 11-3. Often the act of layout planning reveals and triggers process improvements.

Clearly line balance is affected by layout since the time spent reaching or walking to fetch or move materials, parts, tools or fixtures is partly a function of layout. Material handling and storage practices play significant roles as well. The layout planner may "loop," developing an initial layout for the planned process and target line balance, then adjusting them based on the layout and its associated handing-and-storing methods, then adjusting the layout… and so on, to arrive at the best or most acceptable plan.



Station 1 Position 1 – Operator #1	Minutes
1 Seal cab frame	3.25
2 Fasteners and inserts	8.12
3 Mounting brackets	5.17
4 Horn, header lights & grommets	5.14
5 Air filter & A/C seals	2.27
6 Filter support, door & filter	3.33
7 Wiring harness	34.75
8 Brake reservoir	4.22
9 Foot rests	4.53
10 Wiper motor	2.86
11 Shift cable	2.73
12 Master cylinder & brake pedals	11.82
13 Steering column	4.55
14 Electrical connections	1.20
15 Place asm dolly into line	1.20
16 Move cab to asm dolly	5.00
Total Paint Dolly	100.14

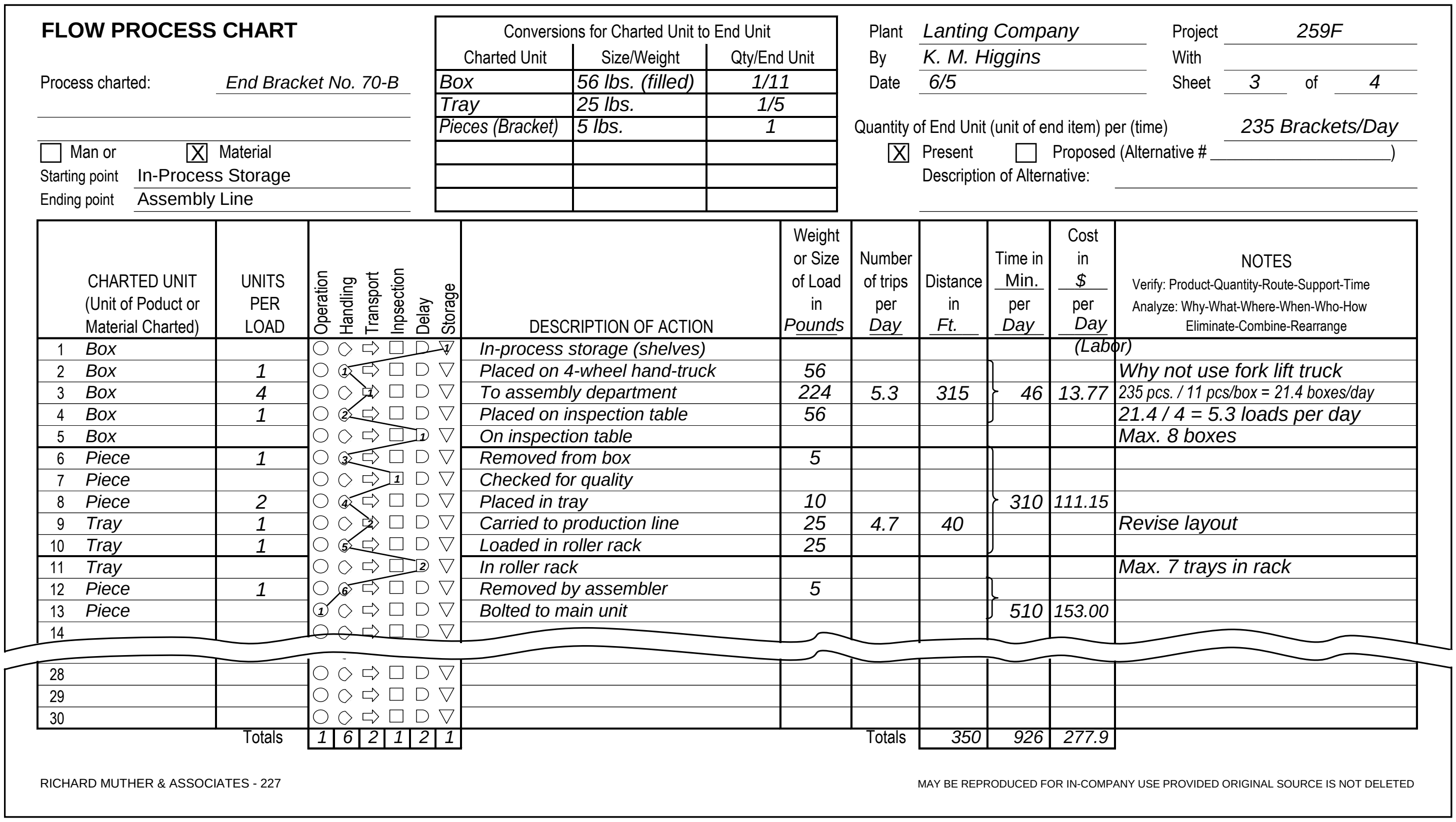
Figure 11-2. Operations and standard times for one station in an assembly line. The process chart shows the preparation of sub assemblies and their flow to the line station where they are installed. Additional assembly operations within the station are listed on the right. These must be assigned to available operators in a feasible and balanced way. Dotted lines surrounding the process chart symbols define activity-areas that will be sized and arranged in the layout. These include racks, benches, staged dollies, the line station and positions within it. Each arrangement may affect the amounts of time allowed for reaching, fetching and moving materials, parts, tools and fixtures.



Notes: 1. Operation time includes load and start. All machines have auto unload.
2. Walk times include pick-up of part from eject position at prior operation.

Figure 11-3. Line balance for a high-volume machining cell making automobile parts. In this example, it is very hard to separate line balance from layout planning. The layout affects the balance through walking times – a function of distance – and also through assignment of operators to machines – a function of distance and the arrangement itself. Here, the U-shaped flow favored in such cells increases the operators' "reach." Counter-clockwise flow leverages the right-handedness of most operators and may save a few seconds per cycle as they approach the machines. The U-shaped layout also makes it easier to add or remove operators as volume rises and falls. Pace and balance are better maintained with the same operator (#1) performing the first and last operation.

The techniques used to analyze *flow of materials* in Section 2 of the SLP pattern are the same as used in overall layout, with adaptations where needed. For example, in Phase II, an operation process chart is used to analyze the flow of one or a few products or materials. In Phase III layout, this takes the form of a flow process chart like that in Figure 11-4. Similarly, when planning the details of one assembly line, a form to show the flow-in from both sides can be more definitive. See Figure 11-5. Any project in which rearrangements and realigning of layouts are a frequent necessity may require its own analysis form.



FLOW PROCESS CHART

Process charted: *End Bracket No. 70-B*

☐ Man or ☒ Material
Starting point In-Process Storage
Ending point Assembly Line

Conversions for Charted Unit to End Unit		
Charted Unit	Size/Weight	Qty/End Unit
Box	*56 lbs. (filled)*	*1/11*
Tray	*25 lbs.*	*1/5*
Pieces (Bracket)	*5 lbs.*	*1*

Plant *Lanting Company* Project *259F*
By *K. M. Higgins* With
Date *6/5* Sheet *3* of *4*

Quantity of End Unit (unit of end item) per (time) *235 Brackets/Day*
☒ Present ☐ Proposed (Alternative # ____________)
Description of Alternative:

	CHARTED UNIT (Unit of Poduct or Material Charted)	UNITS PER LOAD	Operation	Handling	Transport	Inpsection	Delay	Storage	DESCRIPTION OF ACTION	Weight or Size of Load in *Pounds*	Number of trips per *Day*	Distance in *Ft.*	Time in *Min.* per *Day*	Cost in *$* per *Day* *(Labor)*	NOTES Verify: Product-Quantity-Route-Support-Time Analyze: Why-What-Where-When-Who-How Eliminate-Combine-Rearrange
1	*Box*		○	◇	⇨	□	D	*1*	*In-process storage (shelves)*						
2	*Box*	*1*	○	*1*	⇨	□	D	▽	*Placed on 4-wheel hand-truck*	*56*					*Why not use fork lift truck*
3	*Box*	*4*	○	◇	*1*	□	D	▽	*To assembly department*	*224*	*5.3*	*315*	*46*	*13.77*	*235 pcs. / 11 pcs/box = 21.4 boxes/day*
4	*Box*	*1*	○	*2*	⇨	□	D	▽	*Placed on inspection table*	*56*					*21.4 / 4 = 5.3 loads per day*
5	*Box*		○	◇	⇨	□	*1*	▽	*On inspection table*						*Max. 8 boxes*
6	*Piece*	*1*	○	*3*	⇨	□	D	▽	*Removed from box*	*5*					
7	*Piece*		○	◇	⇨	*1*	D	▽	*Checked for quality*						
8	*Piece*	*2*	○	*4*	⇨	□	D	▽	*Placed in tray*	*10*			*310*	*111.15*	
9	*Tray*	*1*	○	◇	*2*	□	D	▽	*Carried to production line*	*25*	*4.7*	*40*			*Revise layout*
10	*Tray*	*1*	○	*5*	⇨	□	D	▽	*Loaded in roller rack*	*25*					
11	*Tray*		○	◇	⇨	□	*2*	▽	*In roller rack*						*Max. 7 trays in rack*
12	*Piece*	*1*	○	*6*	⇨	□	D	▽	*Removed by assembler*	*5*					
13	*Piece*		*1*	◇	⇨	□	D	▽	*Bolted to main unit*				*510*	*153.00*	
14			○	◇	⇨	□	D	▽							
28			○	◇	⇨	□	D	▽							
29			○	◇	⇨	□	D	▽							
30			○	◇	⇨	□	D	▽							
		Totals	*1*	*6*	*2*	*1*	*2*	*1*			Totals	*350*	*926*	*277.9*	

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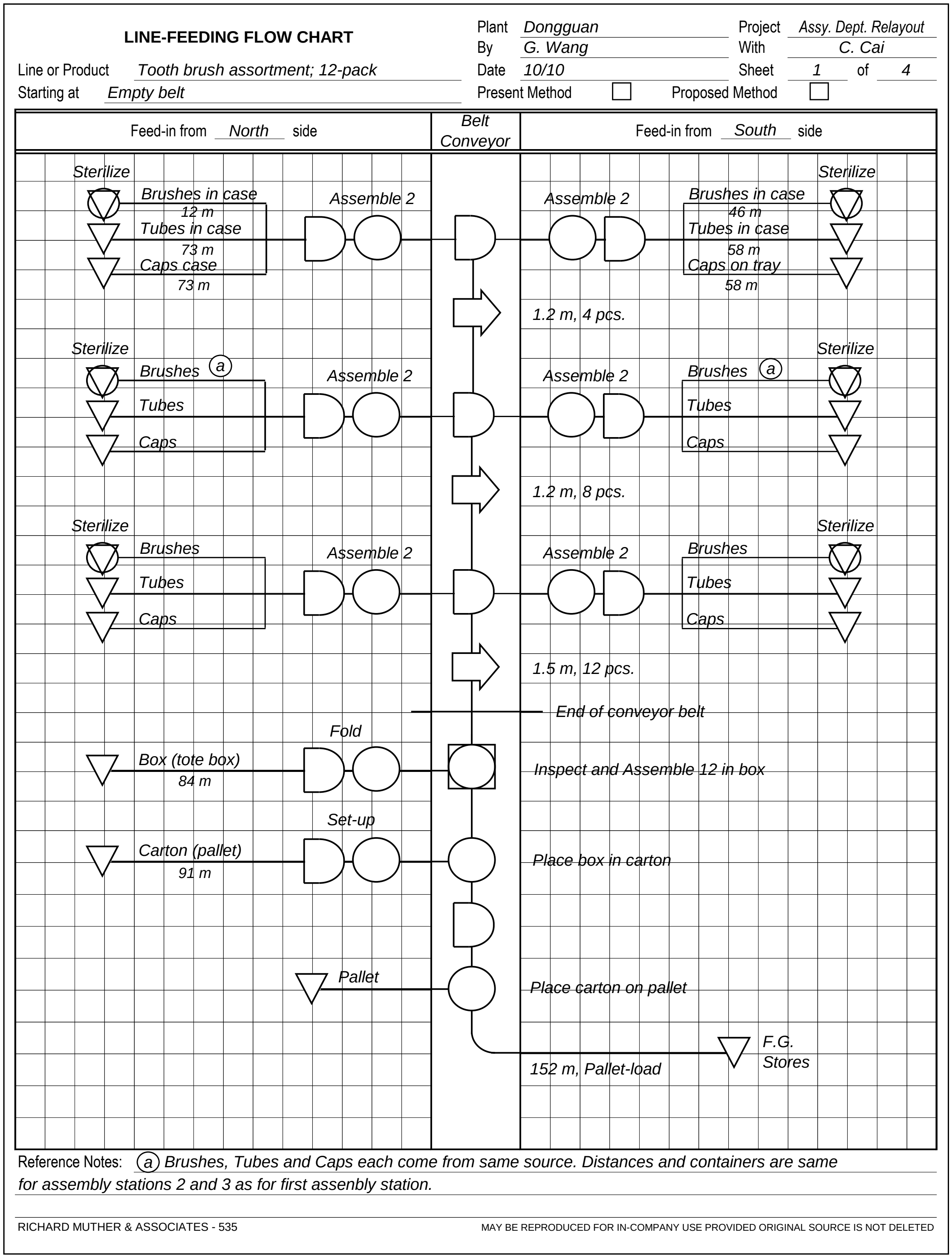
Figure 11-4. Flow Process Chart traces the movement of material through each detailed step of the process. It employs all the process chart symbols. In Phase III, the greater detail of the flow process chart is preferred to the simpler operation process chart that may have been used in Phase II. However, the flow process chart need not be limited to one departmental area. It can be used whenever the full detailed steps of the sequence of flow is wanted, especially when analyzing for material handling improvements, such as when modifying the space relationship diagram for materials handling considerations.

The handling symbol in this chart is made by combining two halves of the operation and transport symbols. By segregating the handling activities, it is easier to distinguish the true operations and true transports, and thereby to analyze more clearly the present or proposed process method. "Handling" occurs when an object is arranged, prepared, transferred, or positioned prior to another action. This definition then limits the "operation" symbol to when an object is intentionally changed in any of its physical or chemical characteristics, or is assembled to or disassembled from another object. It also limits the "transport" symbol to when an object is moved from one place to another.

At the top of the form is a place to make conversions between the various units charted. Even though only one product or material (or product-material group) is recorded, conversions are necessary to develop the information on time and cost.

Note that the time column can be used in a number of ways. It can show the time used *per day* (as in this example) or *per end unit.* It can also show time per charted unit, although then the column can not be totaled, for the frequency varies from one charted unit to another. The same applies to the cost column. In the heading of the cost column is room to note whether we are dealing with labor cost, operating cost, total cost, or some other figures**.**



LINE-FEEDING FLOW CHART

Plant *Dongguan*
By *G. Wang*
Date *10/10*
Project *Assy. Dept. Relayout*
With *C. Cai*
Sheet *1* of *4*
Line or Product *Tooth brush assortment; 12-pack*
Starting at *Empty belt*
Present Method ☐ Proposed Method ☐

Feed-in from *North* side | *Belt Conveyor* | Feed-in from *South* side

Reference Notes: ⓐ *Brushes, Tubes and Caps each come from same source. Distances and containers are same for assembly stations 2 and 3 as for first assenbly station.*

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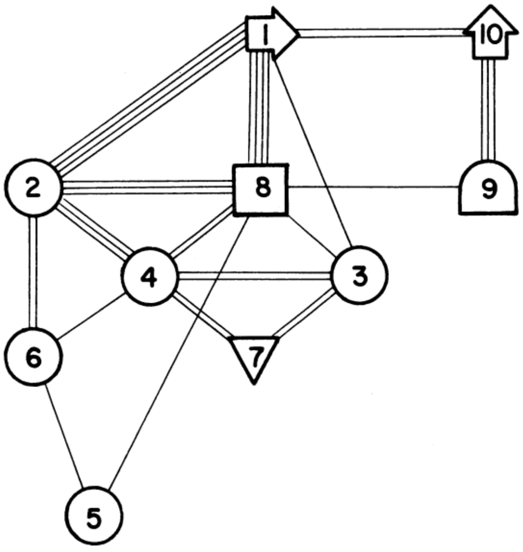
Figure 11-5. Planning the detail flow of material into, through, and away from a production line by means of the line-feeding flow chart. This illustration shows the assembly of an assortment of twelve toothbrushes (in tubes and capped) over a belt conveyor. Companies producing automobiles, appliances, or any other products produced on a line fed from both sides can use this type of chart for their detail layout planning. The grid can be used for line spacing – although this simple example does not do so.

Individual *relationship charts* may be made for the activities within each area. In Phase III, an entire chart may be made for what, in the overall layout phase, was just one activity on the chart. In the detail relationship chart, such activities as the scrap barrel, the computer monitor, and the drinking fountain may be included, while in the overall relationship chart, comparable activities would have been the salvage department, the scheduling office, and the cafeteria. Of course, it is not necessary to build a relationship chart for each line on the overall relationship chart, but where the area is a sizeable one, or where services are important or complex, time is saved in the long run by going through the entire relationship chart procedure for that area.

In *diagramming* the flow or relationships within the area, follow the same procedures as in the overall layout. Some adjustments and modifications are to be expected, but generally stick with the symbols and codes of the SLP conventions. They are meaningful, clear, and consistent. See Figure 11-6. (Also, refer to Figure 6-6. The office area diagramed there could well have been one department of a large office, in which case, the diagram shown would be considered Phase III.)

In areas where flow dominates, such as assembly lines and high-volume piece part processing, the relationship chart and activity relationship diagram may be optional. Process and flow charts may be sufficient since the operational sequence guides and may dictate placement of most activities, machines and equipment. Other-than-flow relationships are still present but are treated as modifying considerations during adjustment. Manufacturing cells are also typically laid out in this way.



1. In-Out Material Staging Area
2. Power Shear #53
3. Federal 30-ton Punch Press #55
4. Zhejiang SNS 55-ton Punch Press #54
5. Federal 30-ton Punch Press #56
6. Power Brake #58
7. Die Rack
8. Inspection Bench
9. Time Clock and Job Assignment Rack
10. Supervisor’s Desk

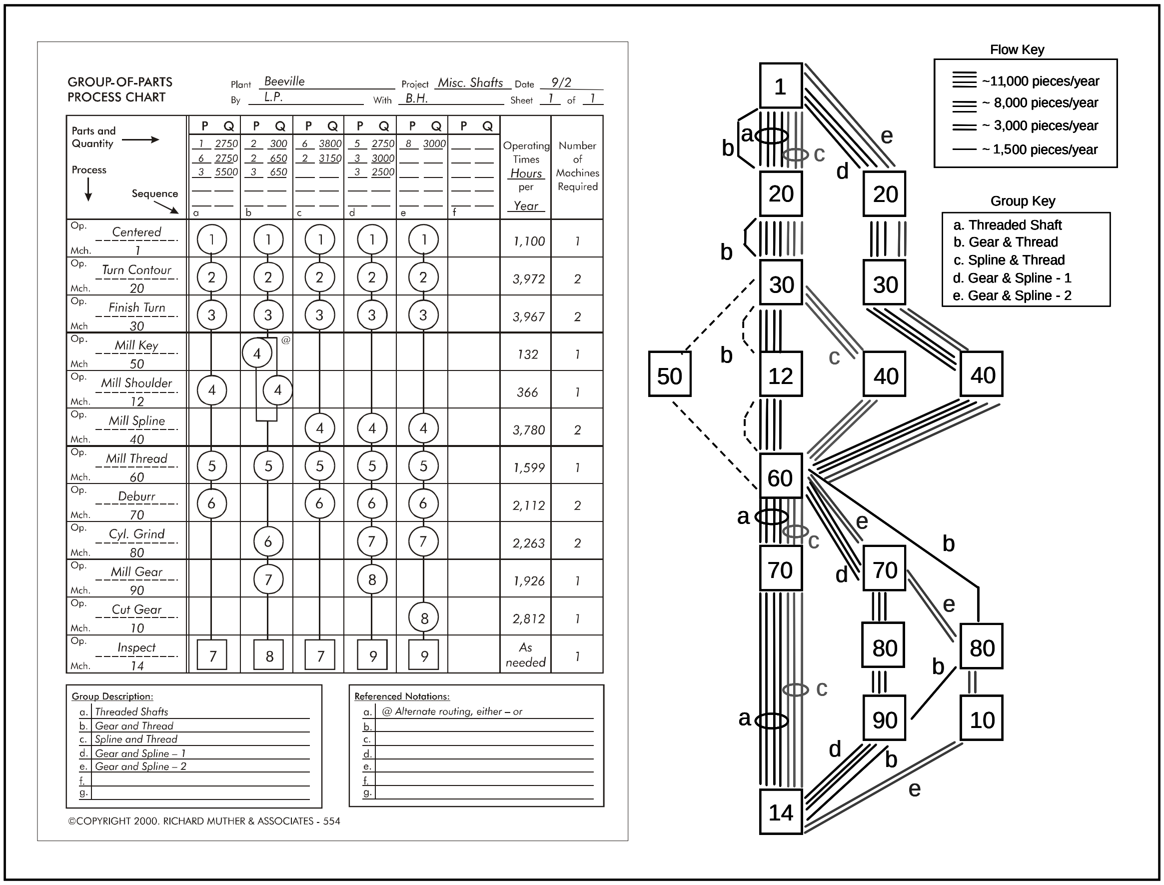
Figure 11-6. Activity Relationship Diagram for detail layout of a press department. This Phase III diagram uses the codes and symbols of the SLP conventions just as in Phase II. Here they represent individual machines, racks, or other local activities, whereas in Phase II they represented entire departments or larger activities. This diagram will be improved, of course, by shortening the four-line and three-line relationships between activities 1, 2, and 8. Compare this diagram with the one in Figure 6-4 to note the similarity in diagramming for Phases II and III.

Planning Manufacturing Cells

A manufacturing cell consists of two or more operations or workstations making a limited number or range or parts or products. Some cells machine, form or fabricate piece parts; others assemble. A few perform all functions. Typically, a cell is relatively small, serves one or one family of parts, is a closely coupled series of operating stations dedicated to these parts only, and is scheduled, controlled and treated as a single work center. It is essentially a small or short production line (or layout by product) for a group of similar items and may be virtually self-managed. Thus it can be considered a “mini-factory.”

Cell layouts are usually based on material flow, without the need for relationship charting. The relationship diagram is one of material flows between operations as shown in Figures 11-7 and 11-8. Cell layout is usually straight-forward since it follows closely the process chart or flow diagram.

But to fully plan an effective cell also requires the setting of handling methods, operating procedures and personnel policies and practices. Systematic Planning of Manufacturing Cells (SPMC) was developed to address this full scope of cell planning. A short-form of the SPMC method is presented in Appendix XIII. It can be used with or as an alternative to SLP when planning a detailed cell layout – or not used, if the cell operations and management have been planned and the only need is for a layout.



GROUP-OF-PARTS
PROCESS CHART

Plant Beeville
Project Misc. Shafts
Date 9/2
By L.P.
With B.H.
Sheet 1 of 1

Parts and Quantity →	a P	a Q	b P	b Q	c P	c Q	d P	d Q	e P	e Q	f P	f Q
	1	2750	2	300	6	3800	5	2750	8	3000		
	6	2750	2	650	2	3150	3	3000				
	3	5500	3	650			3	2500				

Process ↓ Sequence ↘	a	b	c	d	e	f	Operating Times Hours per Year	Number of Machines Required
Op. Centered Mch. 1	1	1	1	1	1		1,100	1
Op. Turn Contour Mch. 20	2	2	2	2	2		3,972	2
Op. Finish Turn Mch 30	3	3	3	3	3		3,967	2
Op. Mill Key Mch 50		4 @					132	1
Op. Mill Shoulder Mch. 12	4	4					366	1
Op. Mill Spline Mch. 40			4	4	4		3,780	2
Op. Mill Thread Mch. 60	5	5	5	5	5		1,599	1
Op. Deburr Mch. 70	6		6	6	6		2,112	2
Op. Cyl. Grind Mch. 80		6		7	7		2,263	2
Op. Mill Gear Mch. 90		7		8			1,926	1
Op. Cut Gear Mch. 10					8		2,812	1
Op. Inspect Mch. 14	7	8	7	9	9		As needed	1

Group Description:
a. Threaded Shafts
b. Gear and Thread
c. Spline and Thread
d. Gear and Spline – 1
e. Gear and Spline – 2
f.
g.

Referenced Notations:
a. @ Alternate routing, either – or
b.
c.
d.
e.
f.
g.

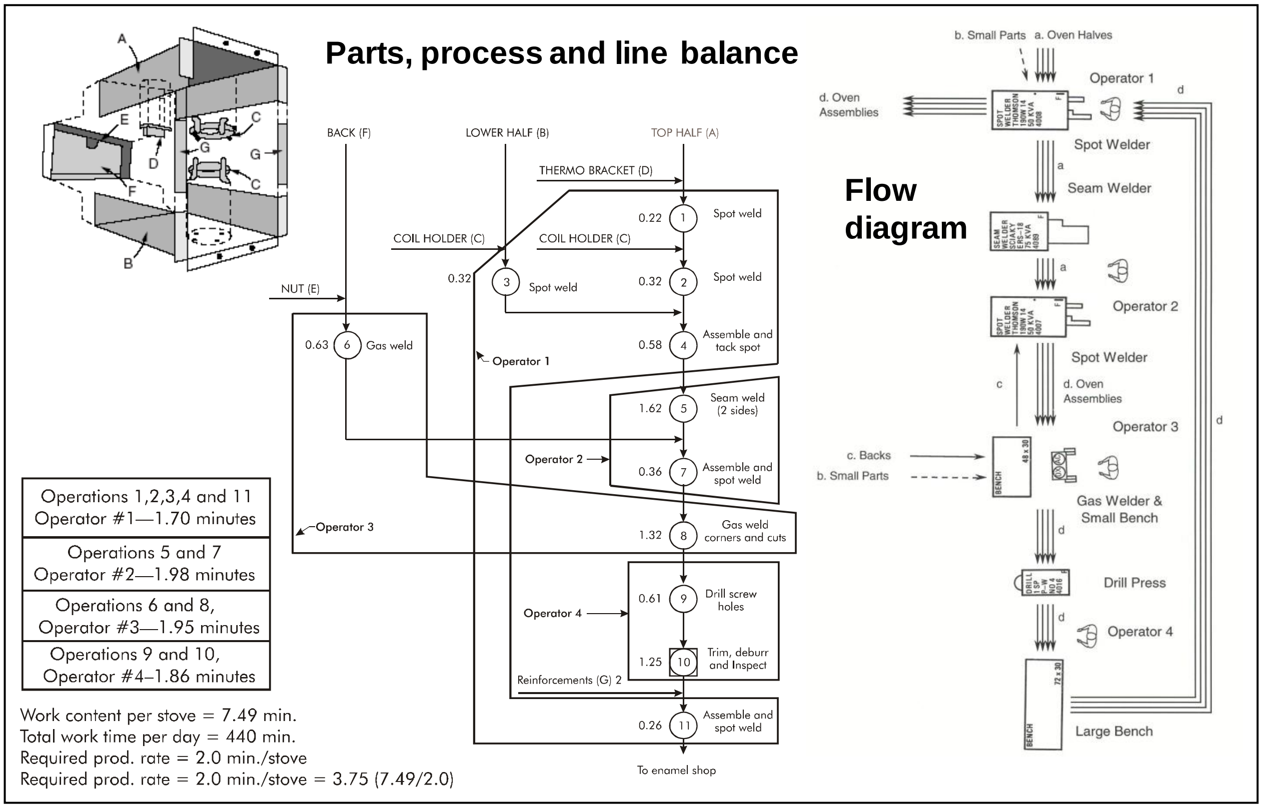


Figure 11-8. Assembly process, line balance, and flow relationship diagram. Here, the diagram is drawn as a rough arrangement of templates ready for adjustment into a layout. By using groups of scaled templates to represent each operator station, the planner incorporates space requirements into the diagram. If drawn at the same scale as the space available, this diagram can be adjusted into alternative layout plans.

In terms of the SLP pattern of procedures, this simple illustration shows Section 1 analysis of key inputs (P, Q, R and T) and definition of activity-areas; Section 2 flow of materials and relationship diagram; and Section 3 space and space relationship diagram. (From the book: Planning Manufacturing Cells, by Lee Hales and Bruce Andersen, Society of Manufacturing Engineers).

Figure 11-7. Cell flow diagram (opposite) shows flow relationships in number of lines between machines represented by numbered squares. A lower case letter designates the group of parts associated with each flow. These are circled as “packs” of parts with the same routing. With scaled templates for each machine and the space available in the overall block layout, this visualization is sufficient to develop a preliminary layout and begin its adjustment into alternative plans. While the diagram is laid out “straight through” from top to bottom, the layout may differ based on space available, line balance, material handling, storage and other considerations.

Note that the source document is an adaptation of the multi-product process chart described in Chapter 4. This form and the cell flow diagramming technique are explained in the booklet: Simplified Systematic Planning of Manufacturing Cells by Richard Muther et al.

In figuring *space required* (Section 3 of the SLP pattern), the planner deals with the space for each individual machine, worker, set-down space, and the like. This means working with actual dimensions of each space-occupying element to be included. If the planner recorded the Machinery & Equipment Layout Data pictured earlier in Figure 7-2, the necessary information will be available. But if the Phase II space figures were simply in tabular form, the planner must now determine the actual space for each element. Ideally this will be done in the form of templates as shown in Figure 11-9. This is an excellent example of a thoroughly detailed and dimensioned template. Such detail may not be needed for light assembly areas, bench work or banks of small, simple machines. But for large and fixed machinery and equipment, it is valuable.

Many planners and teams lack the time, skill and patience to draw complete and detailed templates. They may rely on an incomplete manufacturer's catalog template, or an outline of the machine's base (doors closed and projections missing), or they may just work "quick and dirty" with block templates on a grid. Recognize however, that the purpose of detail is to avoid oversights in the layout. At best, inaccurate templates lead to delays and rework during planning; at worst to costly delays and adjustments during and after installation. Then, the cost of detailed templates may look like a bargain.

Absent effective templates, the workaround – in existing operations – is to determine the space requirements and develop the layout right in the shop. There you can "go see" and measure the missing details of clearances, extremities, moving parts, access points, utility connections, auxiliary and ancillary equipment, and the like.

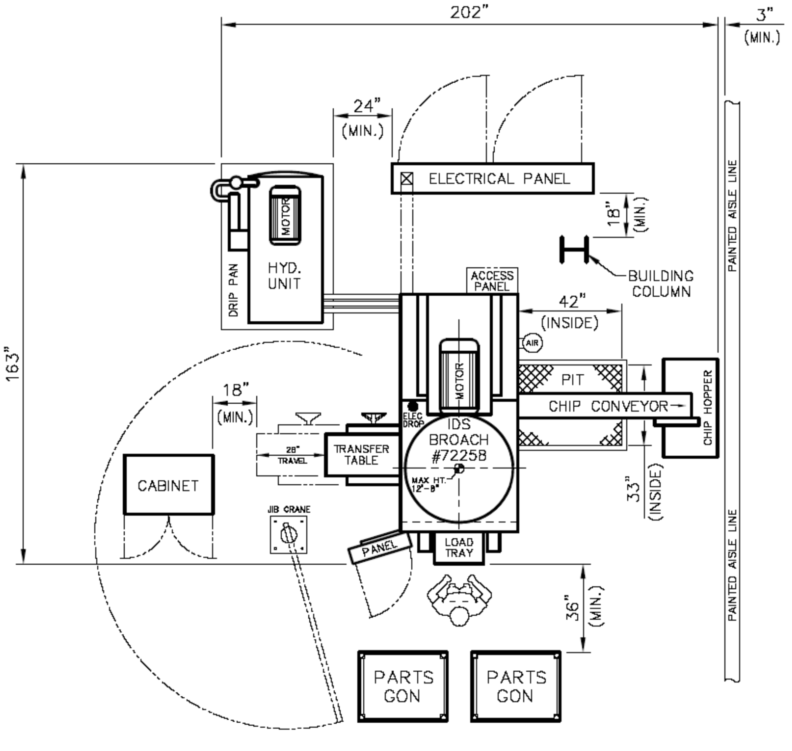


Figure 11-9. Detailed and dimensioned machine template. Courtesy of Integrity Design Services. This illustration and what it shows are discussed more fully in Chapter 12 on workplace layout.

The overall *space available* is already established in amount and condition with the approval of the overall layout. However, it is still possible to exchange space between departments and in most cases to adjust somewhat the general overall layout within its major fixed features. The project after all, is still "on paper." But, if Phase II has properly overlapped Phase III, there should be a minimum of inter-area adjustments affecting the overall layout.

As noted, the activity relationship diagram is converted to a *space relationship diagram* using actual replicas or templates of the space required for each machine or piece of equipment. Just as in Phase II, drawing a space relationship diagram and adjusting it into layouts requires that the planner first pick a scale.

The Scale

Even if the detailed drawings are projected from the electronic model of the overall layout, their plotting and review will typically benefit from a larger scale. But there is no great advantage in having the scale of the detailed layout plan be a multiple of the general overall layout. Pick the scale that best suits the purpose.

While the scale for Phase II can have almost any dimensions, the recommended scale for detail layout is ¼ inch equals one foot (or two centimeters equal one meter metric).[1] Anything much bigger is too space-consuming. Anything smaller begins to lose accuracy. A scale of 1/8 inch equals one foot (or one centimeter equals one meter metric) can be used under the following situations:

1. The area to plan is large (approximately 100,000 square feet or more).
2. The production materials are relatively large (like airplanes or motor trucks).
3. The operations involve very large equipment (like large paint booths or steel-mill rolling equipment).
4. Prints of existing structures involved are already drawn at that scale.

Otherwise, best practice is to stick with ¼ inch to the foot on all prints and plots. We will discuss methods of visualization through drawings, templates, and models in Chapter 13.

Adjustments to the Detail Layout

In detail layout, the space relationship diagram leads almost immediately to a rough arrangement of scaled equipment templates – Section 4 in the SLP pattern. This rough layout will be subject to *modifications* and practical *limitations*. During this process of adjustment, all manner of analytical techniques may be applied. The most useful will be traditional forms of operations analysis, methods engineering, time study and line balancing. Computer-based simulation may be helpful in some situations. And various problem-solving methods may also play a role. These are documented in various programs and books on Kaizen, Just-In-Time, Lean Manufacturing, World Class Manufacturing, Total Quality Management, Total Productive Maintenance, and Six Sigma.

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[1] Two centimeters equal one meter is a scale of 1 to 50; ¼ inch equals one foot is 1 to 48. One centimeter equals one meter is a scale of 1 to 100; 1/8 inch to the foot is 1 to 96.

Because many detailed manufacturing layouts are based on flow of materials, it is easy to become so focused on the machinery or the workstations where parts and materials are processed that we overlook the provision of space and placement of supporting services, stations and equipment. Of course, their aggregate space needs should have been detected and planned for in the overall layout. And some may be built into our definitions of machine and operator stations. But if not, the layout must be adjusted now to place and fit them in. The most common supporting services are:

1. Process-related
    - a. Tool & die storage
    - b. Fixture storage
    - c. Gage tables and benches
    - d. Tool set up benches and work area
    - e. Inspection area
    - f. Supply storage
    - g. Trash bins and hoppers
    - h. Empty containers and dunnage
    - i. Holding and recovery tanks
    - j. Utilities or auxiliaries (compressors, control panels, dust collectors, etc.)
    - k. Eye-wash station or other safety equipment
2. Personnel-related
    - a. Desks or work areas for supervisors, leads, or engineers
    - b. Meeting area for team work, if not provided outside of the cell)
    - c. Bulletin board for visual control techniques
    - d. Computer terminals and printers, network drops and taps
    - e. Fax machines and telephones
    - f. Public address speaker
    - g. Document storage
    - h. Ring binder or other printed reference materials and procedures

If these are significant enough to the layout's effectiveness, the planner may want to revisit the use of a relationship chart and activity relationship diagram.

Many of the modifying considerations and practical limitations discussed in Chapter 9 will also be present here in Phase III but localized to the area being planned. Chief among these will be

Material handling methods – at entry and exit points and for moves within the area being planned: Accessibility, internal aisles, conveyor locations, interference at load/unload and set-down points, operator safety with respect to handling equipment…

Materials management and storage – how much must be stored within the area? Use of kitting. Storage equipment, its footprint and servicing by material handling equipment. (Refer to Figure 9-8).

Building features and utilities – column interference, precise locations of walls, openings, pits, foundations, roof vents and access to necessary electrical, water, drains, compressed air…

For detailed layouts based on flow of materials, the planner must also address the always-present other-than-flow relationships between the activities. In manufacturing layouts the most common of these relationships include:

1. Visual control; face-to-face contact and communication between personnel
2. Shared utilities and auxiliaries such as electrical, air, ventilation, chip and fluid recovery, etc.
3. Shared equipment, especially for material handling or service

4. Shared personnel (between operations and stations and potentially with neighboring activity-areas in the overall layout)
5. Noise, contamination, and vibration – often leading to the separation or isolation of equipment
6. Location of tools, gages, and other support equipment close to point of use

When the flow pattern *within an area* is not dictated by the overall layout, it is wise to develop two or more alternatives around the four basic patterns in Figure 11-10. Even within the same flow pattern, alternative layouts will develop from different handling-and-storing methods, machine and station designs and orientations, and different adaptations to the space available.

Adjustments to the Overall Layout

As the detailed layout is worked out, the planner may discover even better arrangements by changing or shifting the space and configuration of areas already allocated in the overall layout. Within practical limits, it is logical to make these adjustments in the overall layout. And it is also logical to make adjustments in the detailed layouts of other adjacent areas being planned. Moving main aisles, relocating

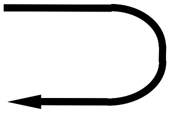
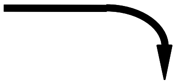
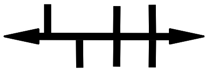
Straight Thru 	1. Easy to understand, follow, schedule, and control. 2. Allows straight, inexpensive handling methods. 3. Easy access on two sides. 4. Avoids congestion at point of delivery and take away.
U-Flow or Circular 	1. Automatically returns product, holding fixtures, and mobile handling equipment to cell entrance. 2. Delivery and take away point are the same; allows convenient handling to and from the cell. 3. Workers in center can assist one another more readily. 4. Easier to assign multiple operations to an operator. Allows easier line balancing.
L-Flow 	1. Allows fitting lengthy series of operations into limited space. 2. Lets feeding cells start on an aisle and end at point of use. 3. May allow isolation of dangerous or costly-to-move equipment in the elbow, with savings in implementation cost and/or two directions for expansion. 4. Easy to segregate in-flow and out-flow of physically different materials, products, supplies, and special services.
Comb or Spine 	1. Lends itself to two-way flow. 2. Well suited to cells with highly variable routings. 3. Allows "fingers/teeth" to be segregated for special requirements. 4. Well-suited to functional cells.

Figure 11-10. Basic flow patterns within activity-areas. These may lead to alternative layouts. Benefits of U-flow can be seen in Figure 11-3. But each has its place. From the booklet: Simplified Systematic Planning of Manufacturing Cells, Richard Muther et al., Management & Industrial Research Publications.

departmental area limits, and altering the position of proposed utility trenches are examples of such adjustments. As a result, it is best not to fix too finally any single detailed area until all detailed areas are planned, or at least until all areas surrounding the one in question are planned. Time will not always permit this; one may have to move ahead with a schedule of installation right behind detail planning. Recognize, however, that in so doing one is foregoing certain opportunities for making improvements.

Checks

Checking the layout before it is finalized is always sound practice. Generally checks are made in one of three ways:

1. Challenging the layout with pre-established or standard check questions
2. Asking others to review it
3. Making further refinements, such as a three-dimensional model

Check Questions involve such challenges as, "What would happen if we oriented the layout 180 degrees? . . . if we flopped it over the other way? . . . Does it comply with safety codes and regulations?" If the plan cannot be justified in the face of these questions, the planner is not yet ready with a recommendation. Other check questions are

Will it increase production?
Will it reduce costs?
Will it improve housekeeping?
Will it eliminate accidents?
Will it produce a better product?
Will it increase floor space?
Will it improve morale?
Will it reduce waste?
Will it reduce scrap?
Will it improve other working conditions?
Will it increase or decrease maintenance?
Will it provide insurance benefits?
Will it provide tax benefits?
Will it improve sanitation?

In addition to these general questions, watching out for the common problems in Figure 11-11 will help to avoid oversights and reduce the number of time-consuming revisions required. Note that item 1 on the list refers to complete templates like that shown in Figure 11-9. The principles in Figure 11-12 may also be helpful.

Reviews can be made individually or in joint meetings. Both are practical. First having individual and then joint meetings on the same project is probably best. These reviews are over and above any solicitation of ideas from these same people or participation by them during the actual planning – which have been emphasized as extremely important, from both a practical and psychological view. Reviews with others include:

Heads of operating departments involved
Heads of supporting-service departments involved
Other staff planning engineers responsible for industrial engineering, materials handling, methods, plant engineering and/or maintenance, office manager, and the like, as practical
Safety director or safety engineer
Personnel director
Your direct supervisor

Issues and Conditions to Watch Out For in Detail Layout

1. Accuracy and completeness of templates.
2. Complete dimensions for all equipment.
3. Location of machine access panels.
4. Location of electrical panels and auxiliary equipment locations.
5. Side access to machines.
6. Operator control panel locations and clearance if mounted on swing arms.
7. Attachment points for utilities and cabling.
8. Size of auxiliary support equipment such as washers, ovens, and storage racks.
9. Extent of tool and fixture storage racks.
10. Location of gage and tool tables and benches relative to machine work areas.
11. Location of scrap baskets, containers or shelves.
12. Direction of flow and points of machine loading and unloading – counter-clockwise and right to left, since most people are right-handed. In single-piece flow situations, this allows machines to be approached and comfortably loaded from the right, while holding the incoming part in the right hand.
13. Ability or need to reverse machine load and unload points (left-hand; right-hand).
14. Straight vs. angled, curved or irregular placement and orientation of machines.
15. Detailed material handling methods within and between machines and workplaces.
16. Design of parts containers and baskets for in-coming items, internal movement, and out-going.
17. Widths and turning radii of conveyors if used.
18. Vertical elevations where overhead clearances and handling may be a problem.
19. Placement and extent of overhead equipment such as fume and exhaust hoods.
20. Position of overhead lighting – watch for glare, reflection, and shadow in undesirable locations.
21. Access and escape routes for all personnel.
22. Overall size and shape of the area relative to boundaries agreed upon in Phases I and II.
23. Integration of the area with other upstream and downstream areas and operations – especially for parts delivery.

Figure 11-11. Things to watch out for during detail layout in manufacturing plants. Adapted from: Planning Manufacturing Cells, Lee Hales & Bruce Andersen, Society of Manufacturing Engineers.

Three-dimensional modeling – physical or with computer graphics – is both a form of checking and a refinement of planning. There is nothing like a model to help others visualize a plan. When others review the planned layout in modeled form, they feel the impact of possible improvements. And by going through the extra refinement of building a model, the planner finds still additional improvements to make in the layout.

Characteristics of Lean Layouts

1. Output of each operation or station is adjacent to the input of the next.
2. Close placement and orientation of machines allow one operator to run several machines.
3. Narrow machine faces, enabled by overhead control panels and vertical door openings.
4. When U-shape flow pattern is appropriate, first and last operation should be adjacent so that the same operator can perform them.
5. Each operator's start and finish points are close together.
6. One- or single-piece, balanced flow and material handling between operations.
7. Where part characteristics permit, container-less flow between operations, with operators performing the movement.
8. Where part characteristics permit, use of chutes and slides for incoming parts, to compress space and avoid the need for containers and their handling.
9. Where single-piece or container-less flow is impractical, use of small batches, small containers, and small buffers.
10. Small, narrow handling equipment, if it must be used at all.
11. Overhead handling equipment where appropriate to reduce aisle space required.
12. Tools, gages and supplies located close to points of use, with tools and fixtures dedicated to each machine or station.
13. Avoidance of fixed barriers (conveyors, railings, machinery, auxiliary cabinets, control panels…) along operator paths within or between stations.
14. Provision of flexibility for rapid and easy rearrangement.
15. Raw materials and incoming parts stored close to points of use and easily obtained by operators.
16. Parts or materials stockrooms or "supermarkets" close to the stations and areas that they supply.
17. In overall layouts where one activity-area feeds another, the output point of the upstream area should be adjacent to or nearby the input point for the downstream area. The output point of the last area in a processing sequence should be close to the shipping docks or to its internal customer operation.

Figure 11-12. The term "lean" is used here to mean efficient, effective and free of wasteful practices. This list contains the common characteristics of lean or "waste-free" layouts and can be used as a checklist. Most of these principles are simply time-honored common sense ways to minimize material handling effort and lost operator time.

Moreover, models can be used to check for interference between fully-extended equipment and material handling clearances by moving models of the material, container, or transport equipment right through its route.

Mock-ups and walk-throughs at full scale – perhaps with the operators themselves are occasionally a practical form of visualization and adjustment of detailed layouts. Mock-ups as a method of visualization are discussed in Chapter 13.

Evaluation and Approval

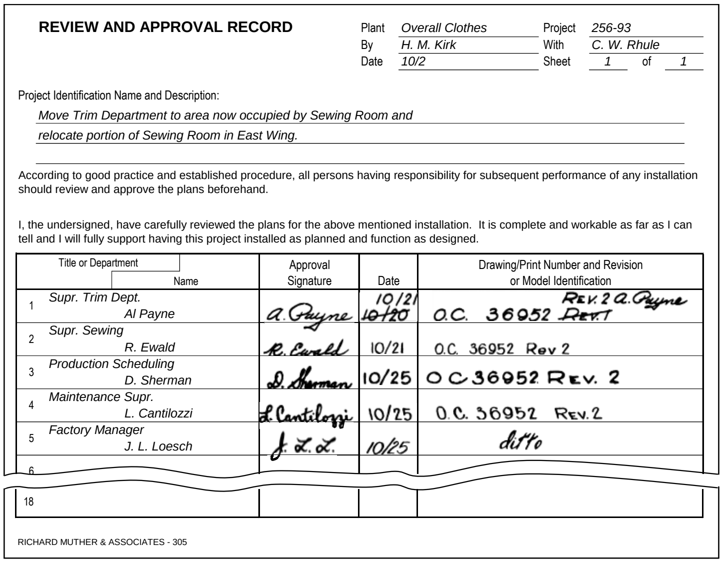
It is common in detail planning to adjust one’s way to a single plan – the one that is to be approved. But it is much better practice to present two or more significantly different alternatives, evaluate them based on costs and intangibles, and then select the best. Of course, this selected plan may still be refined, right up to installation. But formal evaluation of alternatives in Section 5 of the SLP pattern promotes participation by operating people and builds commitment to make the selected layout work.

In Chapter 10, we discussed getting approval for the general overall layout from higher management since long-range or major commitments are being made. If time permits and when planning new construction or a major capital investment, it is good practice to have a topside reappraisal of the layout details before the final authorization of funds.

At the same time, in simple rearrangements or where there is no major investment, the evaluation of alternatives, selection and approval of the detailed layout plans logically rests "down the line." As a general rule, this final approval lies with the person responsible for making the general overall layout function. This person usually goes along with detailed layouts which do not violently readjust the already-approved overall layout, and that are agreed to by subordinates in their areas. Approval for detailed layouts is sought from:

1. The people responsible for making each area operate
2. The people in charge of the services which support the operating areas
3. Safety personnel and interested engineering people
4. The group(s) responsible for making the installation
5. The operations manager for the area covered by the overall layout

Regardless of whom you ask to evaluate or approve the detailed layout, retain the consistency of the SLP conventions. It is helpful to others when the planner always shows the conveyors and storage equipment in orange or yellow, or when four lines always mean the greatest, most significant, or best. Indeed, the SLP conventions can serve as an added means of communications, assuming the plans contain adequate information to begin with.



REVIEW AND APPROVAL RECORD

Plant *Overall Clothes* Project *256-93*
By *H. M. Kirk* With *C. W. Rhule*
Date *10/2* Sheet *1* of *1*

Project Identification Name and Description:
Move Trim Department to area now occupied by Sewing Room and relocate portion of Sewing Room in East Wing.

According to good practice and established procedure, all persons having responsibility for subsequent performance of any installation should review and approve the plans beforehand.

I, the undersigned, have carefully reviewed the plans for the above mentioned installation. It is complete and workable as far as I can tell and I will fully support having this project installed as planned and function as designed.

	Title or Department Name	Approval Signature	Date	Drawing/Print Number and Revision or Model Identification
1	*Supr. Trim Dept.* *Al Payne*	A. Payne	10/21 ~~10/20~~	O.C. 36952 ~~Rev. 1~~ Rev. 2 A. Payne
2	*Supr. Sewing* *R. Ewald*	R. Ewald	10/21	O.C. 36952 Rev 2
3	*Production Scheduling* *D. Sherman*	D. Sherman	10/25	O C 36952 Rev. 2
4	*Maintenance Supr.* *L. Cantilozzi*	L. Cantilozzi	10/25	O.C. 36952 Rev. 2
5	*Factory Manager* *J. L. Loesch*	J. L. L.	10/25	ditto
6				
18				

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Figure 11-13. Review and Approval Record is basically a sign-off sheet – paper or perhaps electronic – signifying that the individual concerned has reviewed, and is in agreement with, the proposed layout.

Because of the many people involved, it is good practice to have each approver sign the detailed layout plan or an approval record similar to Figure 11-13. This does not preclude them changing their minds later on, or think up a further improvement. The sign-off encourages critical examination and makes it more difficult for people to change their minds. The layout would never be installed if everyone involved were given a free hand with changes. In any case, if new or unforeseen possibilities crop up later on, or if the layout planner has made a serious error, no sign-off is going to hold back making a change.

In fact, changes during installation are bound to occur, and should be expected. Planning costs would be astronomical if the planner tried to avoid every possible change. No; what the planner wants is:

1. To have each person involved take time from an otherwise busy day to study the proposed layout
2. To have each person understand how the layout is planned to operate so each will get full value from the layout later on
3. To have each person agree that the layout is satisfactory and workable based on the plan being reviewed
4. To have an organized way of checking off those who have reviewed the layout plan
5. To force the layout planner actually to check with others to be sure all good ideas are incorporated in the plans
6. To create feelings on the part of those responsible for the functioning of the layout that they have been consulted and are not being "pushed around"
7. To show a person with final responsibility for approval that subordinates are all in agreement

The sign-off procedure ensures that these advantages are obtained. And, if it is made a formal procedure, it saves the layout planner time in getting the check-review and approval. When "the procedure" – not the "individual" – calls for sign-off approvals, relations are on a businesslike basis rather than a personal one. This is an important distinction when subordinate layout planners must ask those in superior positions for some written indication of their approvals.

Detail Planning Examples

In the introduction to Part Three, the sequence of SLP planning for an overall layout is illustrated. Figure 11-14 shows the sequence of steps for planning the detailed layout of one department, Activity No.2 – Silk Screen.

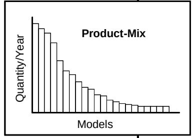
Note that each step of the pattern of procedures is considered. In other departmental areas, different emphasis is placed on certain steps and different kinds of worksheets are used.

Figure 11-14. An illustrative example of the application of SLP in Phase III – Detailed Layout Planning. This is Activity Area 2 (Silk Screening Department) of the overall block layout, the planning sequence of which was illustrated in the Introduction to Part Three

PLANNING A DETAIL LAYOUT

Key Input Data for:
② Silk Screen Department

P Q R S T
② ② ② ② ②

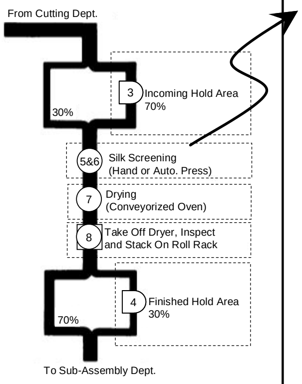


List of Activity Areas
1. Entrance (From Cut)
2. Exit (To Assembly)
3. Incoming Hold
4. Finished Hold

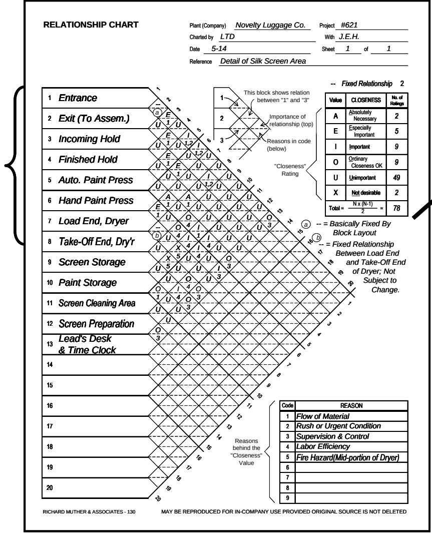
13. Foreman's Desk

1. Activity-Areas

Flow of Materials in Silk Screening Dept.
(4,000 Bags per Day)



2. Flow of Materials



RELATIONSHIP CHART

Plant (Company) *Novelty Luggage Co.* Project *#621*
Charted by *LTD* With *J.E.H.*
Date *5-14* Sheet *1* of *1*
Reference *Detail of Silk Screen Area*

1. *Entrance*
2. *Exit (To Assem.)*
3. *Incoming Hold*
4. *Finished Hold*
5. *Auto. Paint Press*
6. *Hand Paint Press*
7. *Load End, Dryer*
8. *Take-Off End, Dry'r*
9. *Screen Storage*
10. *Paint Storage*
11. *Screen Cleaning Area*
12. *Screen Preparation*
13. *Lead's Desk & Time Clock*
14.
15.
16.
17.
18.
19.
20.

-- *Fixed Relationship* 2

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	2
E	Especially Important	5
I	Important	9
O	Ordinary Closeness OK	9
U	Unimportant	49
X	Not desirable	2
Total = $\frac{N \times (N-1)}{2}$ =		78

ⓐ -- = *Basically Fixed By Block Layout*
ⓑ -- = *Fixed Relationship Between Load End and Take-Off End of Dryer; Not Subject to Change.*

Reasons behind the "Closeness" Value

Code	REASON
1	*Flow of Material*
2	*Rush or Urgent Condition*
3	*Supervision & Control*
4	*Labor Efficiency*
5	*Fire Hazard(Mid-portion of Dryer)*
6	
7	
8	
9	

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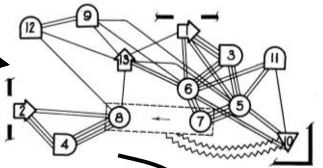
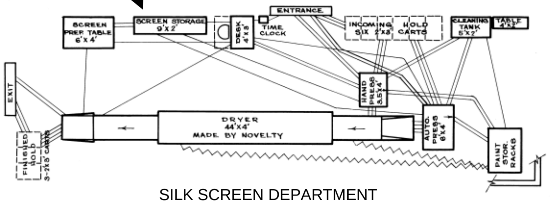
2. Relationships (Flow & Other)

SILK SCREEN DEPARTMENT
ACTIVITY-RELATIONSHIP DIAGRAM



2. Relationship Diagram



SILK SCREEN DEPARTMENT

ROUGH ARRANGEMENT
OF TEMPLATES

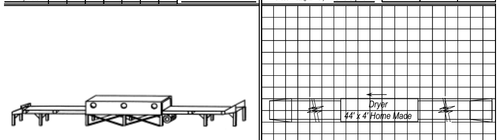
MACHINERY & EQUIPMENT LAYOUT DATA

Company/Unit/Plant *Novelty Luggage* Project *#621*
Prepared by *LTD* With ______ Date *5-17*
Water *No* Steam *No* Drains ______
Comp. Air *No* Gas *Yes*
Foundation *No* Pit *No* Level/Lag ______
Exhaust *Yes* Sp'l. Elect. ______
Max. Height ______
Weight (less attatch.) ______

Electrical	H.P.	Volts	Cycle	Phase	Amps.		
Drive Motor	1	220	60	3			
Auxiliary Motor							
Auxiliary Motor							

Name/Type *Dryer* File ______
Manufacturer *Novelty Luggage* Size/Model *44 ft.*
Speed/Capacity *10 Ft./Min.* Signif. Ident. ______
Left-Right *44 ft.*
Front-Back *4 ft.*
Net Floor Area *176 sq. ft.*
Worker/Main.Area *88 sq. ft.*
Material Set-down *79 sq. ft.*
Area for Aisles *--*
Service/Other *--*
Gross Area (plan for) *345 sq. ft.*

Co. Mach./Equip. Identification Numbers Covered by this Sheet



ELEVATION SKETCH OF PHOTO SOURCE
Reference Notations/changes

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3. Space Requirements

MACHINERY & EQUIPMENT AREA & FEATURES SHEET

Company/Plant *Novelty Luggage* Bldg/Dept/Area *Silk Screen Dept.*
Project *#621*
By *LTD* With ______
Date *5-15* Sheet *1* of *1*

Identification Data		Space									Physical Features Required															
Machine or Equipment Identification Number	Name and/or Description	Left – Right	Front – Back	Height	Area for Machinery or Equip. in Sq. ft.	Operator(s) Work & Maintenance Area	Material Set-down Area Sq. ft.	Total Area each Machine or piece of Equip. Sq. ft.	No. of Machines/Equip.	Total Net Area* (in Sq. ft.)	110 - A.C.	120 - A.C.	Other Power	Ampere Rating		Water	Steam	Drains	Compressed Air	Other Piping	Foundation/Pit	Exhaust/Hood	Dust Collector			Comments - - - - - Shape/Configuration Special Requirements
1	*Entrance from Cutting*									--	-	-	--	--		-	-	-	-	--	-	-	-			
2	*Exit to Assembly*									--	-	-	--	--		-	-	-	-	--	-	-	-			
3	*Incoming Hold*							ⓐ 36	--	36	-	-	--	--		-	-	-	-	--	-	-	-			
4	*Finished Hold*							ⓑ 18	--	18	-	-	--	--		-	-	-	-	--	-	-	-			
5	*Auto. Paint Press*	6'	4'	5'	24	12	52	88	1	88	✓	-	--	--		-	-	-	✓	--	-	-	-			
6	*Hand Paint Pess*	3.5'	4'	5'	14	7	39	60	1	60	✓	-	--	--		-	-	-	✓	--	-	-	-			
7								--		--	-	-	--	--		-	-	-	-	--	-	-	-			
8	*Auto. Dryer*	44'	4'	4'	176	88	79	345	1	345	✓	✓	--	--		-	-	-	-	--	-	✓	-			
9	*Silk Screen Storage Cabinet*	9'	2'	7'	18	18	--	36	1	36	-	-	--	--		-	-	-	-	--	-	-	-			
10	*Paint Storage* ⓒ							20	--	20	✓	-	--	--		✓	-	-	-	--	-	✓	-			
11	*Cleaning Tank & Table* ⓓ	5'	2'	3'	10	10	--	20	2	36	✓	-	--	--		✓	-	✓	✓	--	-	-	-			
12	*Silk Screen Prep. Table*	6'	4'	3'	24	12	--	36	1	36	✓	-	--	--		-	-	-	-	--	-	-	-			
13	*Foreman's Desk & Time Clock* ⓔ	4'	3'	3'	12	12	--	24	2	28	✓	-	--	--		-	-	-	-	--	-	-	-			

* Required space for main or delivery aisles and service areas not included.

Total Net Area Required* (in *Sq. ft.*) *700*
Aisles *325*
Services *--*
Other *--*
Total Area Req'd. *1025*

Space available as planned in Phase II is 1,100 Sq. Ft. -- Balance O.K., LTD 5-15.

Reference Notes:
a. *Room for six 3' x 2' carts*
b. *Room for three 3' x 2' carts*
c. *Paint storage should be out of the way against the wall.*
d. *Table is 4' x 2' with 2' for worker -- Total 16 sq. ft.*
e. *Allow 4 sq. ft. for time clock*

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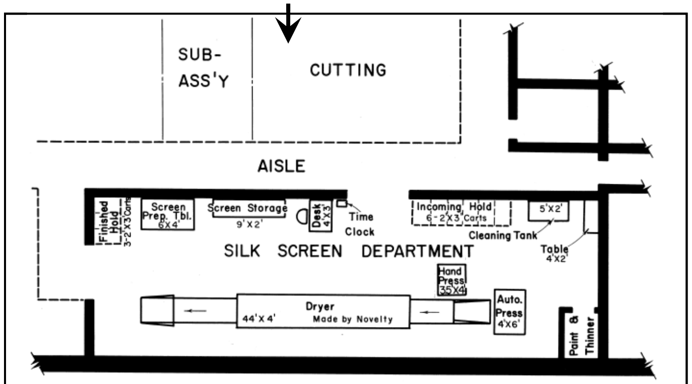
3. Space Relationship Diagram

4. Alternative Layouts, Modification & Refinement

5. Evaluation & Selection



DETAILED LAYOUT OF SILK SCREEN DEPARTMENT

Scale: 1/8" = 1'-0"

5. Selected Layout Plan Phase III – Silk Screen Department

The example in Figure 11-15 shows the detail planning for a larger and more complicated layout. Here, SLP has been used to plan the sheet metal fabrication department in a large manufacturing plant. The flow lines on the process chart were quantified based on numbers of parts and moves per day of pallets and carts. Each flow was converted to a vowel-letter rating and posted on a Relationship Chart where other-than-flow relationships were added. A relationship diagram was made to guide the adjustment of scaled templates into several alternative layouts. These were then rated with the weighted factor method to select the best plan.

Simplified Systematic Layout Planning

A short form of SLP is often useful in Phase III planning. For those who have mastered the full SLP methodology, it offers no particular advantage so far as actual planning is concerned. But, for new planners, or for small departments where the supervisor wishes to layout his or her own area, it can be of real value.

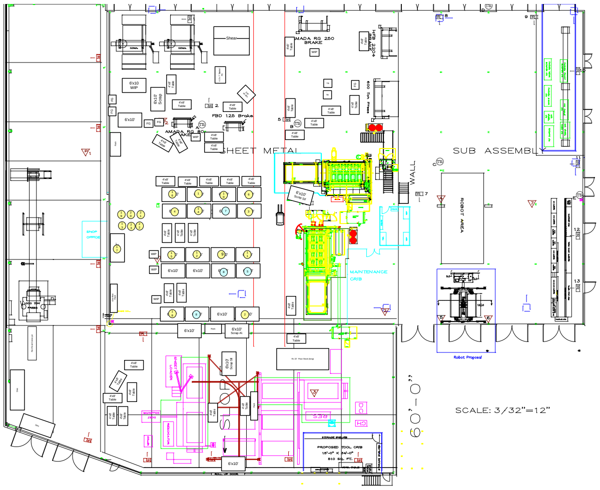
Simplified SLP is described briefly in Appendix XIV. Essentially, it condenses Phases II and III into a six-step pattern, as shown in Figure 11-16. Note that Simplified SLP uses only one symbol – the circle – for relationship diagramming, does not employ color or shading codes, and provides no quantitative means of determining flow of materials. It should not be used for large projects or projects having a major flow of materials. Rather, it lends itself especially well to layout planning of small areas like offices, laboratories, service shops, tool rooms, and similar "non-production" activities.

The experienced planner should be cognizant of the very practical use to be made of Simplified SLP to subcontract the layout planning of certain areas to those responsible for operating that area. This does not mean releasing a proprietary right; on the contrary, the planner can expand his or her reach by indirectly and temporarily getting others to participate. Others trained to use Simplified SLP (the training can be done for a group of supervisors in one day) can apply its simple organized procedures. The planner assists each trainee as needed, and audits the layouts submitted. Thus the planner retains responsibility for layout planning but demonstrates the ability to get results from others. Most important, the planner can save time to devote to the critical areas that require planning expertise.

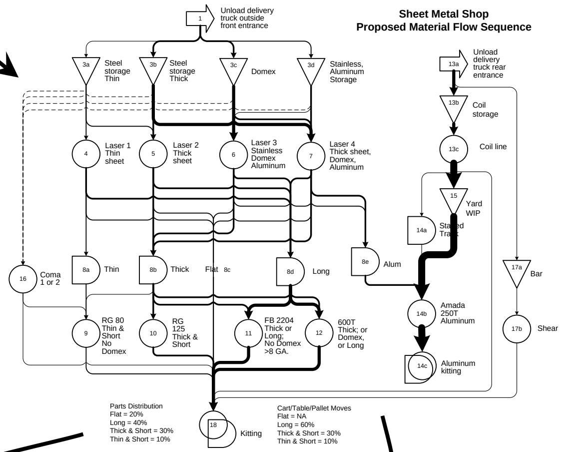
Figure 11-15. Example of detail layout planning with SLP. Relative flows of materials quantified on the process chart and converted to vowel-letter ratings. Combined flow and other relationship chart and diagram guides placement of scaled templates. This sheet metal “job shop” makes several thousand parts on laser cutters and a variety of punches and presses. The layout project began by challenging the current process to identify improvements. Improved flow paths were based on families of parts with common material, gauges, and lengths. Handling equipment remained unchanged with rolling steel tables used to move, hold and kit stacks of parts between operations. Other-than-flow relationships involved shared operators and handling equipment, lines of sight for supervision and communication, safety, and noise. The planning was performed by a team of supervisors and operators in a one-week project, receiving top management approval on the final morning.

DETAIL LAYOUT PLANNING WITH SLP

Location & existing layout



Improved process & flow analysis

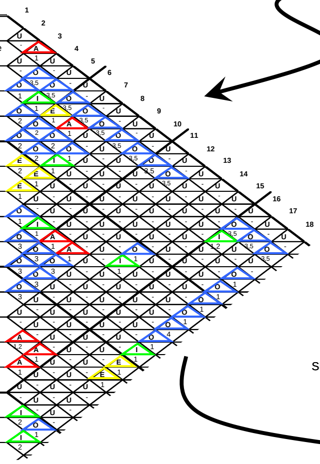


Combined Relationship Chart – Flow & Other

Code	Reason
1	Material Flow
2	Shared personnel/staffing
3	Ease of supervision
4	Parts tracking
5	Convenience

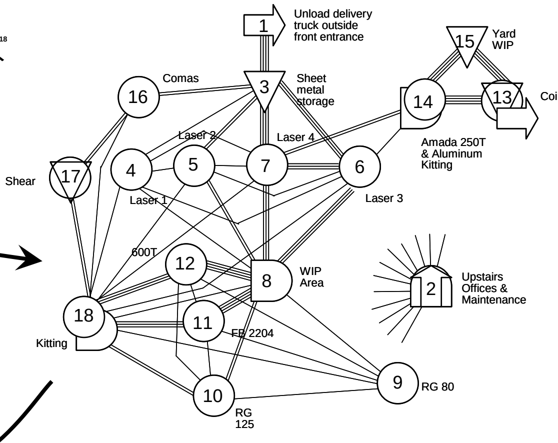
OPERATIONS

No.	Name/Description
1	Truck Unload
2	Upstairs offices & maintenance
3	Sheet Storage
4	Thin Laser #1
5	Thick Laser #2
6	Stainless/ Al. #3
7	Thick Stainless / Al #4
8	WIP Storage on Tables
9	RG80 Press
10	RG125 Press
11	FB 2204 Press
12	600 T
13	Coil Press Line
14	Amada Press & Alum. Kitting
15	Alum Yard Storage
16	Coma 1& 2
17	Flat stock Shear
18	Kitting (Steel)

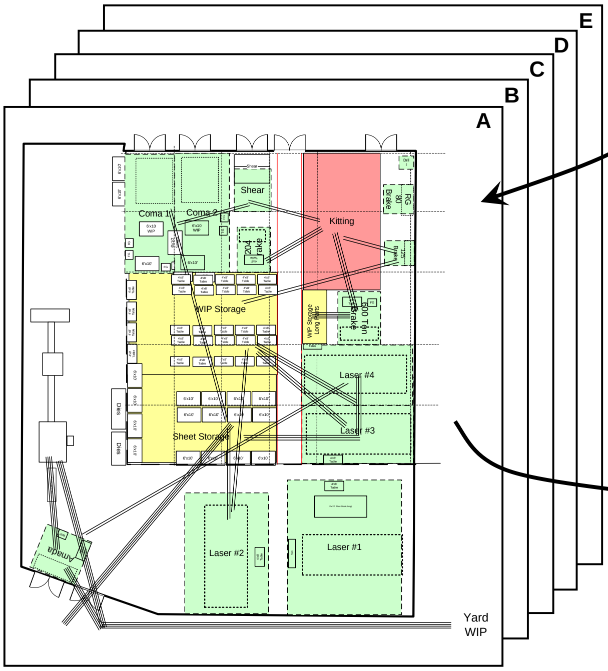


Relationship Diagram

Sheet Metal Storage Activity-Relationship Diagram



Space & Alternative Layouts



Evaluation

EVALUATING ALTERNATIVES

Plant *Gainesville*

Project *Sheet Metal Rearrangement* Date *12/15*

Weights set by *SB, LH, JJ* Tally by *LH*

Ratings by *SB, LH, JJ* Approved by ______

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important	X	Not Acceptable

Description of Alternatives:

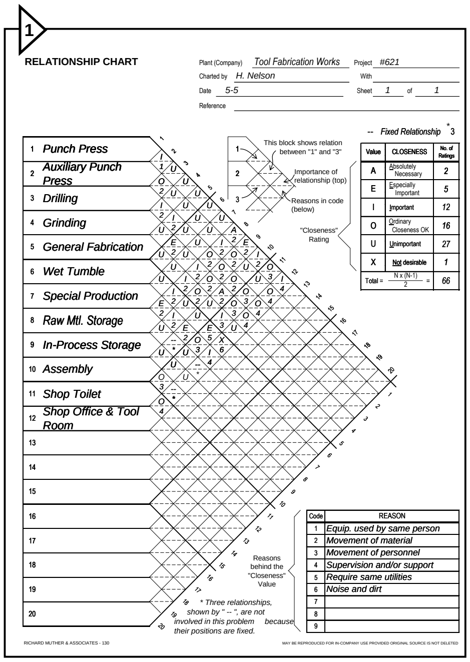
Enter a brief phrase identifying each alternative.

A. *No equipment moves*
B. *Amada stays; Relocate Lasers 3 & 4*
C. *Amada moves; Relocate Lasers 3 & 4 & all Brakes*
D. *Lasers 3 & 4 stay; Comas move & all presses*
E. *Everything moves*
F. *Large kitting area across rear*

FACTOR / CONSIDERATION	WT.	ALTERNATIVE A	B	C	D	E	F
1 *Improved material flow*	*10*	*U* / *0*	*O* / *10*	*E* / *30*	*E* / *30*	*A* / *40*	*A* / *40*
2 *Ease of implementation*	*3*	*A* / *12*	*I* / *6*	*O* / *3*	*E* / *9*	*O* / *3*	*O* / *3*
3 *Impact on operator efficiency*	*9*	*U* / *0*	*I*	*E* / *27*	*A* / *36*	*A* / *36*	*A* / *36*
4 *Effective use of space*	*9*	*O* / *9*	*I* / *18*	*I* / *18*	*E* / *27*	*A* / *36*	*A* / *36*
Totals		*21*	*34*	*78*	*102*	*115*	*115*

Selected Plan

PLANNING A FACTORY DEPARTMENT LAYOUT



1

RELATIONSHIP CHART

Plant (Company) *Tool Fabrication Works* Project *#621*
Charted by *H. Nelson* With
Date *5-5* Sheet *1* of *1*
Reference

No.	Activity	2	3	4	5	6	7	8	9	10	11	12
1	*Punch Press*	I 1	U	U	U	U	U	A 2	E 2	I 2	O 3	I 4
2	*Auxiliary Punch Press*		O 2	U	U	U	U	I 2	O 2	U	U	O 4
3	*Drilling*			I 2	I 2	U	U	O 2	O 2	O 2	O 3	O 4
4	*Grinding*				U	E 2	U	I 2	O 2	A 2	O 3	O 4
5	*General Fabrication*					U	U	I 2	O 2	U	I 3	U
6	*Wet Tumble*						U	I 2	U	U	E 5	X 6
7	*Special Production*							E 2	I 2	E 2	O 3	I 4
8	*Raw Mtl. Storage*								U	-- *	U	-- *
9	*In-Process Storage*									U	U	U
10	*Assembly*										O 3	-- *
11	*Shop Toilet*											O 4
12	*Shop Office & Tool Room*											
13												
14												
15												
16												
17												
18												
19												
20												

This block shows relation between "1" and "3"

Importance of relationship (top)

Reasons in code (below)

"Closeness" Rating

-- *Fixed Relationship* *3

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	2
E	Especially Important	5
I	Important	12
O	Ordinary Closeness OK	16
U	Unimportant	27
X	Not desirable	1
Total = $\frac{N \times (N-1)}{2}$ =		66

Reasons behind the "Closeness" Value

Code	REASON
1	*Equip. used by same person*
2	*Movement of material*
3	*Movement of personnel*
4	*Supervision and/or support*
5	*Require same utilities*
6	*Noise and dirt*
7	
8	
9	

* *Three relationships, shown by " -- ", are not involved in this problem because their positions are fixed.*

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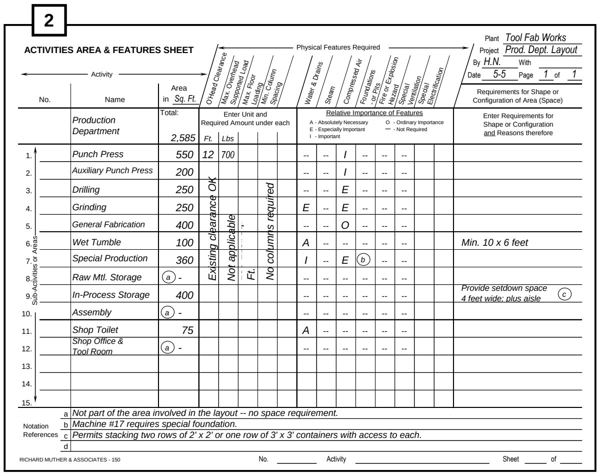


2

ACTIVITIES AREA & FEATURES SHEET

Plant *Tool Fab Works*
Project *Prod. Dept. Layout*
By *H.N.* With
Date *5-5* Page *1* of *1*

Physical Features Required

Enter Unit and Required Amount under each

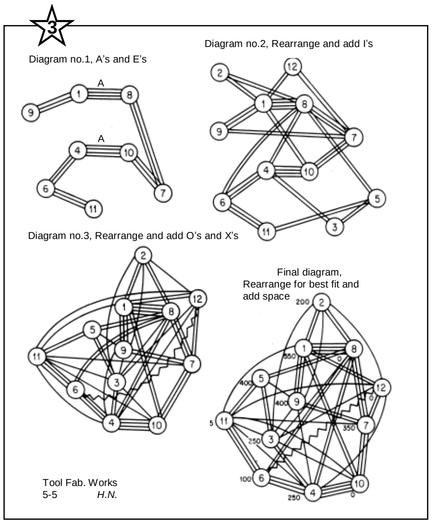
Relative Importance of Features: A - Absolutely Necessary; E - Especially Important; I - Important; O - Ordinary Importance; — - Not Required

No.	Name	Area in *Sq. Ft.*	O'Head Clearance	Max. Overhead Supported Load	Max. Floor Loading	Min. Column Spacing		Water & Drains	Steam	Compressed Air	Foundations or Pits	Fire or Explosion Hazard	Special Ventilation	Special Electrification		Requirements for Shape or Configuration of Area (Space)
	Production Department	Total: *2,585*	Ft.	Lbs												Enter Requirements for Shape or Configuration and Reasons therefore
1.	*Punch Press*	*550*	*12*	*700*				--	--	*I*	--	--	--			
2.	*Auxiliary Punch Press*	*200*						--	--	*I*	--	--	--			
3.	*Drilling*	*250*	*Existing clearance OK*	*Not applicable*		*No columns required*		--	--	*E*	--	--	--			
4.	*Grinding*	*250*						*E*	--	*E*	--	--	--			
5.	*General Fabrication*	*400*						--	--	*O*	--	--	--			
6.	*Wet Tumble*	*100*						*A*	--	--	--	--	--			*Min. 10 x 6 feet*
7.	*Special Production*	*360*						*I*	--	*E*	ⓑ	--	--			
8.	*Raw Mtl. Storage*	ⓐ -			*Ft.*			--	--	--	--	--	--			
9.	*In-Process Storage*	*400*						--	--	--	--	--	--			*Provide setdown space 4 feet wide; plus aisle* ⓒ
10.	*Assembly*	ⓐ -						--	--	--	--	--	--			
11.	*Shop Toilet*	*75*						*A*	--	--	--	--	--			
12.	*Shop Office & Tool Room*	ⓐ -						--	--	--	--	--	--			
13.																
14.																
15.																

Sub-Activities or Areas

Notation References
a *Not part of the area involved in the layout -- no space requirement.*
b *Machine #17 requires special foundation.*
c *Permits stacking two rows of 2' x 2' or one row of 3' x 3' containers with access to each.*
d

RICHARD MUTHER & ASSOCIATES - 150 No. ______ Activity ______ Sheet ____ of ____



3

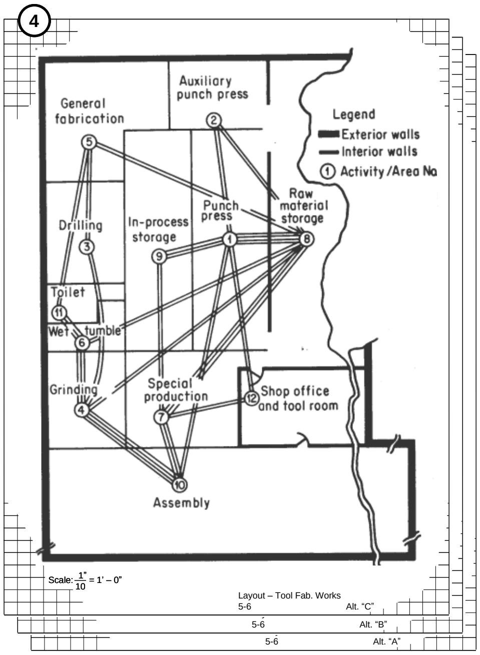
Diagram no.1, A's and E's

Diagram no.2, Rearrange and add I's

Diagram no.3, Rearrange and add O's and X's

Final diagram, Rearrange for best fit and add space

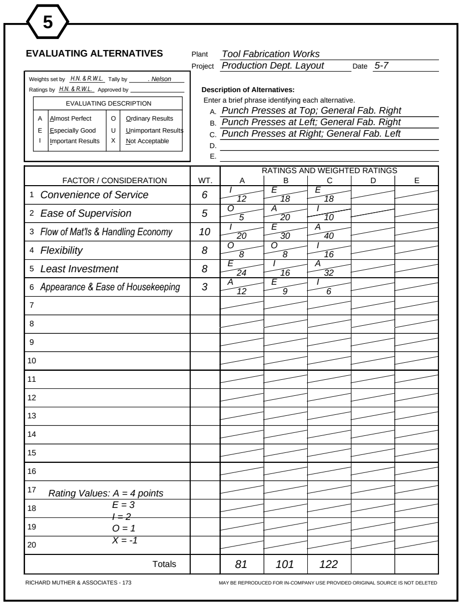
Tool Fab. Works
5-5 *H.N.*



4

Scale: $\frac{1"}{10}$ = 1' – 0"

Layout – Tool Fab. Works
5-6 Alt. "C"
5-6 Alt. "B"
5-6 Alt. "A"



5

EVALUATING ALTERNATIVES

Plant *Tool Fabrication Works*
Project *Production Dept. Layout* Date *5-7*

Weights set by *H.N. & R.W.L.* Tally by *. Nelson*
Ratings by *H.N. & R.W.L.* Approved by

EVALUATING DESCRIPTION

A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant Results
I	Important Results	X	Not Acceptable

Description of Alternatives:
Enter a brief phrase identifying each alternative.
A. *Punch Presses at Top; General Fab. Right*
B. *Punch Presses at Left; General Fab. Right*
C. *Punch Presses at Right; General Fab. Left*
D.
E.

	FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1	*Convenience of Service*	*6*	*I 12*	*E 18*	*E 18*		
2	*Ease of Supervision*	*5*	*O 5*	*A 20*	*I 10*		
3	*Flow of Mat'ls & Handling Economy*	*10*	*I 20*	*E 30*	*A 40*		
4	*Flexibility*	*8*	*O 8*	*O 8*	*I 16*		
5	*Least Investment*	*8*	*E 24*	*I 16*	*A 32*		
6	*Appearance & Ease of Housekeeping*	*3*	*A 12*	*E 9*	*I 6*		
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17	*Rating Values: A = 4 points*						
18	*E = 3* *I = 2*						
19	*O = 1*						
20	*X = -1*						
	Totals		*81*	*101*	*122*		

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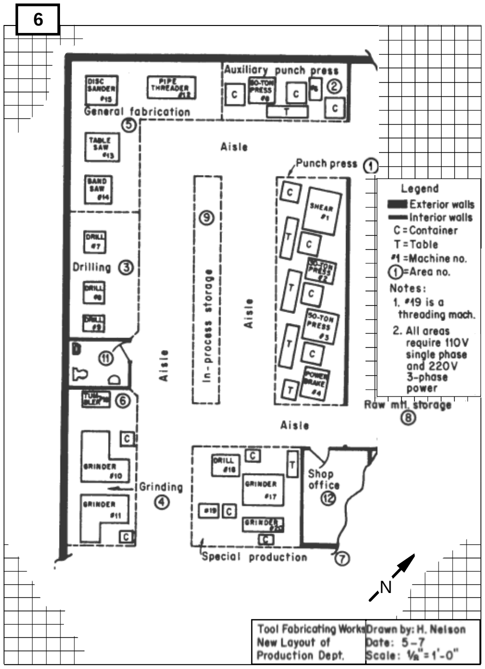


6

Tool Fabricating Works New Layout of Production Dept.	Drawn by: H. Nelson Date: 5–7 Scale: 1/8" = 1'-0"

Figure 11-16. Example of the application of Simplified SLP to the planning of a small factory layout. Note the absence of a formal flow analysis. Flow is simply considered and rated along with other reasons for closeness.

Chapter 12

Workplace Layout

In Chapter 11 we discussed detail layout procedures to locate each individual machine and piece of equipment *within an activity-area*. Usually this machinery and equipment encompasses several operator workplaces that will be laid out during the normal course of adjustment. That is, the workplace layouts will “take care of themselves.” The planner may mentally envision alternative arrangements *within a workplace*, and may even briefly visualize some of these with templates or sketches, but does not take time to analyze and record internal workplace relationships, or the details of the space – beyond that already represented in the templates. Nor does the planner develop two or more alternative workplace layouts and then subject them to formal evaluation to select the best. But there are times when such formal planning does make sense for a single workplace or station. This chapter addresses those situations and their planning.

The Value of Workplace Layout

Layout planning time is largely a function of the number of objects to be placed. So each time we “drop down” one level in physical planning – from site to plant, from plant to activity-area, from activity-area to workplace – if we divide the area being planned into the same number of entities, the time will be about the same. This means that planning a single workstation could take as much or more time than the overall plan for an entire plant or site! But such an investment may be worthwhile when:

1. The workplace will be replicated many times, so its total impact on investment and/or operating cost is significant
2. The workplace is new and unfamiliar and will be highly-fixed and costly to modify after installation if problems are discovered
3. The workplace involves custom-designed or custom-configured machinery and equipment being built by outside suppliers or integrators – and driven primarily by process engineering considerations
4. Space is costly or limited and the planner needs to squeeze out any waste
5. Existing workplaces are not standardized and this affects productivity, cycle time, supervision and appraisal of operator performance
6. Existing workplaces are a source of hazard or injury
7. Operators are resisting a proposed detail area layout because they cannot see or do not understand the workplaces within it; or they do not feel that all of their needs have been considered

As the illustrations in this chapter will show, much of the Systematic Layout Planning (SLP) procedure applies directly to workplace layout. However, some terminology differs to fit the small nature of the layout, and some working forms, conventions and techniques are adapted to address the 3-dimensional nature of the planning.

Workplace Layout in SLP

Workplace layout finalizes the position of all objects – machines, controls, work surfaces, parts and materials, hand tools, fixtures, parts bins, and other smaller pieces of equipment. Here the planner is working with the limits of human motion at the machine or bench, and with clearances and distances between various elements of the workplace. The resulting layout may change or adjust the results of the higher-level area layout and even some aspects of the process itself.

For convenience and ease of project management, and to avoid unnecessary loops through detail *area layout*, it is often most practical to perform *workplace layout* in Phase III Detail Layout, during Section 4 – Modifications and Limitations. However, workplace layout should be performed much earlier, even in Phase II, when new, different and long-lead-time equipment is involved, or perhaps in conjunction with line balancing for labor-intensive detail layouts. Once workplace layouts have been finalized, alternative detailed plans can be evaluated and approved in Section 5 of the SLP pattern. Any unresolved workplace issues, or unfinished design can be completed in Phase IV Installation.

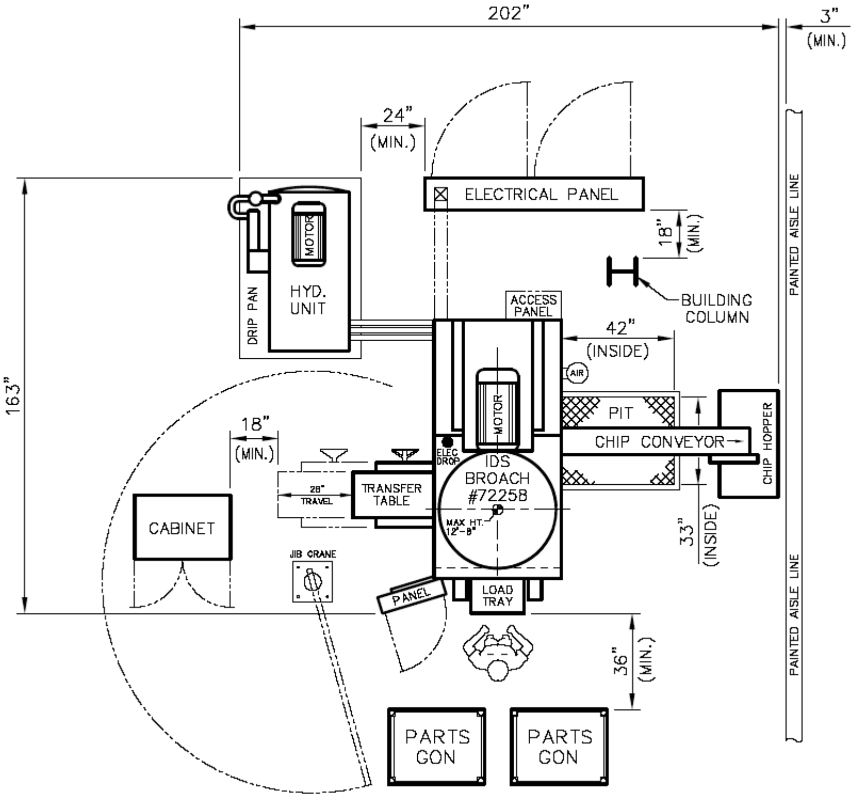
Types of Workplaces

Workplaces are as varied as the facilities and operations in which they are found. From a planning perspective, three types are common in manufacturing plants.

1. Machine- or equipment dominated – the operator runs or tends one or more pieces of machinery or equipment. Configuration is largely determined by the needs of the process and the nature of the machinery. Robotic stations are a special case. Fully-automated flexible machining centers and automated assembly systems are also “workplaces” of a sort and need layouts. But we will consider these and similar installations to be part of machine design and outside the scope of this book.
2. Labor-intensive bench work – items, parts, materials or products are presented, handled and processed by one or more people. Most common are assembly, testing, inspection, and packaging.
3. Assembly lines – operators work beside a line, attaching items and performing operations on a work piece that is moved through or past their stations.

Machinery and Equipment Workplaces

When working with existing machinery, complete and detailed templates are essential. Figure 12-1 lists 25 things that you should know to make good machinery and equipment layouts. The need for floor pits, trenches, pads, and foundations will require interaction with the plant engineer. So also will column- and overhead-supported handling equipment, and the need for exhaust hoods, dust collection, ventilation, and the like. Try to control and carefully place the attachment points for utilities: air, water, drain pipes, gas, and electrical. When these are inaccessible or widely separated, the station will be more costly to service and maintain and eventually to move. If the planner is stuck with existing machines there may be little that can be done. But when new machines are being designed and purchased, the principles of machine design in Figure 12-2 should be observed.



1. Chip or waste conveyors and their hoppers, tubs or carts
2. Hand wheels
3. Maximum table travel in all directions
4. Hydraulic tanks including pans
5. Swing of turrets (turret lathes)
6. Swing of radial drill arms
7. Electrical control cabinets
8. Buss duct runs on transfer lines
9. Air and hydraulic lines as part of a machine
10. Location of machine access panels
11. Doors to control panels and gear boxes in open position.
12. Operator's normal position (show with symbol or arrow).
13. Left-to-right dimension across front of machine.
14. Front-to-back dimensions.
15. Point of maximum height.
16. Center line of work tables or spindles when the facing direction of the machine may be unclear.
17. Machine number and name or type.
18. Status: available, in storage, at another plant, new, on order, etc.
19. Work platforms when necessary, measured to outside dimensions.
20. Pits, measured to inside dimensions.
21. Isolated floor, measured to outside dimensions.
22. Position of motor
23. Positions of control panel, switches or adjustment
24. Positions of electrical, air connection
25. Minimum clearances between:
    a. Moving parts and stationary objects (racks, cabinets, tubs, etc.)
    b. Machine extremities
    c. Clearance from permanent support posts
    d. Machine and work part tub stored in front of machine… allow additional space when operator’s back is to moving part on another machine.
    e. Machine extremity, containers, conveyor, etc. and aisle line.
    f. Jib crane mast and machine extremity.

Figure 12-1. What the workplace planner should know about machine and equipment stations. Templates should contain as much of this information as possible. Time spent learning and incorporating the 25 things listed here will save time and expense later as oversights are detected and corrected. Artwork courtesy of Integrity Design Services.

Principles of Machine Design for Effective Workplace Layout

1. Minimize machine width, especially the side-to-side dimensions and working area at the operator's position. Narrow machine fronts allow closer placement of machines, promoting single-piece flow and the ability of one operator to run two or more machines. Target working area 24 inches wide, or the length of the part -- whichever is greater.
2. Vertical door openings, rather than side-to-side, to minimize width.
3. Minimize the size of control cabinets and panels.
4. Place operator displays above and close in to minimize overall machine width.
5. Use low-cost, industry-standard controls – electrical, electronic, pneumatic, and hydraulic. This will promote lower overall cost and greater ability to justify new and dedicated machinery.
6. Modify or redesign machines to eliminate unnecessary projections, access locations, or door swings that increase space required and travel distance to parts and next machine.
7. Eliminate structures protruding into the operator's walk paths.
8. Design for manual loading of machines or part feeders and automatic ejection back to the operator. This promotes proper sequence of operation and single-piece flow. Together with a machine cycle that is less than the operator cycle, it will also eliminate the condition of the operator waiting on the machine.
9. Minimal reaching required to load the machine.
10. Easily-initiated, "one-touch" start with finger switch, touch screen, etc.
11. Simple guarding to ensure that the operator is clear before the cycle begins.
12. Designed for quiet operation or shielded to reduce noise.
13. Designed for use with quick-change tooling and interchangeable fixtures.
14. Designed to enable quick changeovers – measured in a few seconds or minutes.
15. Built-in cycle counter to warn and stop machine at predetermined tool change frequency.
16. Include built-in gauging and inspection devices.
17. Where rearrangement is likely, use portable, easily moved equipment with the following features and characteristics:
    a. Integrated frame
    b. Simple leveling system
    c. Place all shut-offs together
    d. Flexible utility drops and quick-release fittings and couplings
    e. Above-ground, self-contained systems and reservoirs for coolants, chips, etc.
    f. Avoid foundations, consider heavy floor plates instead

Figure 12-2. Principles of machine design for effective workplace layout. While machine design is always dominated by the processing requirements themselves, good design will also consider the needs of the operator, the set-up and changeover crew, material handlers, maintenance and service people, installers and future movers. Adapted from a longer list by GM Saginaw Steering Gear, now Nexteer Automotive.

The orientation or *hand* of a machine can be critical in workplace (and detail area) layout. By this we mean whether the operator controls and the load/unload points can be flipped – "left-hand/right-hand" – to make it easier for one operator to attend two machines. In the absence of this ability, the operator may have to walk around or climb over one machine or conveyor to reach the other. When this takes too long or is risky, it becomes impractical for one operator to run two machines.

An example appears in Figure 12-3. Here, new packaging machinery had been designed for right-hand only. The cost for left-handed machine design was high and not justified for one installation. But 30 or more lines were planned, so this workplace layout was undertaken to document labor savings and justify the left handed designs.

In addition to the sketches below, the activity-relationship diagram in Figure 12-4 was used to show forklift access issues in the planned layout and to suggest the use of more frequent deliveries in smaller, less-than-pallet-sized quantities. Handling and storage methods are common issues and causes for adjustment in all workplace layouts.

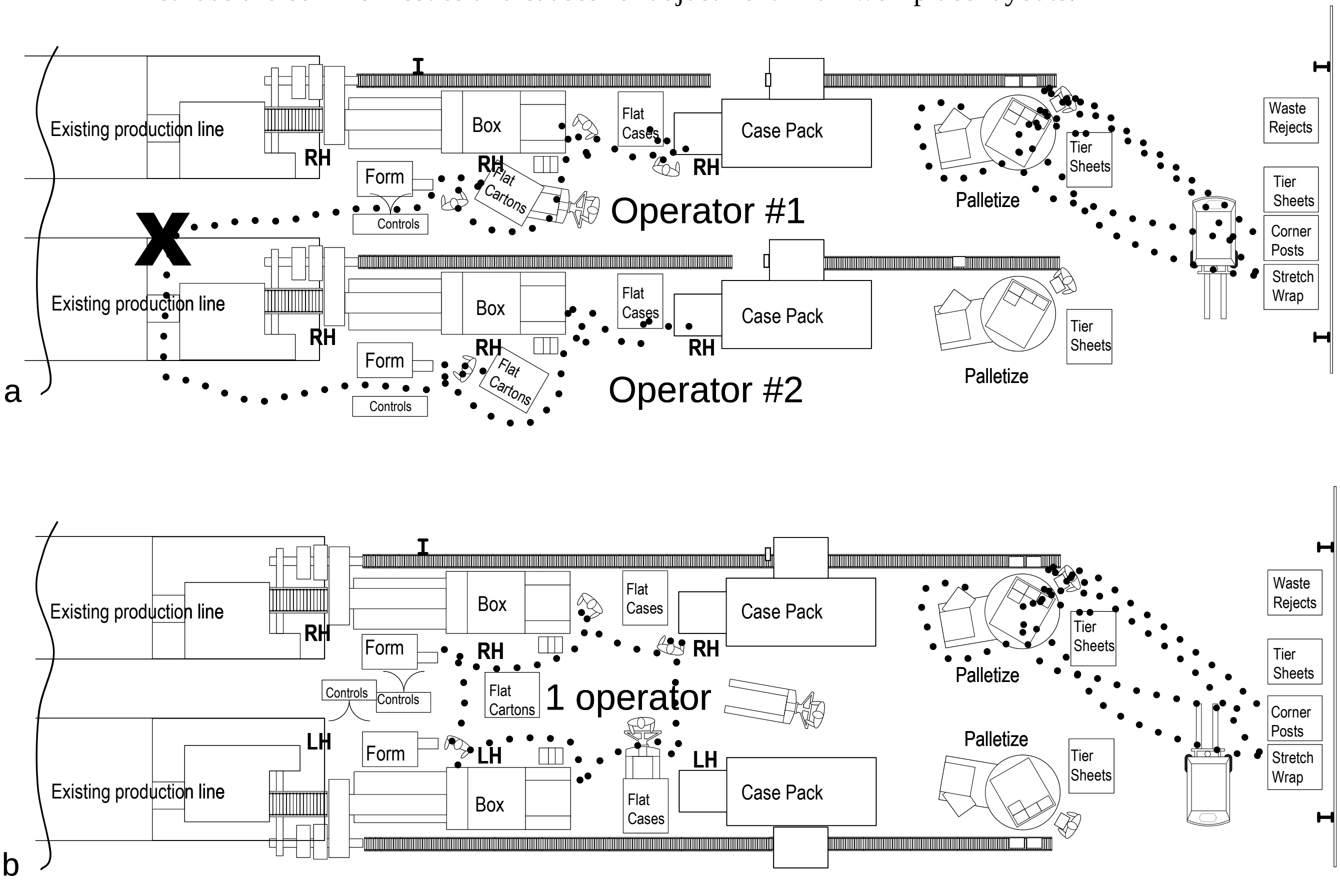


Figure 12-3. Value of right-hand (RH) and left-hand (LH) machine configuration. In layout "a" above, the machines are only right-handed. This leads to an unacceptable "X" walk-path when one operator attempts to run two lines. Not only would it take too long to walk between stations, the path is somewhat dangerous due to a foot-step between tight machines. In layout "b", left-hand configurations permit one operator to run both sets of machines. Delivery of palletized cartons and cases is easier as well. At this scale it is difficult to see, but the control panels had to be downsized in layout "b" and still pose clearance problems.

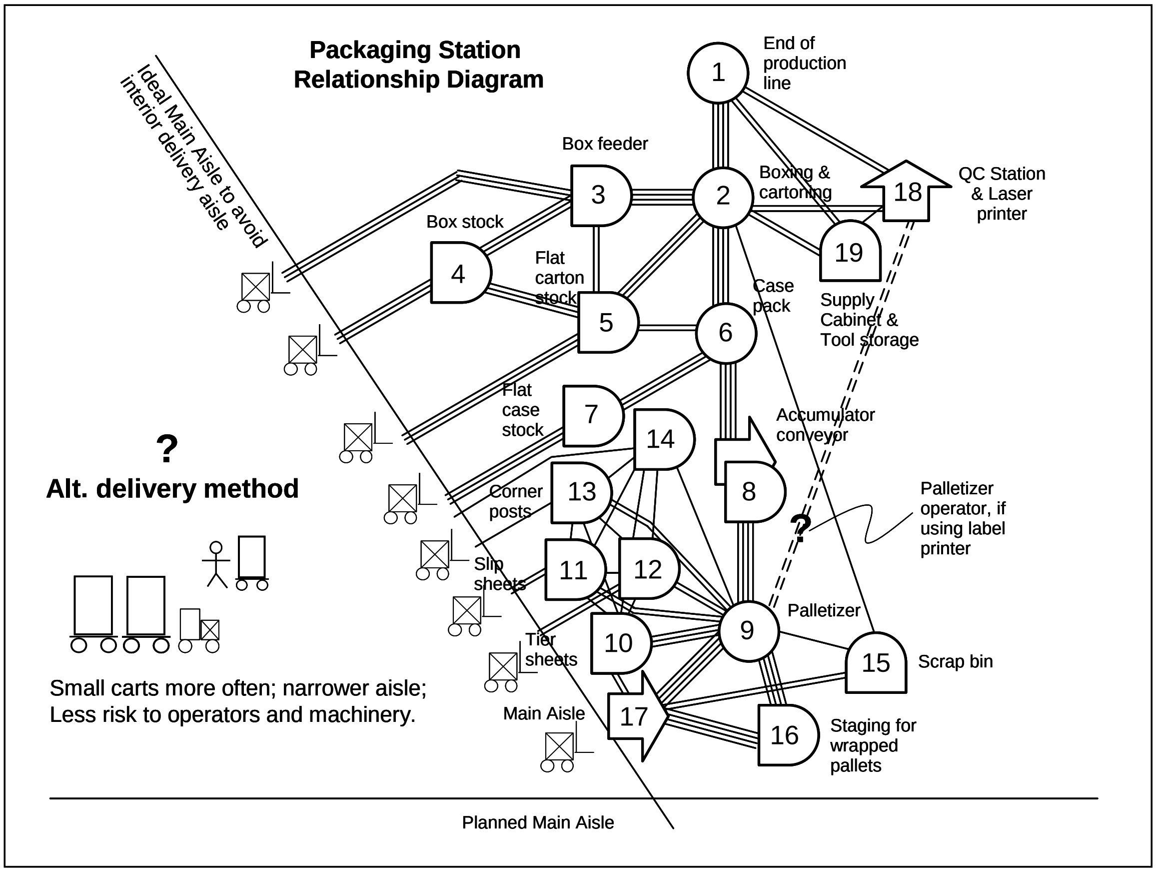
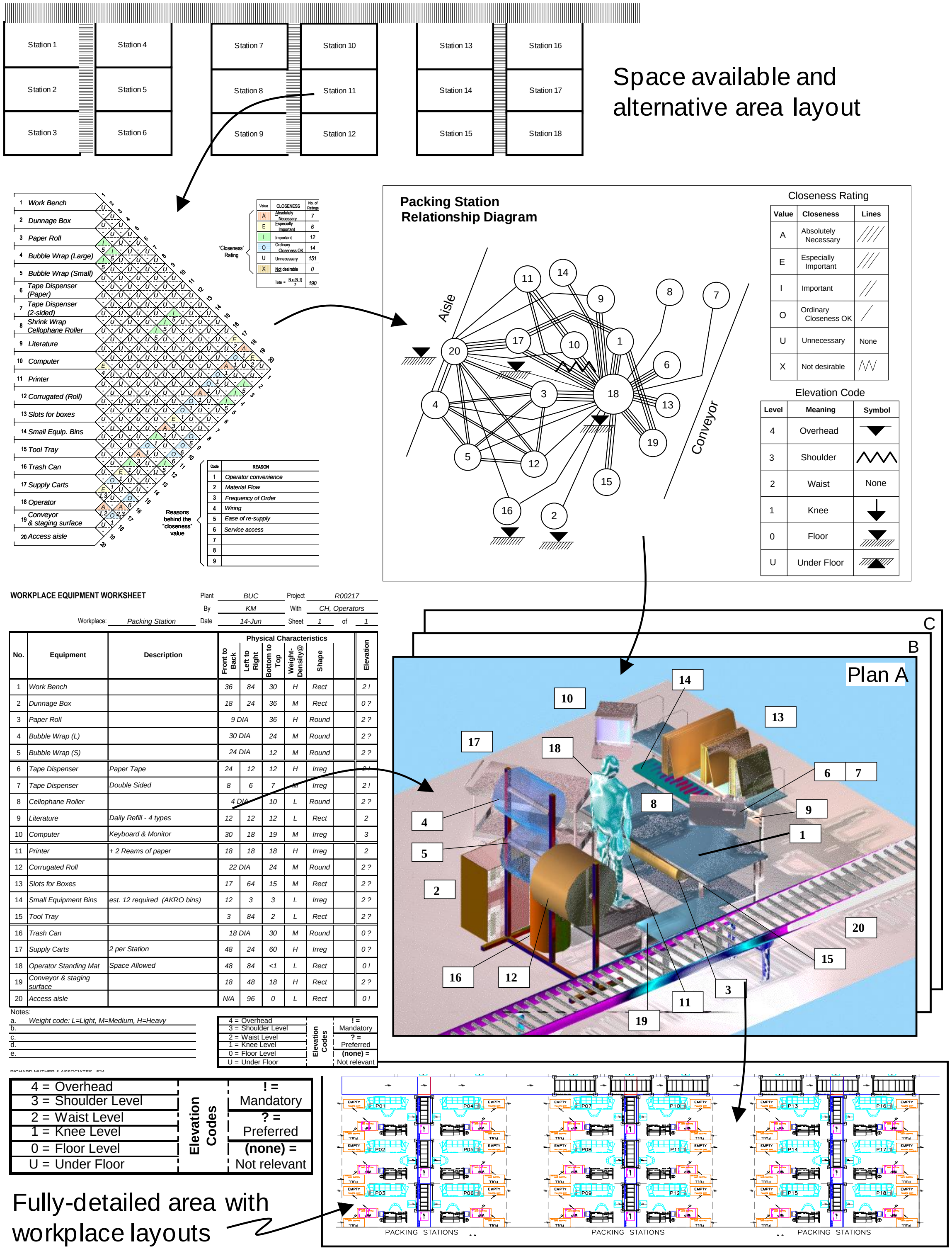


Figure 12-4. Activity-relationship diagram for one packaging station shown in Figure 12-3a (turned 90 degrees with the line running top to bottom instead of left to right). The delay symbols represent pallets of packaging materials used at each operation. The plan is to deliver by fork truck to nine staging points. The number-of-lines convention shows that the heaviest deliveries will be the most distant from the planned main aisle at the bottom of the diagram. Given the tight layout this raises questions of safety for operators and machines. More frequent delivery on small-footprint push carts would reduce risk but may add handling labor since packaging is supplied on pallets. This diagram suggests that the ideal layout would have two packaging stations facing a common delivery aisle. This would require both right- and left-hand machines as shown in Figure 12-3b.

Bench Workplace Layout

From the planner’s perspective, bench work is typically more flexible and forgiving than laying out machinery and equipment-dominated stations. But there can be just as much or more at stake if many stations and operator productivity are involved. For this type of workplace, Systematic Layout Planning and Simplified SLP can be directly applied. However, instead of activity-areas, the planner is laying out equipment, tools, materials and other objects relative to the operator.

Figure 12-5 shows the planning for a standard packaging station in an electronic commerce distribution center. In this operation, loose orders are supplied to the packer on carts. Once packed, they leave by conveyor. Within the station, the packer uses several kinds of packaging materials, tags and tools, prints and inserts a packing slip, and inserts a catalog. The relationship chart and diagram show the operator’s desired closeness to these items. Note that the operator is considered as one “item,” just like the others to be placed.



Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	7
E	Especially Important	6
I	Important	12
O	Ordinary Closeness OK	14
U	Unnecessary	151
X	Not desirable	0
	Total = $\frac{N \times (N-1)}{2}$	190

Code	REASON
1	Operator convenience
2	Material Flow
3	Frequency of Order
4	Wiring
5	Ease of re-supply
6	Service access
7	
8	
9	

Closeness Rating

Value	Closeness	Lines
A	Absolutely Necessary	////
E	Especially Important	///
I	Important	//
O	Ordinary Closeness OK	/
U	Unnecessary	None
X	Not desirable	/\/\/

Elevation Code

Level	Meaning	Symbol
4	Overhead	▼
3	Shoulder	/\/\/\
2	Waist	None
1	Knee	↓
0	Floor	▼
U	Under Floor	▲

WORKPLACE EQUIPMENT WORKSHEET

Plant BUC Project R00217
By KM With CH, Operators
Workplace: Packing Station Date 14-Jun Sheet 1 of 1

No.	Equipment	Description	Physical Characteristics Front to Back	Left to Right	Bottom to Top	Weight-Density@	Shape		Elevation
1	Work Bench		36	84	30	H	Rect		2 !
2	Dunnage Box		18	24	36	M	Rect		0 ?
3	Paper Roll		9 DIA		36	H	Round		2 ?
4	Bubble Wrap (L)		30 DIA		24	M	Round		2 ?
5	Bubble Wrap (S)		24 DIA		12	M	Round		2 ?
6	Tape Dispenser	Paper Tape	24	12	12	H	Irreg		2 !
7	Tape Dispenser	Double Sided	8	6	7	M	Irreg		2 !
8	Cellophane Roller		4 DIA		10	L	Round		2 ?
9	Literature	Daily Refill - 4 types	12	12	12	L	Rect		2
10	Computer	Keyboard & Monitor	30	18	19	M	Irreg		3
11	Printer	+ 2 Reams of paper	18	18	18	H	Irreg		2
12	Corrugated Roll		22 DIA		24	M	Round		2 ?
13	Slots for Boxes		17	64	15	M	Rect		2 ?
14	Small Equipment Bins	est. 12 required (AKRO bins)	12	3	3	L	Irreg		2 ?
15	Tool Tray		3	84	2	L	Rect		2 ?
16	Trash Can		18 DIA		30	M	Round		0 ?
17	Supply Carts	2 per Station	48	24	60	H	Irreg		0 ?
18	Operator Standing Mat	Space Allowed	48	84	<1	L	Rect		0 !
19	Conveyor & staging surface		18	48	18	H	Rect		2 ?
20	Access aisle		N/A	96	0	L	Rect		0 !

Notes:
a. Weight code: L=Light, M=Medium, H=Heavy
b.
c.
d.
e.

Elevation Codes	
4 = Overhead 3 = Shoulder Level 2 = Waist Level 1 = Knee Level 0 = Floor Level U = Under Floor	! = Mandatory ? = Preferred (none) = Not relevant

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Elevation Codes	
4 = Overhead 3 = Shoulder Level 2 = Waist Level 1 = Knee Level 0 = Floor Level U = Under Floor	! = Mandatory ? = Preferred (none) = Not relevant

Figure 12-5. Workplace layout planning for a packaging station. This level of effort would rarely be practical for a single station. But an eventual 24 stations were planned using new equipment and departing from familiar arrangements. The supervisor and two lead packers provided the equipment list, desired elevations, and relationships. Alternatives were sketched and rendered by the planner and evaluated by the supervisor and packers. The selected layout was then incorporated into the final detail layout for the packing department. While the new facility was under construction, an actual prototype was set up for all the packers to see and experience. This led to further refinements before installation.

The most common reasons for closeness will be operator convenience and the frequency or speed of operator reach. But numerous other considerations can be recorded as appropriate; for instance: the need to see (line of sight), the ease of re-supplying parts or servicing equipment, or the need for common wiring and cabling.

A worksheet records each item's dimensions and its desired elevation relative to the floor and the operator. The following conventions are used:

4 = Overhead
3 = Shoulder level to eye level
2 = Waist to elbow level
1 = Knee level
0 = Floor level
U = Under Floor

These can be further coded as Mandatory or Preferred.

The relationship diagram uses circles to represent the items being placed. Mandatory and preferred elevations are shown by graphic symbols next to the circles. The circle spacing and number-of-lines convention are the same as in block or detail layout. When diagramming such manual workplaces, the planner generally begins with the operator and the primary work surface or machine. These are typically an "A-rated" pair of items. Other A relationships are then added to the diagram, followed in vowel-code sequence by the E relationships, then the I relationships, and finally the O's and X's. The resulting diagram guides placement of the workplace items in dimensioned drawings, graphic renderings, or in physical mock-ups or prototypes of the workstation.

When positioning each item, the planner must be mindful of the limits of operator reach or normal working area. Recognize that operator body dimensions vary by region of origin, by sex, and by overall physical condition. Reference tables of anthropometrics data (body dimensions) based on a sample of male United States Air Force personnel may not be representative of middle-aged male factory workers, or teen-aged females. And, using published norms for a national population may not reflect the realities of the plant population at hand. Keep in mind the location of the workplace being designed. For example, optimal work heights in North America are 3 inches (76 mm.) higher than in South India. Optimal work height in North Asia is 3 inches higher than in South China. When in doubt, use full-scale mock-ups and walk-throughs with prospective operators to verify placements and dimensions.

Once alternatives are visualized and understood, the weighted-factor method is ideal for involving operators and others in the evaluation and selection of the best plan. Cost differences must always be considered but typically are not significant between competing workstation layouts. The principles of workplace layout in Figure 12-6 are compiled from various sources. They can be used as a checklist before approving a final layout.

The workplace planning process illustrated in Figure 12-5 can be quick and take as little as one or two days, not counting the time for operators to experiment with prototypes. But even this experimentation time can be expedited and shortened with the use of simple cardboard mock-ups and walk-throughs discussed in Chapter 13.

Principles of Work Place Layout

1. Work surface height is set between 1 and 3 inches below the elbow.
2. An adjustable chair or stool is provided to alternate between sitting and standing positions. (Note: In workplaces where the operator tends multiple machines and is required to continuously walk between them, a chair is inappropriate).
3. Legs and knees can be placed under equipment or work surfaces when seated – no obstructions.
4. An anti-fatigue pad is provided for standing posture.
5. A footrest available when seated.
6. Necessary manual lifting occurs close to the body.
7. The vertical height of necessary manual lifting is minimized.
8. Placement of surfaces and equipment avoids the need to twist the body or pivot the feet during manual lifting or carrying of work pieces or containers.
9. Operator walking and motion paths are free from protrusions or barriers.
10. All tools and materials have a definite fixed place.
11. Tools and materials are located to permit the best sequence of motions (i.e. in sequence of use).
12. Finished material should be closest to the operator; raw material farther away and in the same line of arm-and-hand motion so that set down of finished part leads smoothly to pick-up of the next starting piece.
13. Use “drop delivery” of finished parts where practical – laying the part aside by dropping it into a container, chute, or hole that leads to a container or conveyance.
14. Tools are placed “in line” so that they may be picked as the hand(s) move from one part of the work to the next, up without a special movement.
15. Tools, materials and controls are close in and directly in front of the operator.
16. Knobs, switches, hand wheels or other controls are presented at an angle between 0 and 45 degrees to the plane in front of the body – optimum is probably 30 degrees.
17. Tools are pre-positioned for quick grasp and for easy replacement in the same fixed position. Where possible, tools should be suspended from overhead on springs to automatically retract when released.
18. Tools are put away automatically. If not, the location of the next item to be picked up should be next to the location of tool putaway, so that the operator can put the tool away as his hand moves toward the next item or material.
19. Gravity feeding bins, chutes, and containers should be used to deliver material close to point of use.
20. Work pieces or products are pre-positioned for the next operation.
21. Proper illumination is provided, with minimal shadows, glare, or reflection.
22. Pleasant working conditions are provided in terms of temperature, humidity, dust, fumes, ventilation, noise, color scheme, orderliness, and the like.

Figure 12-6. Principles of workplace layout compiled from various sources and experience.

Assembly Line Station Layout

Assembly line station layout is typically dominated by the movement of the work piece to which parts or items are assembled, and by the presentation and re-supply of the parts and items being used. For these reasons, it is difficult to separate line station layout from the planning of material handling, containment, and storage. The methods of moving the work piece and of replenishing the station can be considered process decisions and thus key inputs (P, Q, R and T) to the station's layout. Figure 12-7 outlines choices and decisions having the greatest impact on line station layout. Most of these will have already been made during higher-level plans for overall layout and material handling – unless station design is being undertaken as part of the materials management system design, in which case station layout may actually come *before* overall plant or detail area layout.

When the tools are small, hand-held and portable, the station layout is typically based on the flow of materials or parts to their points of use on the line. Thus, the planner works from a list of parts or items to be assembled in the station, rates the relative flow intensity of each, and places those with the highest intensity in the most favorable position.

Part or item flow intensity should be measured in a way that considers the relevant transportability characteristics of size, weight, shape, risk of damage, and condition. The significance of these is explained in Appendix I. The SLP vowel-letter conventions can be adapted to rate relative flow intensity as shown in Figure 12-8.

When the assembler must grasp, fetch or walk to stationary tools or work surfaces, their location and frequency of access become part of the layout problem, just as in bench assembly. Here, the relationship chart and diagram become valuable in recording and visualizing closeness desired. The same is true when work instructions must be consulted, or the assembler needs to make face-to-face contact with a co-worker.

Space is determined first and foremost by the size of the objects being handled and assembled. But the replenishment methods and line station storage quantities, the container, and the handling methods to and from their points of use also influence space requirements. For this reason, it is difficult to finalize an assembly station layout without agreement on how much inventory to hold on the line, how often to replenish it, in what containers or packages, with what dimensions and piece counts.

Once the workplace elements are defined and their dimensions known, positioning is always a three-dimensional exercise. The X-Y location determines assembler walking while the Z or vertical elevation of location determines the need for body motion, reaching, lifting, stooping, or climbing. Both the X-Y and Z location contribute to ergonomic risk, particularly when the objects moved are heavy, awkward, difficult to engage or hold with the hands, and/or when the access rate is very high and sustained.

Even in flow-based station layouts, some space will be needed – and some relationships found – for support equipment, tools, computer monitors, printers, display boards, trash bins, shop desks, and the like. These are typically "adjusted in" after flow-based placements are made.

Handling & Replenishment Decisions for Line Station Layout

1. The method of moving the work piece through or past the station (choice is typically a process and handling decision with layout implications, rather than the other way around).
   a. Manual – the assembler(s) move the work piece when complete and/or fetch the next unit with our without mechanical assistance. This is inherently asynchronous but can be indexed with timed signals.
   b. Mechanized – continuous, indexing (paced), or asynchronous. Methods vary:
      1. Conveyors in or on the floor – tow line, roller, belt, inverted monorail, inverted power-and-free… May be a barrier to movement of people and materials at floor level across the line
      2. Conveyors overhead – chain and trolley, power-and-free, spinning tube, electrified monorail…
      3. Guided vehicles – carriers move the work piece without a connecting channel or rail (other than perhaps a buried guide wire)
2. Worker position relative to the work piece:
   a. Stationary seated or standing position next to the line
   b. Mobile at floor level – one side of the line or both, and under the work piece if it can be elevated.
   c. Elevated on a platform along the line
   d. Mobile at floor level and elevated with portable ladder for high positions
   e. On board the conveyor – moving platform or “skillet”
   f. On board or inside the work piece
   g. Under the work piece in a pit or trench
3. Methods of replenishing parts and materials:
   a. Whether to store an item in the station and replenish it, or to deliver it as part of a kit with other items, or to deliver it in sequence at, or before, time of need.
   b. For stored items,
      1. how much to store in the workstation, including package and container quantities. This also impacts the rate and manner of replenishment.
      2. How physically to store, contain and present the items – as packaged or contained by the supplier or upstream operation, or in some different way.
   c. For kitted items, how to deliver the kit to the station –
      1. as a cart or container that is staged ahead of need,
      2. delivered by the arriving work piece itself – perhaps in a basket attached to the work piece, or a cart that moves with it.
   d. For sequenced items, how far in advance to deliver and how to respond to sequence changes
   e. When to deliver to the station and by what method. Does this disrupt the assembler or require the assembler’s action?
   f. How to signal the need for replenishment – by empty container, by card, by electronic signal, by recorded consumption…

Figure 12-7. Assembly line station layout needs decisions on material handling and replenishment as key inputs. These must be made for each class or type of part or material and ultimately for each specific part or item that will be presented, held, handled, and moved. These decisions become part of line station layout If not already reached during higher levels of planning for materials management, overall layout and plant-wide material handling.

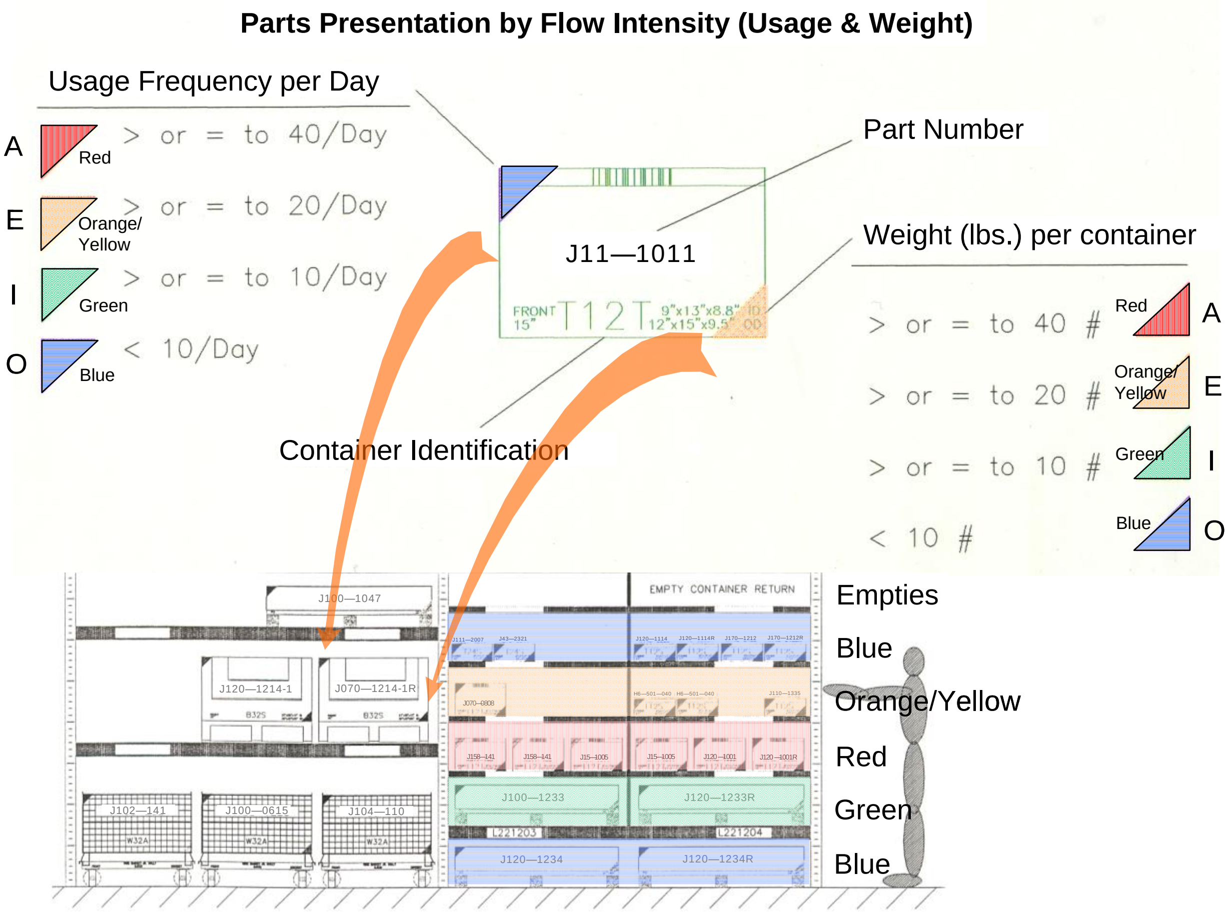
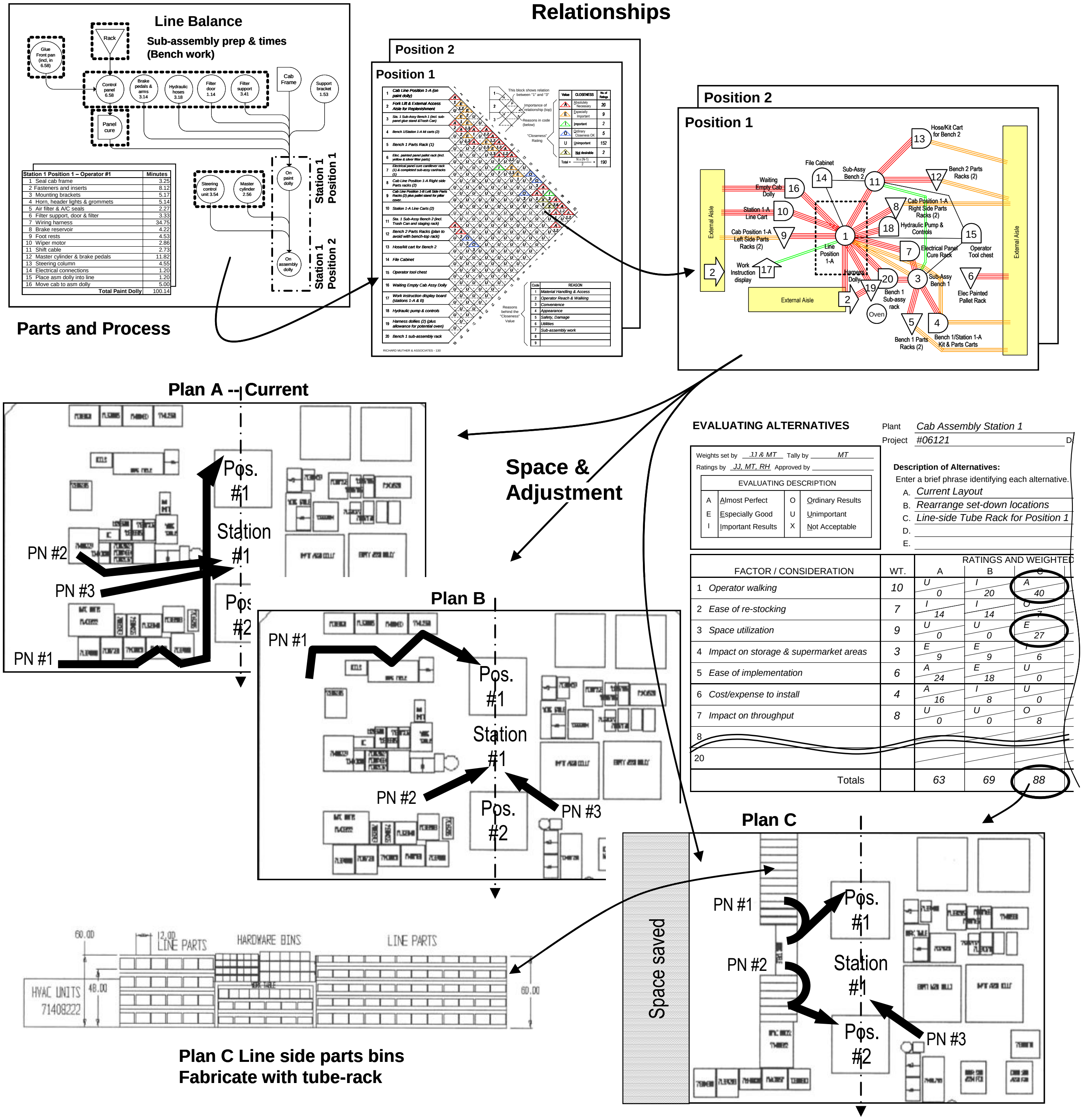


Figure 12-8. Adaptation of the SLP vowel- and color-code convention to indicate the relative flow intensity of part numbers in a line station layout. Parts are positioned in line-side racks based on their usage and weight in order to minimize ergonomic risk and time spent getting the parts. This example is from a truck frame assembly station, so the parts and their containers can be large and heavy. The plant's materials and production managers established replenishment policies for various classes of parts and materials. These answer Question 3 in Figure 12-7 as to which parts must be stored in the station, in what containers, and how many of each. If not already decided, these decisions will postpone final detail and workplace layouts or lead to many incorrect assumptions and subsequent rework.

Figure 12-9 illustrates the layout of an assembly line station using the procedures and conventions of Systematic Layout Planning (SLP). Note how our three fundamentals – relationships, space and adjustment – underlie the planning. The relationship chart and diagram quickly capture, visualize, and get agreement on the desired placement of benches and staging positions. A few minutes spent on these can save hours during template placement in a drawing or experimentation on the shop floor by moving the actual objects.

In this example, the best plan "C" reduces operator walking and saves space with the introduction of a new parts presentation rack. When the workplace layout involves such design and innovation, time should be allowed to purchase or fabricate prototypes, or build mock-ups if these are needed to understand and evaluate the alternatives.



Station 1 Position 1 – Operator #1	Minutes
1 Seal cab frame	3.25
2 Fasteners and inserts	8.12
3 Mounting brackets	5.17
4 Horn, header lights & grommets	5.14
5 Air filter & A/C seals	2.27
6 Filter support, door & filter	3.33
7 Wiring harness	34.75
8 Brake reservoir	4.22
9 Foot rests	4.53
10 Wiper motor	2.86
11 Shift cable	2.73
12 Master cylinder & brake pedals	11.82
13 Steering column	4.55
14 Electrical connections	1.20
15 Place asm dolly into line	1.20
16 Move cab to asm dolly	5.00
Total Paint Dolly	100.14

EVALUATING ALTERNATIVES

Plant *Cab Assembly Station 1*

Project *#06121*

Weights set by *JJ & MT* Tally by *MT*

Ratings by *JJ, MT, RH* Approved by

EVALUATING DESCRIPTION

A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. *Current Layout*

B. *Rearrange set-down locations*

C. *Line-side Tube Rack for Position 1*

D.

E.

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED A	 B	 C
1 *Operator walking*	*10*	*U* *0*	*I* *20*	*A* *40*
2 *Ease of re-stocking*	*7*	*I* *14*	*I* *14*	*O* *7*
3 *Space utilization*	*9*	*U* *0*	*U* *0*	*E* *27*
4 *Impact on storage & supermarket areas*	*3*	*E* *9*	*E* *9*	*I* *6*
5 *Ease of implementation*	*6*	*A* *24*	*E* *18*	*U* *0*
6 *Cost/expense to install*	*4*	*A* *16*	*I* *8*	*U* *0*
7 *Impact on throughput*	*8*	*U* *0*	*U* *0*	*O* *8*
8				
20				
Totals		*63*	*69*	*88*

Figure 12-9. Layout for a single assembly station – one of 23 stations on a line assembling large off-road vehicles. Plan A is the current layout – included to rate against alternatives. Plans B and C are based on flow of materials, using the P-Q-R inputs of the parts list, process chart and line balance. The relationship chart captures use of tools and support equipment. Walk paths are shown for three high-intensity parts. These could be quantified in distance per day, but in this case visualization alone shows that Plan C requires the least walking. Plan C also saves space – an example of how detail layout may enable or lead to adjustment in adjoining station and area layouts, or even to the overall plan. Space-savings are achieved with a new rack for parts presentation at Position #1. Design of this rack thus becomes part of the workplace layout.

Workstation Material Handling Equipment

Many planners envision operators handling the work pieces one at a time or in small containers, passing or carrying them along – without mechanical assistance – to the next workplace or machine. This may be possible when the pieces and containers are of the right dimensions, weight, and condition. But often the production rate is too high, or the parts are too large or too small, or too heavy, or too risky, or too hot, or too oily to be moved by hand. In such cases, work place handling equipment must be used. And even when manual handling is possible, various types of mechanical assistance can often improve the ease and safety of reaching, lifting, and holding of parts, tools, and materials. Such equipment is referred to in the material handling industry as ergonomic assist and safety equipment. "Ergonomic assist" means that the equipment helps conform the work to the physical capabilities and limitations of the operator. Common devices include:

Manipulators
Positioners/Balancers
Vacuum lifts
Hoists, jib and workstation overhead cranes
Conveyors and overhead conveyors
Lift tables, rolling lift tables, and stackers
Ball tables and decks
Air casters and bearings
Dumpers
Adjustable work platforms

Some of these may have already been decided as part of the area or cell's material handling plan (for moving materials between stations). If not, the time to consider them is now, during workplace layout.

Fixtures, Jigs, and Standard Work

In addition to ergonomic assist and safe handling equipment, workplace layout must also take into account the operator's use of fixtures, jigs[1]and tools, and provide for their storage when not in use. In some cases, the introduction of new jigs and fixtures may change and even dominate the station's layout. Where such possibilities exist, the workplace layout planner must wait on and work closely with the fixture designer/maker – perhaps through several iterations of design and try-out. And of course the "voice of the operator" should be heard at all times.

Once the best workplace layout has been selected and approved, it should become part of the process documentation, work instructions, and any visual management display. The Standard Work form pictured in Figure 12-10 is popular for these purposes. In addition to a sketch of the layout, it shows the operator's work sequence and times.

Figure 12-11 shows a slightly different version of the form. This one calls out the operator walk time required by the layout. It is preferred for manufacturing cells and production or packaging lines like the one pictured in Figure 12-3. In such layouts the entire cell or line is considered to be the workplace rather than each individual machine or station.

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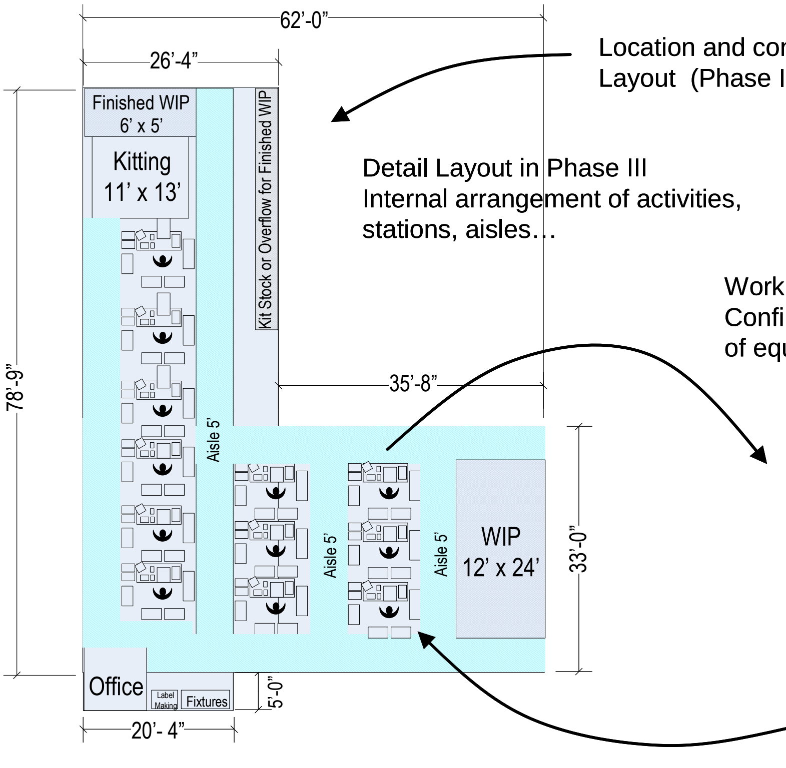
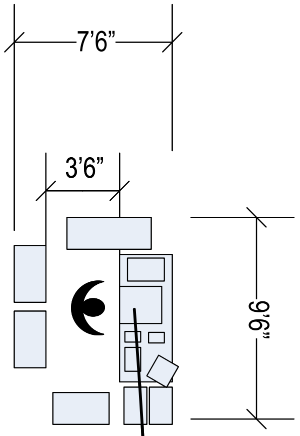
[1] The terms jig and fixture are often used interchangeably. Broadly speaking, a jig is a work-holding device that is not attached to the machine or bench on which it is used, while a fixture is attached.

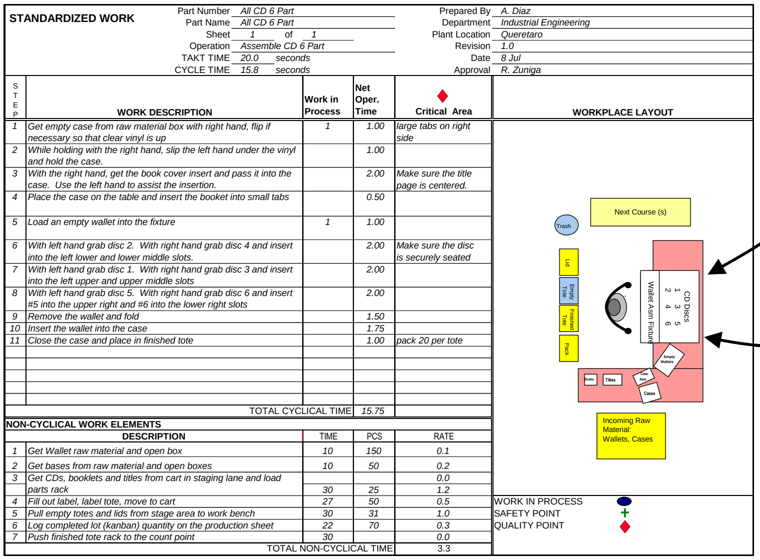


Location and configuration from Overall Layout (Phase II)

Detail Layout in Phase III
Internal arrangement of activities, stations, aisles…

Workplace Layout in Phase III
Confirms area detail and arrangement of equipment within stations…





STANDARDIZED WORK

Part Number All CD 6 Part
Part Name All CD 6 Part
Sheet 1 of 1
Operation Assemble CD 6 Part
TAKT TIME 20.0 seconds
CYCLE TIME 15.8 seconds

Prepared By A. Diaz
Department Industrial Engineering
Plant Location Queretaro
Revision 1.0
Date 8 Jul
Approval R. Zuniga

STEP	WORK DESCRIPTION	Work in Process	Net Oper. Time	◆ Critical Area
1	Get empty case from raw material box with right hand, flip if necessary so that clear vinyl is up	1	1.00	large tabs on right side
2	While holding with the right hand, slip the left hand under the vinyl and hold the case.		1.00	
3	With the right hand, get the book cover insert and pass it into the case. Use the left hand to assist the insertion.		2.00	Make sure the title page is centered.
4	Place the case on the table and insert the booket into small tabs		0.50	
5	Load an empty wallet into the fixture	1	1.00	
6	With left hand grab disc 2. With right hand grab disc 4 and insert into the left lower and lower middle slots.		2.00	Make sure the disc is securely seated
7	With left hand grab disc 1. With right hand grab disc 3 and insert into the left upper and upper middle slots		2.00	
8	With left hand grab disc 5. With right hand grab disc 6 and insert #5 into the upper right and #6 into the lower right slots		2.00	
9	Remove the wallet and fold		1.50	
10	Insert the wallet into the case		1.75	
11	Close the case and place in finished tote		1.00	pack 20 per tote
		TOTAL CYCLICAL TIME	15.75	

NON-CYCLICAL WORK ELEMENTS

	DESCRIPTION	TIME	PCS	RATE
1	Get Wallet raw material and open box	10	150	0.1
2	Get bases from raw material and open boxes	10	50	0.2
3	Get CDs, booklets and titles from cart in staging lane and load			0.0
	parts rack	30	25	1.2
4	Fill out label, label tote, move to cart	27	50	0.5
5	Pull empty totes and lids from stage area to work bench	30	31	1.0
6	Log completed lot (kanban) quantity on the production sheet	22	70	0.3
7	Push finished tote rack to the count point	30		0.0
			TOTAL NON-CYCLICAL TIME	3.3

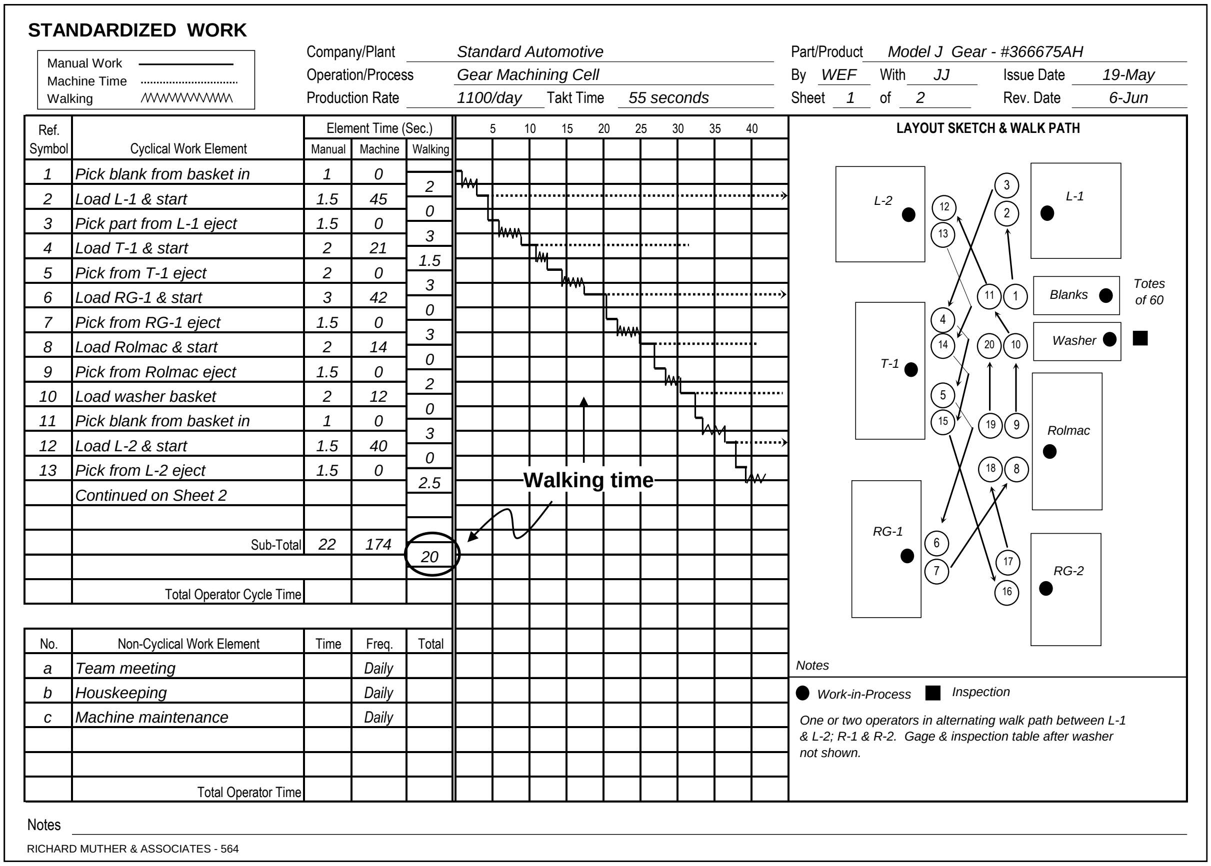
WORKPLACE LAYOUT

WORK IN PROCESS ●
SAFETY POINT +
QUALITY POINT ◆

Standard Work: Operations, Times, & Layout

Fixture design and time study during workplace layout.

Figure 12-10. Workplace layout in the context of overall and detail layout planning. The *area* being planned assembles compact discs (CDs) into vinyl cases for educational programs. In the bench assembly *station* being planned, a printed paper cover is inserted into a vinyl case, six CDs are inserted into a wallet, and the wallet into the case. The layout and assembly sequence will use a new fixture designed in conjunction with the workplace layout. A plywood prototype is pictured and was used to establish time standards for the operation. The workplace layout exercise validates the spacing and dimensions in the detail layout and helps to establish the most productive internal arrangement of equipment and materials within each station.



STANDARDIZED WORK

Manual Work ——
Machine Time ········
Walking ʌʌʌʌʌʌʌʌ

Company/Plant: *Standard Automotive*
Operation/Process: *Gear Machining Cell*
Production Rate: *1100/day* Takt Time: *55 seconds*
Part/Product: *Model J Gear - #366675AH*
By: *WEF* With: *JJ* Issue Date: *19-May*
Sheet: *1* of: *2* Rev. Date: *6-Jun*

Ref. Symbol	Cyclical Work Element	Element Time (Sec.) Manual	Machine	Walking
1	*Pick blank from basket in*	1	0	2
2	*Load L-1 & start*	1.5	45	0
3	*Pick part from L-1 eject*	1.5	0	3
4	*Load T-1 & start*	2	21	1.5
5	*Pick from T-1 eject*	2	0	3
6	*Load RG-1 & start*	3	42	0
7	*Pick from RG-1 eject*	1.5	0	3
8	*Load Rolmac & start*	2	14	0
9	*Pick from Rolmac eject*	1.5	0	2
10	*Load washer basket*	2	12	0
11	*Pick blank from basket in*	1	0	3
12	*Load L-2 & start*	1.5	40	0
13	*Pick from L-2 eject*	1.5	0	2.5
	Continued on Sheet 2			
	Sub-Total	22	174	20
	Total Operator Cycle Time			

No.	Non-Cyclical Work Element	Time	Freq.	Total
a	*Team meeting*		*Daily*	
b	*Houskeeping*		*Daily*	
c	*Machine maintenance*		*Daily*	
	Total Operator Time			

Notes

● *Work-in-Process* ■ *Inspection*

One or two operators in alternating walk path between L-1 & L-2; R-1 & R-2. Gage & inspection table after washer not shown.

Notes

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Figure 12-11. Standard Work form with a column for walking times and showing them graphically in Gantt chart style. The layout is for a piece-part manufacturing cell with 6 machines. (From the book: Planning Manufacturing Cells, by Lee Hales and Bruce Andersen, Society of Manufacturing Engineers).

Workplace Visual Control

As a final step in workplace layout, the planner should be sure to incorporate any elements of visual communication, signage, and control that may have been decided as part of an area or plant-wide plan. Each workplace should apply the agreed upon methods, and make standard uses of color-coding and tagging, signage, labeling, marking, displays, and the like. Ideally, all moveable tools, jigs, fixtures, and parts bins will have their positions marked and be identified in such a way that their absence or misplacement is obvious. Not only do such measures promote orderliness, they also enable flexibility by making it easier to rotate or change operator assignments or to bring in extra operators who may not be familiar with the station.

Note that color coding the actual workplace is different from the SLP convention for coloring the plans. When coloring the actual workplace, standards are most commonly applied to different types of machinery and equipment, and to floor markings. The machinery and equipment types in Appendix VII may be helpful for establishing a standard color scheme. Floors are typically painted or taped to mark personnel and emergency exit aisles, material handling aisles or their edges, and for designated set-down points and positions of various kinds. There are no industry standards but many multi-plant manufacturing companies have set company-wide standards or at least customs that should be checked and observed.

Chapter 13

Visualizing Layout Plans

In this chapter we describe the ways in which layout plans may be visualized. While our focus is primarily on Phase III detail layouts for individual activity-areas, production lines, and workstations, the discussion is relevant for all phases of layout planning, including location and installation.

As suggested in Figure 13-1, plans may be visualized with paper or electronic drawings, computer graphic renderings, and with physical and electronic models. Which methods to use depends upon the nature of the layout and equipment being planned, the planners' budget, tools, time available and skills, and the desire to involve operators and supervisors in the actual planning. Methods appropriate for one situation may be too time-consuming, expensive, or impractical in another. As a result, SLP practice recognizes all major methods of visualization and sets up a guide for which to use in various situations.

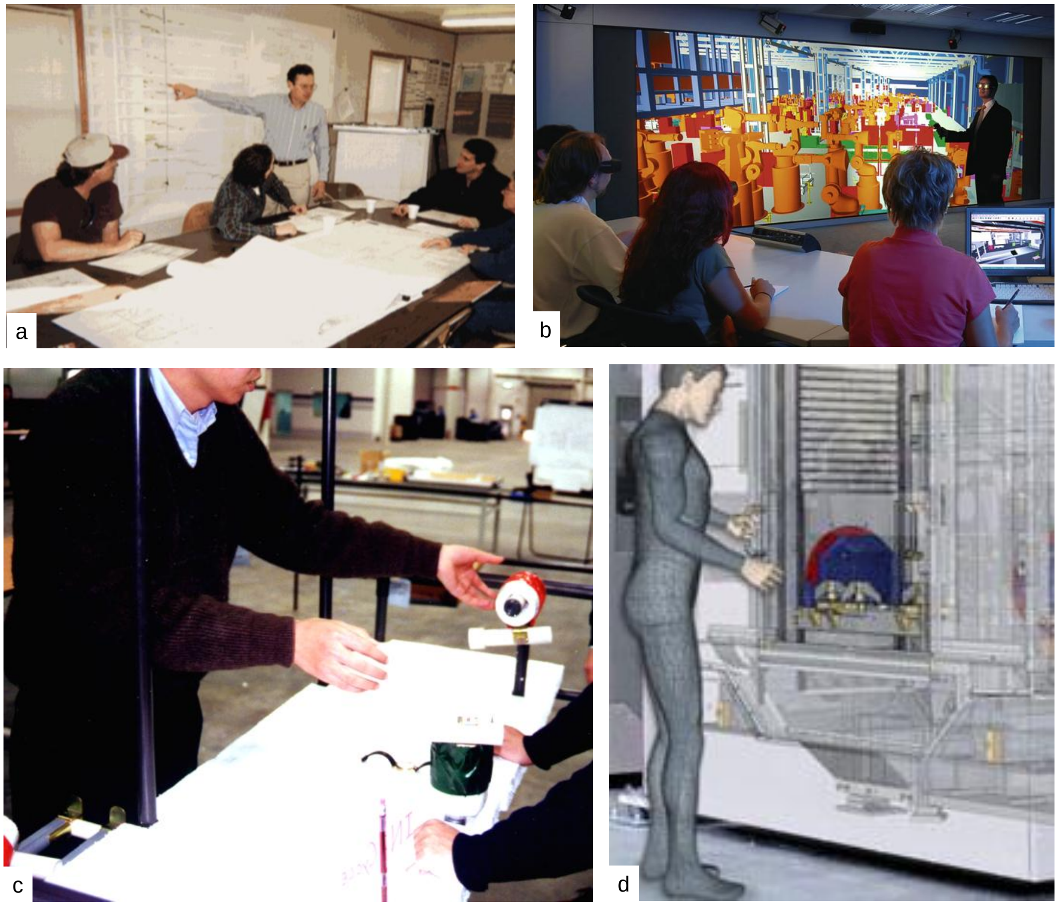

Figure 13-1. Drawings (a) are the most common method of visualization. Projections of 3-D electronic models (b) can be valuable for complex layouts. Physical models and mock-ups (c) are sometimes helpful. Electronic (digital) mock-ups and simulations (d) are state of the art. Courtesy: (a) Stanford Univ. Center for Integrated Facilities Engineering; (b) Mercedes Benz; (d) Siemens PLM Software.

Electronic Drawings

Two-dimensional plan views (from above) are an essential visualization of every layout. Most manufacturing and industrial engineers draw such plans electronically with AutoCAD, MicroStation, or other software for computer-aided design (CAD).[1] An example appears in Figure 13-2. Simple drawing programs and editors such as Visio or even Excel may also suffice. All of the layouts shown in the previous Chapter 12 are examples of two-dimensional (2-D) electronic drawings, with the exception of the workplace rendering in Figure 12-5. The layouts in Figures 12-3 and 12-10 were drawn with Visio; those in Figure 12-9 with Excel.

Two-dimensional, plan-view visualizations are usually sufficient to evaluate, approve and install a layout under the following conditions:

1. Most equipment is of regular or standard height and rests on the floor.
2. Simple or easily-understood overhead material handling; or none at all.
3. Few or flexible tie-ins to overhead utilities.
4. Limited if any tie-ins to the building structure overhead or under the floor.
5. No mezzanines.

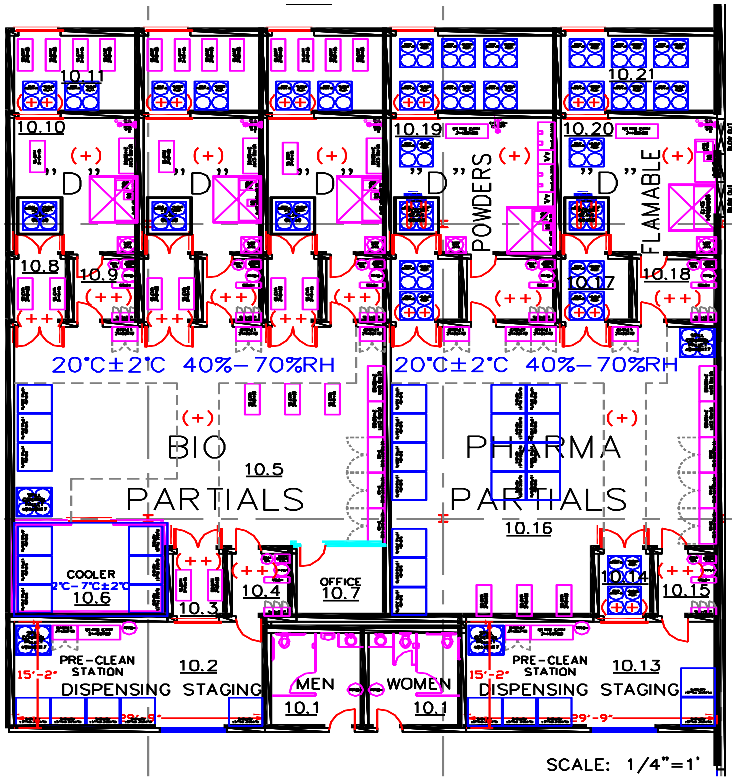

Figure 13-2. Two-dimensional plan view of a layout shows the position of each piece of equipment relative to walls and doors, or other reference points. In this example, annotation (text) shows type of materials being processed, and various zones for air pressure, temperature and humidity control.

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[1] There are numerous commercial products for each layout visualization method discussed in this chapter. Product names and availability are subject to frequent change based on marketeering, mergers, acquisitions, innovations and new business ventures. Products listed here are each representative of a larger class and were popular at the time of writing. Ownership of trademarked names appears on the copyright page at the front of this book.

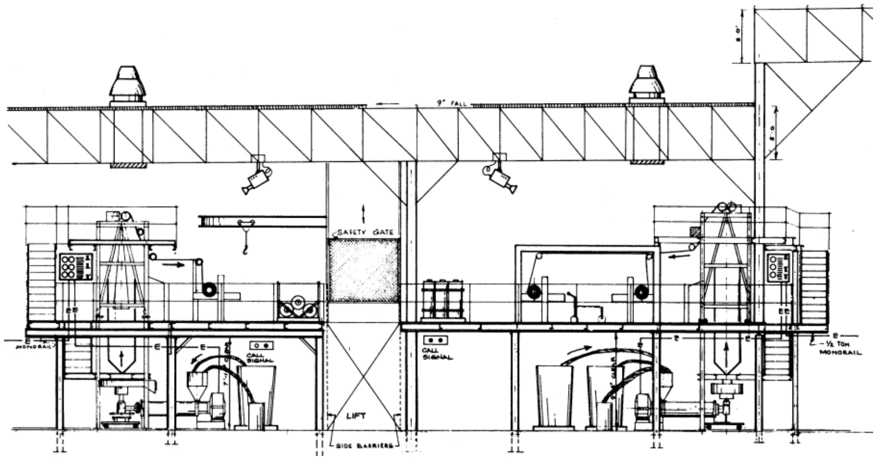


Figure 13-3. Two-dimensional elevation view of a mezzanine installation. Vertical and overhead handling equipment, tie-ins to the building structure and overhead clearance issues make such visualization essential to evaluate, detail and install the plan.

Layouts with mezzanines, overhead conveyors, and tie-ins to overhead or sub-floor utilities, usually need an elevation (side) view. See Figure 13-3. When such elevations are drawn from scratch, they are said to be two-dimensional since all objects are represented in a single plane. If only one or two such views are needed, the time to draw them from scratch may be acceptable. But if more views are needed, or they will need to be repeatedly revised, the planner will be more productive by creating the layout objects in three dimensions (3-D) and plotting cross-sectional views.

Most contemporary CAD (computer-aided design) software presumes that the user will create three-dimensional representations of each object in a design. The result is a 3-D layout *model* that can be sectioned, viewed and plotted from desired angles and view points. This is fundamentally different from drawing views of the layout in 2-D. Objects can be colored, shaded and illuminated to create renderings of the layout. The more features and details defined, the more accurate the model and the more realistic are its renderings. See Figures 13-4 and 13-5.

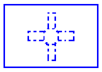
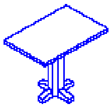
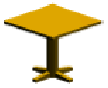
View Mode	**Geometry Displayed**	**Visualization**
2-D	Two-dimensional representation. (Typically the plan view from above).	
3-D	Three-dimensional representations by providing a third dimension for each element. (Typically thickness or height above the base plane in the plan view)	
Render	Colors, shading, reflectivity, features and illumination of surfaces on 3-D objects.	

Figure 13-4. CAD objects defined in three dimensions may be viewed in 2-D from above (plan view) or from any desired angle. With the appropriate software, they can also be rendered. Adapted from FactoryCAD 6.0 User's Guide, courtesy of EAI.

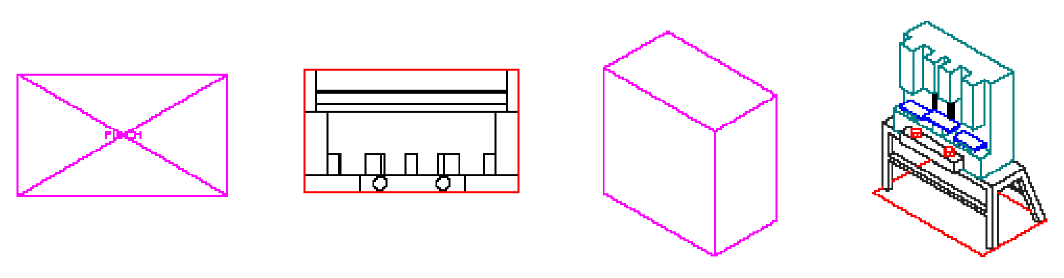


Figure 13-5. When CAD models do not already exist, the planner must decide how much detail to include. Detail enables more accurate visualizations but takes time to create and slows computer performance. Machine tool suppliers may provide excessive detail for layout planning. This should be removed to avoid slow CAD performance. The best CAD software permits detail to be retained but dropped when it is not needed in a particular view or plot. Courtesy of Siemens PLM Software.

While the 3-D capability of CAD software may be present, it need not always be used. But, if objects are defined in only two dimensions, their visualizations are limited to 2-D plans or elevations. Adding a third “Z-axis” dimension to each object’s essential X and Y may require significantly more time to define each piece of equipment. And it will force the planner to decide what features and how much detail are needed. The benefit is that once objects – machinery, equipment, racks, containers – are *modeled* in 3-D, they can be reused just as quickly as 2-D *templates*. Many equipment suppliers can supply 3-D models of their equipment, reducing the creation time. But watch out for excess machine design detail and resulting large files. Ask for versions containing only layout information. Layout-oriented CAD software typically comes with generic models of common equipment that can be quickly dimensioned to their intended sizes in the layout.

Useful features and practices of layout–oriented CAD

Generally the layout planner must use whatever CAD software is already available or in use. And if the objects needed are already defined, there is perhaps no need to change software. But when there is choice, the planner will be more productive using software developed for the specific purpose of industrial layout planning.

The most widely software of this kind is probably the FactoryCAD enhancement to AutoCAD. Developed by Cimtechnologies in the 1980s, this software has had several owners in recent years and is now offered by Siemens PLM Software. (PLM stands for Product Lifecycle Management). While FactoryCAD’s features are no longer entirely unique, they are instructive as to what the industrial layout planner needs. See Figure 13-6.

1. Automatic creation, numbering and lettering of grids and columns.
2. Basic architectural drafting: Automatic drawing and joining of walls, insertion of windows, doors, openings, and docks.
3. Predefined 2-D templates and 3-D objects for commonly used industrial equipment: machine tools, fork trucks, containers, storage racks, conveyors, cranes, vehicles, office furniture, kitchen equipment, rest rooms…
4. Default layer definitions, assignments and names that are consistent with industry practices and terminology. See Figures 13-9 and -10.

5. Default line styles, colors and widths that are associated with templates and object of various types – machinery, material handling equipment, aisle boundaries, building walls, etc. (Like those in Figure 13-13).
6. Parametric, intelligent objects for commonly encountered equipment and layout features. FactoryCAD offers mezzanines, guard rails, fencing and enclosures, conveyors, cranes, floor pits, and many more. Parametric means that the objects can be quickly sized by dragging or keying desired dimensions. Intelligent means that modules or pieces snap together in appropriate ways and the assemblage can be managed as a group. (See Figure 13-6 below).
7. Data management tools for keeping track of and finding the instances of symbols, objects, and blocks of grouped objects in large layouts. Closely related are tools for take-offs, calculations, and reporting.
8. Ability to drop unnecessary detail from displayed objects. This is essential to keep display performance from degrading. Refer back to Figure 13-5. But be sure to understand what is being removed and that the objects are not now missing details essential to effective placement, e.g. door swings, travel limits of moving elements, etc.
9. Special geometric tools for checking clearances and detecting interferences between pieces of equipment.
10. Industry-standard symbol sets various disciplines.

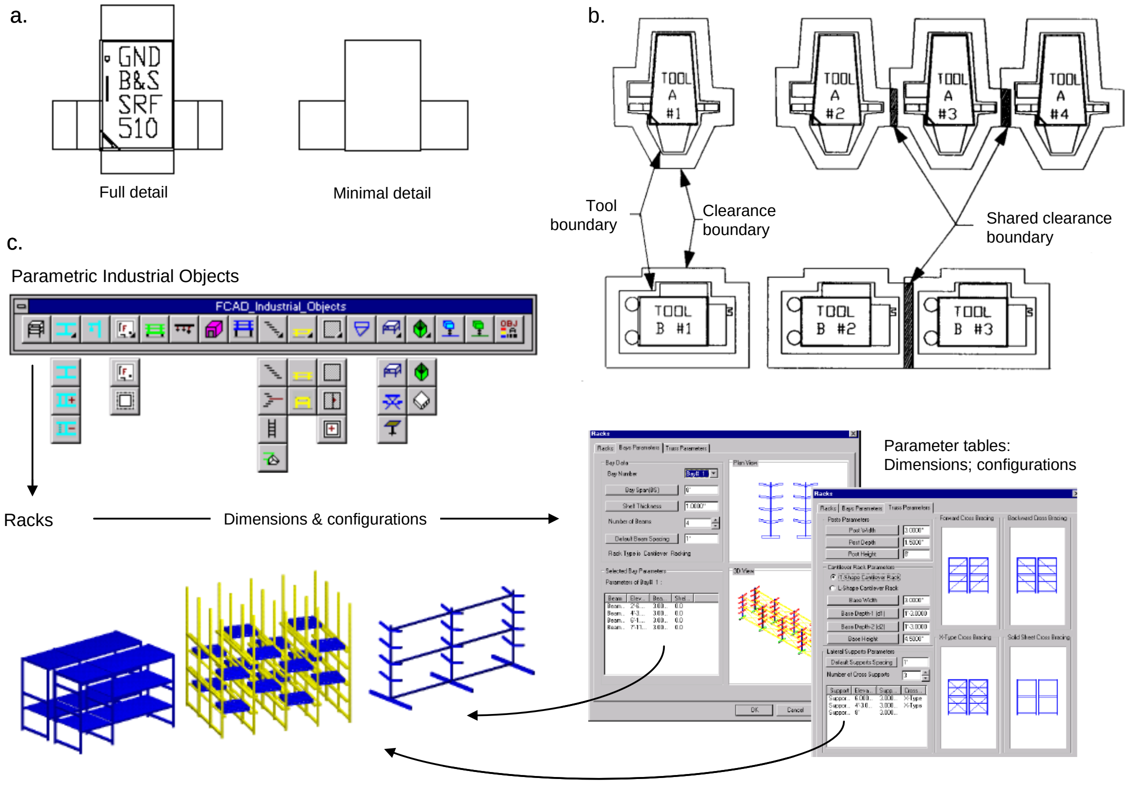


Figure 13-6. Several useful features in layout-oriented CAD software: (a) variable detail; (b) automatic offsets for clearance checking; (c) parametric industrial objects. Courtesy of Siemens PLM Software (FactoryCAD).

Layering and Visualization

A layer is a logical concept used to group and segregate specific data within a CAD drawing or model. Different kinds of information are assigned to separate layers. A short yet effective layering scheme for plant layout drawings appears in Figure 13-7.

Layer Name	Drawing Elements Assigned
BLDG-AISLES	Painted or taped aisle lines on the floor
BLDG-COL	Building columns
BLDG-COL -LINES	Column lines (centerline Linetype)
BLDG-TEXT	Building text / room descriptions or department numbers
BLDG-WALLS	Building walls, doors, windows, etc.
BLDG-UTIL-ELEC	Building utilities - electrical outlets, switches, lighting, etc.
BLDG-UTIL-MEC	Building utilities - mechanical plumbing, piping, HVAC, etc.
BORDER	Drawing titleblock, border, legends & north arrow
CRANE-HOIST	Overhead cranes, hoists, jibs, etc., including support columns to floor
DIM-NOTE	Dimensions and notes for equipment installation & locations
EQUIP	Manufacturing equipment, gage tables, workbenches, etc.
FLOOR-FND	Floor foundation lines, flumes, trenches, expansions joints, etc.
GDRAILS	Guardrails, bollard posts, safety fences, etc.
MATL-HNDLG	Material handling equipment - conveyors, carts, shuttles, chutes, etc.
MATL-STRG	Material storage - gons, bins, containers, dunnage, etc.
MEZZ	Mezzanines, platforms, stairways & ladders
MEZZ-EQUIP	Equipment on mezzanine levels overhead
OPER	Operator work positions (people)
SITE-FENCES	Fences & gates external to building
SITE-LANDSCAPE	Grass, trees, shrubs, etc.
SITE-PROP-LINE	Property lines
SITE-ROUTES	Driveways parking lots, sidewalks, etc. external to building
SITE-TEXT	Site text, descriptions, and numbers
SITE-UTIL	Site utilities external to building - electrical, underground, sewer, etc.

Figure 13-7. Simple layering scheme for plant layout. Additional layers may be added in keeping with the pre-fix structure. For example, if proposed equipment needs to be distinguished from existing, a new layer could be named EQUIP-PROPOSED. Or paint line equipment could be assigned to EQUIP-PAINT. Courtesy Integrity Design Services.

As suggested in Figure 13-8, layers can be displayed or not and grouped to view and plot various elements of interest. This allows the planner and others to see only what is necessary at the moment, without the distraction of unneeded information.

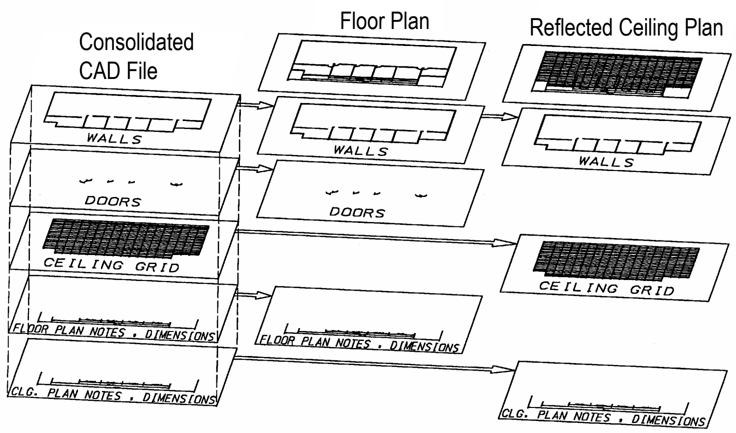


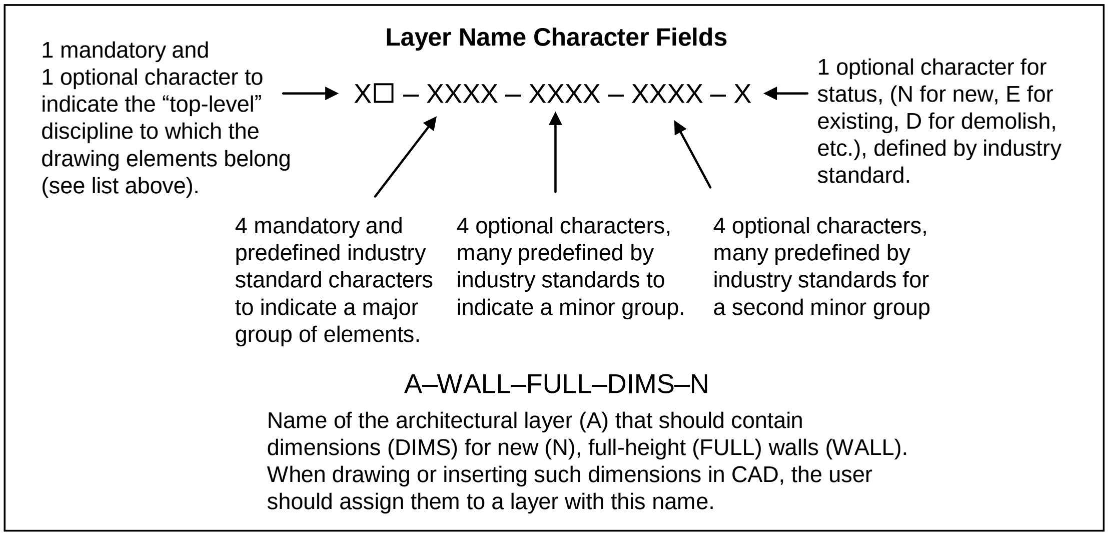
Figure 13-8. Layers separate different kinds of data in a given drawing. Layers can be copied and combined with others to product composite drawings and views of the layout and facility. Standard layer names become important when layers are created or shared by two or more planners.

Layers also facilitate the orderly exchange of information between drawings and between the layout planner and others – plant engineers, architects, equipment suppliers, and contractors. For such exchanges to be effective, the parties need to use the same layer definitions. To this end, various professional and industry groups have published standard layer names and conventions for drawings of the built environment. As often happens, the international standards organization (ISO) has arrived at a similar yet different layer naming convention than the United States. The ISO Layer Standard is 13567. The U.S. layer standard – largely from the American Institute of Architects (AIA) – is part of the U.S. National CAD Standard, published by the National Institute of Building Sciences. Version 4 of this standard defined almost 1,500 layers – putting it at the extreme opposite of the simple list in Figure 13-7. The top-level structures of the ISO and U.S. standards appear in Figure 13-9. The U.S. convention for layer naming is illustrated in Figure 13-10.

ISO-13567	
A-	Architect
B-	Building surveyors
C-	Civil engineers
E-	Electrical engineers
F-	Facility engineers
G-	GIS engineers and land surveyors
H-	Heating and ventilating engineers
I-	Interior designers
L-	Landscape architects
Q-	Quantity surveyors
S-	Structural engineers
T-	Town and country planners
W-	Contractors
X-	Sub-contractors
Y-	Specialist designers
--	Manufacturer

US National CAD Standard®			
A-	Archtectural	M-	Mechanical
B-	Geotechnical	O-	Operations
C-	Civil	P-	Plumbing
D-	Process	Q-	Equipment
E-	Electrical	R-	Resource
F-	Fire Protection	S-	Structural
G-	General	T-	Telecommunications
H-	Hazardous Materials	V-	Survey/Mapping
I-	Interiors	X-	Other Disciplines
L-	Landscape	Z-	Contractor/Shop Drawings

Figure 13-9. Top-level layer designators in two standards for CAD layer names. The ISO standard uses the top-level concept of an agent. The U.S. standard uses disciplines. Appended sequences of letters and/or numbers further define each layer's content.



1 mandatory and 1 optional character to indicate the "top-level" discipline to which the drawing elements belong (see list above).

1 optional character for status, (N for new, E for existing, D for demolish, etc.), defined by industry standard.

4 mandatory and predefined industry standard characters to indicate a major group of elements.

4 optional characters, many predefined by industry standards to indicate a minor group.

4 optional characters, many predefined by industry standards for a second minor group

A–WALL–FULL–DIMS–N

Name of the architectural layer (A) that should contain dimensions (DIMS) for new (N), full-height (FULL) walls (WALL). When drawing or inserting such dimensions in CAD, the user should assign them to a layer with this name.

Figure 13-10. General form and example of layer naming in the U.S. National CAD Standard® 4.0. (The latest version at the time of publication is 6.0). Most 4-letter character codes are mnemonic English abbreviations of design and construction terms.

Both the ISO and U.S. efforts have been driven by the needs of architectural and civil engineers, and contractors to visualize all kinds of designs and construction. As a result, hundreds of pre-defined layers are of little or no interest to industrial layout planners while others that are essential in complex manufacturing layouts and industrial facilities designs are missing and must be user-defined.

In smaller facilities where the layout planner works alone and is the keeper of all drawings, the use of industry layer standards and their differences may be of little or no consequence. The same is true when layout planning is rare and detailed visualizations and drawings are prepared by outside consultants or equipment suppliers.

But in large companies that routinely rearrange and construct facilities throughout the world, layouts are critical inputs to diverse teams of design firms, machine builders, equipment suppliers, mechanical and electrical contractors, and constructors. Here, the standardized naming and use of layers helps various users to find, see and work with only the information that they need for a particular task, rather than the entire model. Some companies with central CAD staffs have published their own layer standards for their projects. Figure 13-11 is an example from the Chrysler automobile company, circa 2008.

File Naming and Coordination Among Disciplines

Standard layer names help to manage and find information within drawings or models. Standard file names help to find and exchange the desired drawings and models. On large projects or those being planned by several disciplines, the parties need to work in parallel with drawings created by others. Finding the correct drawing is essential. This means finding the drawing with the desired contents – disciplines and layers – and on the correct version or release. Both are accomplished with standard file naming conventions.

Figure 13-11. Standard layer names as used by Chrysler about 2008. At that time, these were central to Chrysler's CAD requirements for manufacturing facilities planning, design, construction, and rearrangement. Note the similarities of top-level discipline designators on the left to the U.S. National CAD Standard (AIA) list in Figure 13-9 and the use of the layer naming convention in Figure 13-10.

Chrysler added non-conflicting designators for disciplines essential to automotive plant layout and design. See, for example: J for Material Handling (Mobile) and N for Conveyors. The optional second character separated equipment (Q) used in different parts of the manufacturing process. Thus, QB defined layers containing equipment for Body-in-white (sheet metal assembly, before trim, paint, chassis, and final assembly). QF, QP, QS, and QT defined equipment layers for these downstream operations. With second letters designating "areas", layers could be used to isolate different zones or "departments" of the manufacturing facility. Thus, "JM" would isolate mobile material handling equipment in machining areas; "NP" would isolate conveyors in the paint shop, etc.

Note the use of the layer standard's optional second 4-character set. For example, ROBT-MHDL and ROBT-WELD separated different kinds of robots onto their own layers. In this way, several hundred standard layers were defined.

One-letter status characters may be appended to the 4-character groups. Chrysler's were nearly identical to those in the U.S. and ISO standards. (NOTE: Outside of Chrysler and the U.S. standard, many designers put a status code in the #2 position of the top-level discipline designator. Thus AD refers to architectural elements to be demolished. Others use a mnemonic code such as DEMO in the second or third 4-character set of the layer name.)

CAD Layer Naming

Discipline designators

Adapted and extended from
the US National CAD Standard

A	Architectural
B	Architectural Ceiling
C	Civil/Site
CG	Civil Grading
CS	Civil Survey
CU	Civil Utility
E	Electrical/Power distribution
F	Fire Protection
H	Environmental/Hazardous
J	Material Handling (Mobile)
K	Plotting (Sheet files)
M	Mechanical/Piping/HVAC
N	Conveyors
P	Plumbing
Q	Equipment (generic)
QB	Equipment: Body in White
QF	Equipment: Trim, Chassis, Final
QP	Equipment: Paint
QS	Equipment: Stamping
QT	Equipment: Powertrain
S	Structural
T	Telecom/Computer networks

Layer Names and Colors

(Examples from a list of hundreds of discipline-groups and sub-groups)

A-	AISL		Aisles	MED GRAY
A-	BLDG-	OTLN	Building outline	CYAN
A-	CRIB		Skilled trades areas, cribs, maintenance crib, work areas	DRK GRAY
A-	DOCK		Docks, ramps, dock area	MED GRAY
A-	PITS		Pits and trenches	BLUE
J-	FORK		Fork truck	YELLOW
J-	LIFT		Container/rack lift & lift table	BLUE
J-	MRSH-	AREA	Material marshalling areas, secondary storage	BLUE
J-	OPER		Operators, workers, job description	BLK/WHT
J-	RACK		Part racks & text	BLUE
J-	SCAL-	TRUK	Truck scales	BLK/WHT
J-	TRUK-	SEMI	Semi truck & trailer	BLK/WHT
J-	TUGG		Tow tractor, tugger	YELLOW
J-	TURN		Container turntable	BLUE
Q☐-	BNCH		Work benches, tables	GREEN
Q☐-	BOTH		Booths, enclosures and related text	MED GRAY
Q☐-	BRAK-	AREA	Pre-fabricated team meeting, break areas	BLK/WHT
Q☐-	CRAN		Overhead rails, bridges, hoists, cranes	YELLOW
Q☐-	EQPT		General equipment layer	BLUE
Q☐-	ROBT-	MHDL	Material handling robots & related text	ORANGE
Q☐-	ROBT	WELD	Weld robots & related text	ORANGE

Desired visualizations by combinations of layers

Area Descriptions

B	Body in white
C	Civil (Site plan)
D	Die Shop
F	Trim, Chassis, Final
G	Foundry
K	Small press
L	Large press
M	Machining
P	Paint
S	Stamping
T	Powertrain
Z	Overall/Site

4-character group and optional sub-group codes for "subjects" or "aspects" within the top-level discipline designated.

Status Designators

N	New
E	Existing
C	Change (Kit)
D	Demolish
F	Future
T	Temporary
M	Move
X	Not in contract
H	Hatch pattern

Add as suffix following discipline-group code.

Adapted from: Chrysler Manufacturing CAD Requirements
https://gsp.extra.chrysler.com/mfg/amedd/facility/index.htm

Typically, file names incorporate discipline or subject-group codes similar to the layer names already discussed. In fact, drawings comprised of several commonly-needed layers can be created and identified by a single discipline-group code. An example from the Chrysler company appears in Figure 13-12. The 4-character discipline-group code in the example is consistent with the layer meanings in Figure 13-11. Thus the “J” in JAMD refers to mobile material handling equipment; the “AMD” to automated material delivery.

In addition to file names, standards for sheet and revision numbering, and other title block information are important to finding and sharing layouts. Document control is valuable for tracking which drawing version is the latest or should be used for what purposes, and who is authorized to make changes. Document control helps to know which parties are using a drawing at any moment, should its authors make changes, and to alert authors when others have prepared derivative plans.

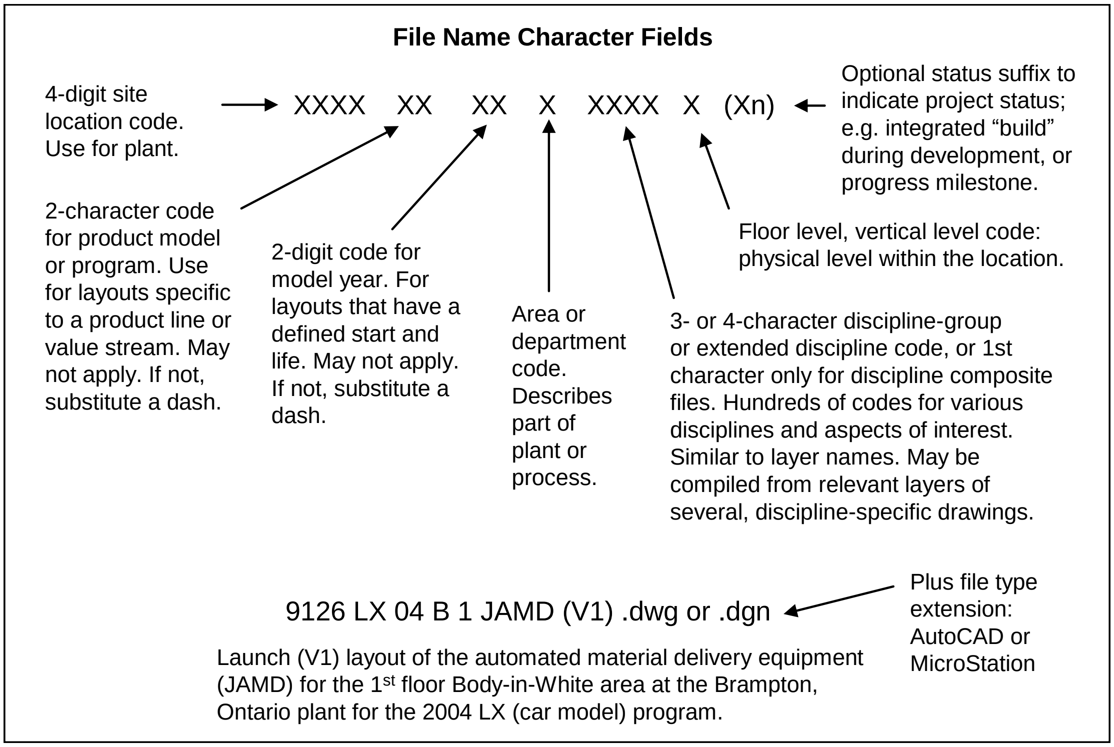


Figure 13-12. Chrysler file-naming conventions about 2008. In addition to standard layer names shown in Figure 13-11, Chrysler also defined standard file names as shown above. In a large organization or complex design project, file names help each discipline to find the drawings it needs to work in parallel with others while avoiding inconsistent or conflicting decisions.

Chrysler’s conventions helped to locate drawings by location, by product model housed, by time period for layouts with a launch date and defined life, by area or department within location, by discipline or “subject”, by floor level, and by “status” in terms of the design process itself.

Most companies’ facilities are less complex than Chrysler’s and do not need this many fields. But the principles apply to all sound file naming schemes. For example, in a single site with four numbered buildings, the 4-digit site location code above could become “1A04,” meaning “Building No. 1, Bay A04” where “A” and “04” are column lines within Building No. 1. The 2-character model code could identify a product-specific view or portion of a facility, or a value stream within it. The 2-digit model year could refer to the stages of a multi-year implementation program.

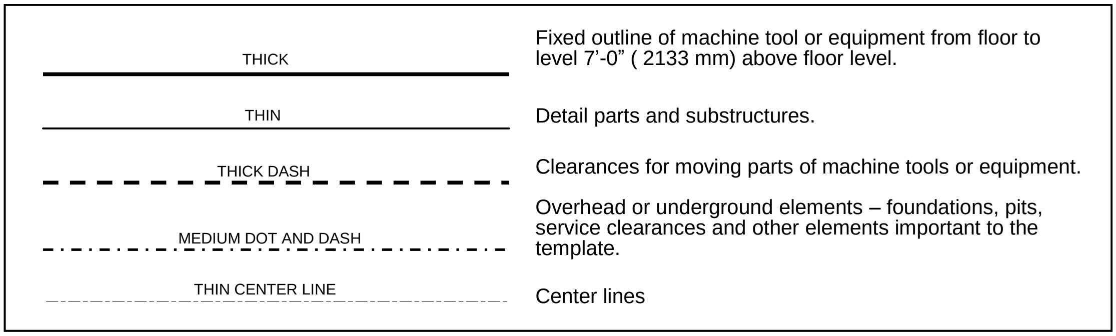
Most readers will not be involved with the complexity of Chrysler’s standards. But any time that two or more planners create or contribute to layout visualizations, they should agree on how each will use layers and file names. Even the lone planner will benefit from their thoughtful and consistent use. As noted earlier, layout-oriented CAD provides pre-defined drawing layers – typically with some conformance or similar to the ISO and U.S. National CAD Standard.

Drafting and Template Standards

Layouts are easier to read and understand when planners use standard line weights and line styles, colors, lettering, north arrows and orientations, drawing scales, and drawing origins. While such drafting standards are beyond the scope of this text they are also important to effective layout visualization.

Examples of line weights for plant layout appear in Figure 13-13. An example of annotation standards for 2-D templates appears in Figure 13-14.

Use of color deserves careful attention. While vivid on a computer screen, some colors plot and photocopy very poorly or not at all. Watch out for colors that drop out when reproduced in black and white. Colors should be tested in various modes of reproduction. Those with problems should be identified, excluded from use and alternatives found, regardless of industry standards or default settings in CAD software.



THICK	Fixed outline of machine tool or equipment from floor to level 7’-0” (2133 mm) above floor level.
THIN	Detail parts and substructures.
THICK DASH	Clearances for moving parts of machine tools or equipment.
MEDIUM DOT AND DASH	Overhead or underground elements – foundations, pits, service clearances and other elements important to the template.
THIN CENTER LINE	Center lines

Figure 13-13. Suggested line styles and weights for plant layout templates and drawings. From an early standard of the American Society of Mechanical Engineers.

1. Type of machine or equipment
2. Name of manufacturer
3. Style, model, size or capacity
4. Owner’s identifying (tag) number
5. Operator’s normal position (by arrow or symbol)
6. Left-right, front-back, height dimensions.
7. M – Position of motor
8. C – Position of control panel, switch, or adjustment
9. A or E – Position of Elect. or Air Connection
10. * – Point of maximum height

Figure 13-14. Data to be included (displayable) on templates. Items 1, 2 and 3 are mandatory. The rest are optional depending upon the circumstances. Clearly, much more information about each machine needs to be known and should be in a database and associated with its template. See also Figures 7-2 and 12-1.

Computer-graphic renderings, fly-through, and animation

One benefit of 3-D CAD is the ability to render the layout in various views. Most software contains some ability to color objects, shade them, texture their surfaces, and illuminate them in various ways. Some CAD software is extremely powerful in this regard. In addition, or as an alternative, many specialized software products such as 3DStudio are also available for photo-realistic rendering. These can import and render CAD drawings regardless of the software used to create them.

Some software permits the viewer to move or “fly” through the rendering – essentially stringing together a sequence of view points into a “movie.” While this is not animation – the elements in the scene do not move – it is often an effective way to visualize certain aspects of a layout, especially from an operator or material handler’s perspective.

More powerful still is software that shows the motion of 3-D objects in a scene or view of the model. In this way, the planner can view animations of a layout to see parts moving on conveyors, mobile handling equipment and robots in action, and people moving between operations. This form of layout visualization has become a popular sales tool for material handling equipment suppliers and integrators. Examples of rendering and animation appear in Figures 13-15.

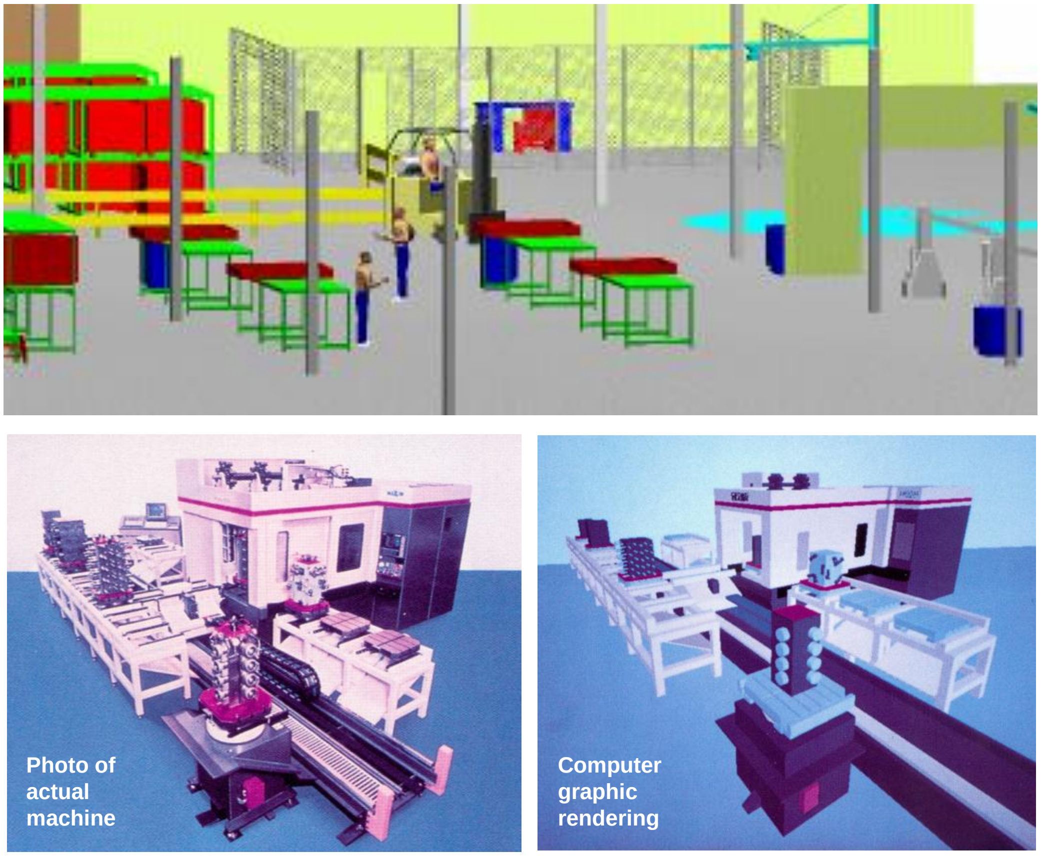


Figure 13-15. Top: Scene from a 3-D layout animation in FactoryCAD, courtesy of Siemens PLM Software. Bottom: Side-by-side comparison of actual and rendered machining center using Silma, (now Adept) Soft Machines, illustrating the question of how much detail is necessary.

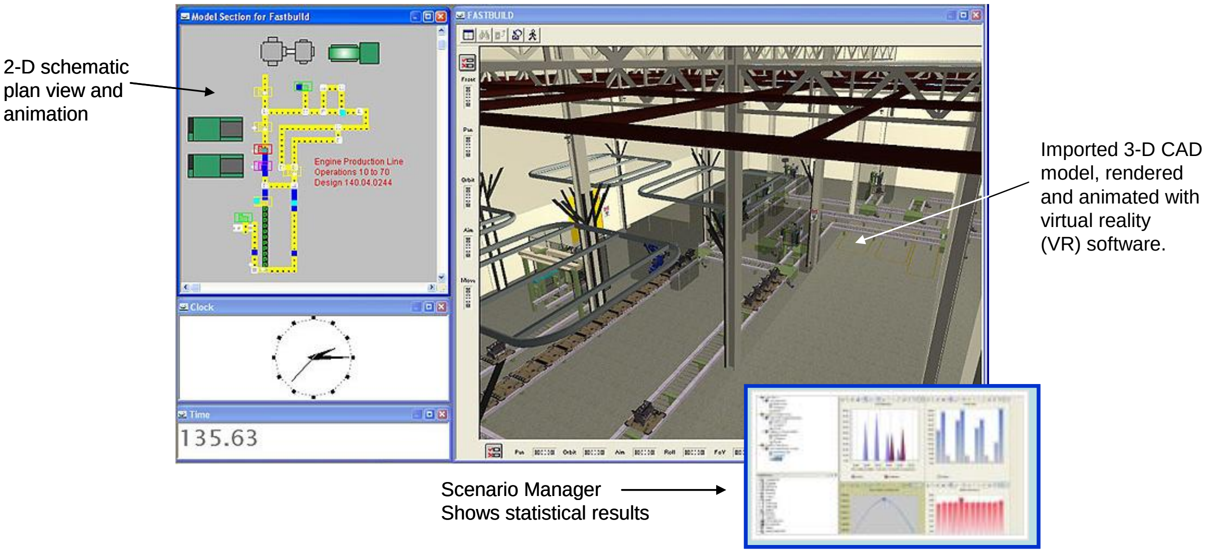
Animation of Discrete Event Simulations

Discrete event simulation models the behavior of various kinds of processes and systems. Each is commonly represented in software as a chronological sequence of events occurring in time and changing the state of a system. Commercial software for discrete event simulation augments statistical reports with graphical animation of objects in the system. This helps to see problems or situations that may be missed by viewing statistical reports alone. Animation also helps explain the simulation model and the system to others. Examples of such software include: ProModel, Witness, AutoMod, and Arena.

Normally, the process and even the system design are inputs to detail layout planning. But since the precise layout of equipment and people will influence system performance, simulation may be used in parallel with layout planning to evaluate the impact of alternative plans. (In terms of SLP, this typically falls in Phase III, Sections 4 and 5 of the SLP Pattern).

Simulation modeling requires special skills, training, experience and software. It is a technical field in its own right, at least as broad as layout planning and therefore beyond the scope of this text. However, planners should recognize its animations as another method of layout visualization. An example appears in Figure 13-16.

Note that in some discrete event simulation software, the layout visualizations are not dimensionally precise unless they have been imported from a CAD model. Still, even schematic visualizations can help to explain both the process and the general layout to those not directly involved in its design. At the same time, if CAD layouts are imported, care must be taken to manage updates and be sure they are consistent with the latest plan.



2-D schematic plan view and animation

Imported 3-D CAD model, rendered and animated with virtual reality (VR) software.

Scenario Manager Shows statistical results

Figure 13-16. Elements of the Witness simulation software. The traditional 2-D schematic is complemented by rendering and animation of an imported 3D layout. The ultimate purpose is to statistically analyze behavior and results under various scenarios. But such software offers the layout planner an additional method of visualization. Courtesy Lanner Group: www.lanner.com

Digital Mock-Up and Product Life Cycle Management

The highest form of visualization technology is that of the digital mock-up. In this method, the 3-D CAD model is simulated both as a system of discrete events and as a dimensionally precise model of physical objects in space, including movement of the manufactured parts and their containers between machine tools, robots, and operator workstations. Operator movements and fields of view are simulated with specialized software. As with discrete event simulation, the behavior of the production system can be analyzed under various operating conditions and failure modes. At the same time, physical interferences and collisions between moving objects can be detected, along with ergonomic problems for human operators. With some software, it is also possible to simulate and emulate the behavior of control systems comprising software, firmware, electro-mechanical, pneumatic and hydraulic devices. In this way, a manufacturing system can be "run" and "de-bugged" in virtual reality – before it is built. Some engineers refer to this as virtual manufacturing or virtual commissioning.

Digital mock-up is best understood as the last stage in product and process development prior to product launch. As such, it belongs to a field of data management called Product Lifecycle Management (PLM). PLM advocates the use of integrated information systems from product conception through manufacturing and field service, to end-of-life disposition, and ultimately through product phase-out. In the context of PLM, the layout planner is just one of many actors, but plays a critical integrative role, since the product and its processing must be brought together and realized in a physical facility.

Today, large-scale digital mock-ups of production are used mostly during design of automotive plants and similar billion-dollar facilities with multi-year lead times, material handling automation, and robotics. See Figures 13-17 and 13-18. This is partly because less complex undertakings with less risk do not need such detailed simulation. Another reason is cost. The software, hardware, and information technology staff needed for digital mock-up are beyond the budgets of most manufacturing plants and companies – hundreds to thousands of dollars per second of simulation. And most projects do not have enough engineers to provide all the data that digital mock-ups require. Technology costs will come down as they have for CAD, but the issues of risk, need, and staffing will remain.

Digital mock-ups of production lines require many data exchanges and integration between software products. Siemens PLM Software (Tecnomatix) and Dassault Systèmes (Delmia) provide full sets of applications. Bentley Systems offers a full set of applications for facility mock-up. But most would-be users of this technology will not buy all new software or from one or two sources. So they will need to integrate a variety of specialized applications – product design, numerical control and robot programming, facility design, human operator modeling, and discrete event simulation. This integration typically takes years.

From the perspective of Systematic Layout Planning (SLP), digital mock-up should occur late in Phase III Detail Layout. Ideally, a sound block or overall layout will have been developed in Phase II and tentative detail layouts prepared within each block. These detail layouts are then exported to the mock-up effort and refined there. Once finalized, the adjusted 3-D layout will be passed back to the layout planner for final checking and drawing production. This may involve stripping out unnecessary detail from the mock-up.

Figure 13-17. Example of digital mock-up and 3D discrete event simulation of an automotive body-in-white production line. Courtesy of Dassault Systèmes (Delmia). A key purpose is to detect interference and collisions between the many moving elements of the line.

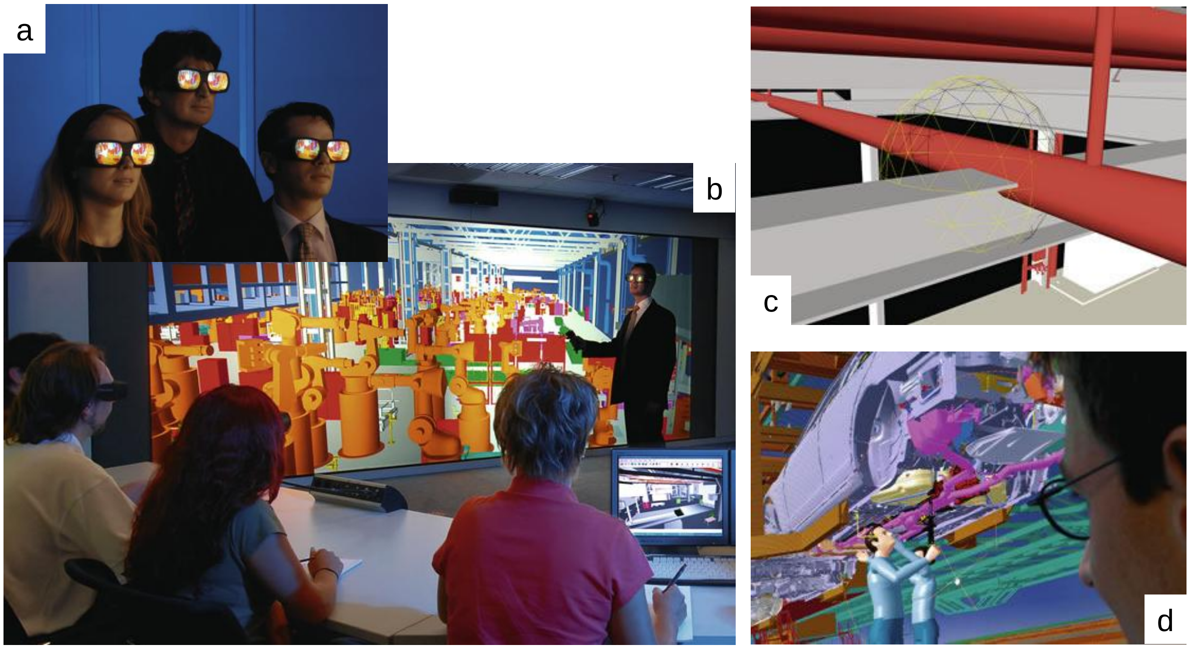


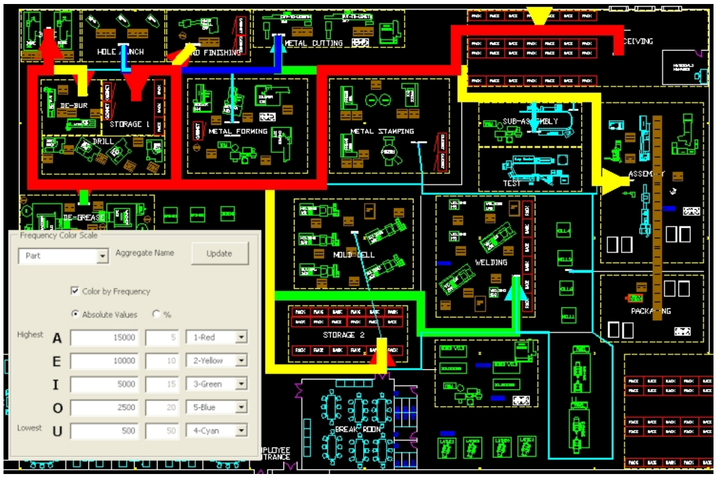
Figure 13-18. The future of digital mock-up. Daimler uses a rear-projection screen and 3D goggles to view a facility mock-up (a, b). Based on MicroStation, facilities design software detects interference among facility components – here (c) between utilities and building structure. Delmia software simulates product, equipment and operator movement (d) to detect collisions, interferences, access and ergonomic problems.

Daimler reports that early mock-ups on large projects may reveal a thousand or more interferences but frequent reviews leave only a handful to be discovered during installation. The change orders eliminated can save up to 20% of the installation cost – a good return on the investment in mock-up technology. Changeover times are reduced and ramp-ups are faster. Courtesy of DaimlerChrysler.

Visualizing Material Flow

The visualization of material flow directly on the layout is a valuable exercise in Phase II block or overall layout to assure that travel distance is minimized by the placement of activity areas. In Phase III detail layouts, flow often dictates the line-up of machines and travel distance is less important. Here, the planner is more interested in the walk paths and distance of operators fetching or moving parts or themselves between operations and stations. Both kinds of movement can be visualized by adding flow lines to a drawing. Typically line colors are used to visualize different classes of material and line thickness is used to indicate rate or volume of flow – thicker is higher.

FlowPlanner and FactoryFlow are two software products that make this kind of visualization easier and more powerful.[1] Both are far more than visualization tools. Their purpose is to plan material handling methods. Both calculate pieces of handling equipment needed and estimate costs with standard time data for various methods applied to travel distances in a layout. Both compute and visualize aisle traffic as shown in Figure 13-19. An earlier more complete illustration of FlowPlanner appeared in Figure 10-14.



Frequency Color Scale

Part ▾ Aggregate Name Update

☑ Color by Frequency

● Absolute Values ○ %

Highest	A	15000	5	1-Red ▾
	E	10000	10	2-Yellow ▾
	I	5000	15	3-Green ▾
	O	2500	20	5-Blue ▾
Lowest	U	500	50	4-Cyan ▾

Figure 13-19. FlowPlanner computes and visualizes aisle traffic with the SLP vowel- and color-code conventions: A-Red, E-Yellow, I-Green, O-Blue, U- Uncolored. Courtesy of ProPlanner.com

Software for Automated Block Layout Generation

No discussion of layout planning software would be complete without mentioning mathematical programs for automatic generation of layout plans. These plot a block layout and are thus loosely related to visualization. But their purpose is to take inputs of *relationships* and *space* and automate their *adjustment* into a layout. Most college texts on layout and facilities design devote hundreds of pages to these programs and their underlying mathematics. Their use in industry is rare. The interested reader should consult: *Facilities Design* by Sunderesh S. Heragu, CRC Press, 2008; and *Facilities Planning and Design* by A. Garcia-Diaz and J. MacGregor Smith, Pearson Education, Inc., 2008.

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[1] FlowPlanner and FactoryFlow were developed by Dave Sly, founder and President of ProPlanner. FactoryFlow was developed in the 1980s as a companion product to FactoryCAD. Both are owned today by Siemens PLM Software. All three products are faithful to the conventions of Systematic Layout Planning (SLP).

High Touch Visualization Methods

The term "*high touch"* was coined in the early 1980s by author and futurist John Naisbitt. It refers to interaction with people in contrast to interaction exclusively with computers and software. In the context of layout planning, the term refers to methods of visualizing by hand. These include:

- *Hand-drawn sketches* – typically on a whiteboard, flip chart, grid sheet or scaled architectural plan of the space available.
- *Template arrangement* – typically scaled and color-coded paper or cardboard outlines placed on a grid sheet or architectural plan. (Refer back to Figures 9-13 and 9-14).
- *Physical model* – typically a static model made of cardboard, wood, or Styrofoam or toy blocks at a table-top scale. (See Figures 13-20 and 13-21).
- *Full-scale mock-up* – representing equipment faces and outlines with various materials and equipment: wood, corrugated cardboard, steel tubing, existing benches and racks, etc. (See Figure 13-22).

These methods are in stark contrast to *"high tech"* computer-based visualization. They won't do for detailed design of an automobile assembly plant. But even when 3D CAD and rendering are available, such simple "high touch" methods have a sound place when planning small or relatively straightforward rearrangements or expansions. This is especially true when the planning is done on the shop floor or conference room table with operators and first level supervisors. Some refer to these methods with pride as Cardboard-Aided Design. They may follow with detailed CAD models and drawings, but swear by the value of early and direct shop floor involvement.

Figure 13-20. Physical scale model in cardboard and wood for 5,000 square meters of metal fabrication and assembly, including overhead cranes and a mezzanine. Built by supervisors and planners on the floor of the plant, this model enabled management and workers to understand the plan. It also helped to visualize how the rearrangement could be made while staying in production.

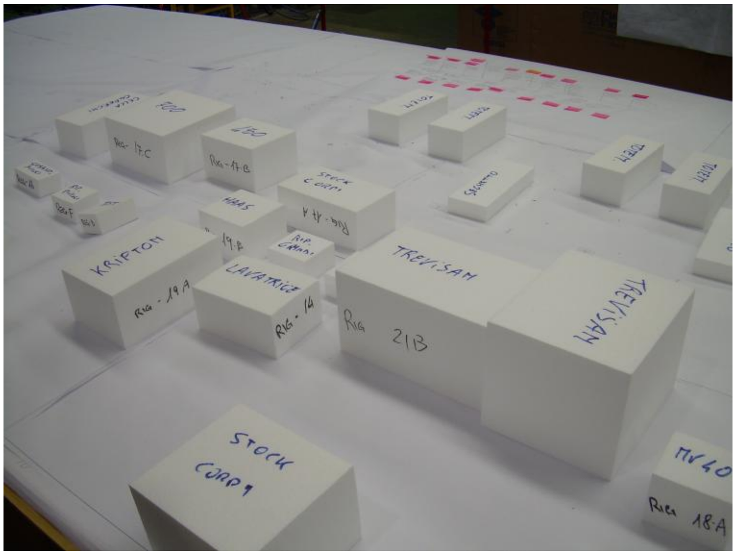

Figure 13-21. Physical model using Styrofoam blocks to represent machine tools and equipment. The Kaizen Promotion Office arranged for the blocks to be made and provided them to the layout planning team. Blocks are placed on a plot of the layout developed using SLP. All planning was conducted and the model was built on a large makeshift table in the middle of the shop.

Figure 13-22. Full scale mock up of a simple machining cell using steel tubing, plywood, cardboard, Styrofoam, and tables borrowed from the office. A 16-person team planned the layouts and mocked up six similar cells during a 10-day period. Each mock-up visualized a paper template layout developed with SLP. Layouts were refined by adjusting the mocked-up equipment. Planners then walked through the production cycles for representative parts, confirming cycle times and completing standard work forms. This mock-up is for the standard work form shown earlier in Figure 12-11.

Guidelines for Layout Visualization

Visualization methods are not mutually exclusive and they often co-exist in the same plant and in the same layout project. Therefore, the layout planner should understand their pros and cons, and make the most appropriate uses of each method. A guide listing the conditions favoring each method is given in Figures 13-23 and -24.

METHOD	CONDITIONS FAVORING
Hand-drawn sketch -- typically on grid or scaled architectural plan, but also on white board or flip chart.	1 When you need quick ideas for alternative arrangements 2. When you are roughing out ideas before positioning templates or drawing in CAD. 3. When you are working with a team on the shop floor or around a conference table. 4. When the layout is relatively simple with a few pieces of machinery and equipment. 6. When the equipment is highly regular; multiple instances of standard equipment. 5. When surveying an existing layout or machine for which there is no drawing.
Scaled templates -- typically of paper on grid or scaled base sheet of available space.	1. When you want to actively involve others in developing layouts. 2. When you want to rapidly explore ideas and rough, approximate arrangements. 3. When you are working with a team on the shop floor or around a conference table. 4. When you will follow up later with a precise drawing or CAD model. 5. When equipment is largely free-standing with easily-made utility connections. 6. When the equipment is highly regular; multiple instances of standard equipment. 7. When the project is to quickly rearrange operations without new construction.
Physical scale model -- typically wood, cardboard or Styrofoam.	1. When the layout has vertical elements hard to see in a 2-D drawing or templates. 2. When the layout involves many outsiders or needs to be sold or explained to managers and employees. 3. When the equipment is highly regular; multiple instances of standard equipment. 4. When you have the skills, time and space available for modeling.
Full scale mock-up -- typically of steel tube, wood and cardboard.	1. When the equipment is small and simple enough to be represented by its envelope and key surfaces only. 2. When the layout consists of only a few simple benches, racks, or small free-standing machines. 3. When you want to involve others in refining a detail layout already drawn. 4. When you need to walk-through the layout to determine cycle times. 5. When you will follow-up with precise CAD drawings. 6. When you have the space, time and materials to do it.

Figure 13-23. Conditions favoring “high-touch” visualization methods.

METHOD	CONDITIONS FAVORING
2-D CAD drawing	1. When you are ready to be dimensionally precise about the layout. 2. When you are following and refining sketches and template arrangements developed by planning teams. (You already have their input). 3. When the layout has few elevation issues involving mezzanines, overhead handling and utility tie-ins overhead or under the floor. 4. When you are preparing for a full-scale mock-up.
3-D CAD model	1. When multiple elevations or sectional views will be required (due to issues with moving elements, overhead clearance and tie-ins) 2. When you are following and refining sketches and template arrangements developed by planning teams. (You already have their input). 3. When 3D models already exist and can be used. 4. When the layout is for new construction and must integrate with other disciplines; and when numerous views and sections will be needed. 5. When a color rendering is needed to explain or sell the plan.
Computer graphic rendering	1. When you need to explain the layout to others not involved in its development. 2. When you need to sell the plan to others not involved in the planning. 3. When new and expanded buildings are subject to public scrutiny.
Computer graphic animation of discrete event simulation	1. When in doubt about the capacity or performance of a complex process or system. 2. When you need to explain a system to others (in addition to the layout). 3. When the layout and system are too large or complex for a physical mock-up. 4. When trained and experienced modelers are available or can be retained.
Digital mock-up -- computer graphic and discrete event simulation of a 3D CAD model	1. When designing large, expensive and complex new plants and/or highly automated manufacturing systems. 2. When complex design is being performed concurrently by different groups and outside professionals using different CAD systems. 3. When the layout involves movement of large irregular parts in tight quarters. 4. When the information technology and know-how are in place to make it happen.

Figure 13-24. Conditions favoring various electronic visualization technologies.

Part Four

Introduction to Part Four

Part One set forth the fundamentals of SLP – its framework of phases, its key input data, and its pattern of procedures.

Part Two exploded the pattern. We described in detail how to apply the procedure of each box, or step, for general overall layout planning and set forth a series of simple conventions, describing how to use them with various procedures in the pattern.

Part Three was devoted to describing detail layout planning. As Part Two covered Phase II of the framework, Part Three covered Phase III.

Part Four includes three chapters. These final chapters are devoted to Phase I and IV of the framework and to how layout projects should be managed.

Recall that Phase I, Location of the area to be laid out, comes first in the four-phase framework, but that we postponed its discussion. We did so because Location does not always fall under the responsibility of the layout planner and because its SLP significance can better be understood after thorough study of the two strictly layout planning phases.

This postponement is not meant to belittle Phase I. Every layout project has its four phases, regardless of who is responsible for executing each one. Even a minor rearrangement of a small department involves four phases. But were the whole company to be relocated, such a project would be only a small part of what would be considered detail layout planning. In minor relayouts, the planner must first know whether the area involved is to remain in its present location, and if not, where it is to be placed. This is Phase I, Location. Then the area is planned generally (II), in detail (III), and installed (IV). (Refer to Figure 2-3 *for a pictorial recap of these four phases in action.)*

Actually, the planner must look at the phases from the viewpoint of the area being laid out. Otherwise, the four phases may not be seen clearly. From the standpoint of one building on a site, a departmental relayout occurs as Phase III – or III-A. But, if the department is relocated within the building, this location is Phase I for the department; yet it is a readjustment of the general overall layout (II) from the standpoint of the total building. Thus, the four phases involved in every layout project should be considered from the viewpoint of the area being laid out.

Chapter 14
Location

This chapter describes the planning that occurs in Phase I of the SLP framework to determine the Location of the area to be laid out. It covers several common interpretations, beyond "Plant Location" as generally defined. We limit the discussion to the location of a single site or activity-area since this is the most common situation encountered by layout planners.

Meaning of Location

The term *location* means the place something is. In the narrowest sense, detail layout planning involves the *location* of each piece of machinery and equipment. If the layout project were to relocate only one machine, the phases would be:

I. Locate the area where the machine is to be laid out.
II. Place it generally for best flow and in relation to its supporting services.
III. Align and orient it with the specific features of equipment immediately adjacent to it.
IV. Plan and make the installation.

At the other extreme, *location* may involve an international problem of site selection. But the usual location problem is neither so simple nor so complex. It may be what is generally described as Plant Location. Most often, it is finding where to locate an expanding department within a given building (or complex of buildings on a site), or finding a location in another building (or site) in the same community or nearby area.

As a result, location problems typically involve questions like these: Do we build a new building or stay where we are? Do we expand into the finished goods warehouse and rent new warehouse space or do we expand to the South and rearrange the whole plant? Do we consolidate the office area on the second floor or leave it divided? Questions like these, which involve determining the location of the area(s) to be laid out, should be answered before serious layout planning.

Getting Organized

When the need is to find a new site, the first step is to clearly assign responsibilities. In smaller companies this frequently involves a committee or team, though some member of top management remains as chairman. Even in large companies where a central staff of specialists may be available to provide technical analyses, a specific official, usually of the product or operating division directly involved, is in charge of investigations. Still, picking a new location for the company or for an expanded major branch is a problem involving practically all top-level management or their representatives. In large, multi-plant companies, this is true of the top management of the division involved.

Location projects involving a new site usually follow the same four-phase overlap-and-refine logic of most projects:

- I. Set specifications, scope, restrictions.
- II. Analyze and select general region or community.
- III. Analyze and select specific site.
- IV. Procure the site.

In any case, each location problem boils down to essentially three features or elements; (1) what is wanted; (2) what is available; and (3) what is most suitable.

Location Requirements

"What is wanted" is frequently termed location requirements, or specifications. These requirements typically include:

1. Area – size or amount of space required
2. Condition – nature and characteristics of the space
    - a. shape, orientation
    - b. topography and drainage
    - c. subsoil and understructure
    - d. prevailing wind
    - e. site (or building) improvements or preparations
    - f. relocation of existing utility lines or pipelines
    - g. flood history
    - h. site access ways
3. Relationship with sources and destinations
    - a. raw materials
    - b. suppliers
    - c. customers or markets
    - d. related transportation (rail, truck, water, air)
    - e. related travel convenience
4. Contacts
    - a. with personnel – supply, availability, type, labor history
    - b. with utilities and auxiliaries – electric power, water, gas, coal, fuel oil, sewage and waste disposal
    - c. with local services – local transportation, communications, banks, commercial and professional services, police, fire, trash
    - d. with government – taxes, zoning, easements, restrictions, codes
5. Surroundings
    - a. general – physical climate, state and community attitude, neighborhood, appearance
    - b. housing, hospitals, health and welfare
    - c. schools and education, recreation, cultural opportunities
    - d. city planning, roads
    - e. other business attitude

6. Investment
    a. land
    b. site improvements
    c. buildings, construction, rent
7. Profit Potential
    a. operating costs
    b. savings and return

With these requirements spelled out – usually in a longer, specific list – a search is begun for what is available.[1] As pointed out, this may involve regions first, communities next, and then specific sites. As we get closer to the actual site selection, the data sought becomes more specific. In any event, there is a matching or comparing of the requirements (what is wanted) with the areas available to decide what is most suitable.

Short- and long-range utility requirements, labor needs, transportation activity and floor space should all be specified in quantitative terms as shown in Figure 14-1. To the extent practical, planners should try to express otherwise subjective location and site requirements in measurable terms like those in Figure 14-2. Getting data will be tedious and at times impossible, but measurable comparisons reduce subjectivity when comparing alternatives.

Preliminary research, to reduce the number of potential locations, should be done with maps and economic data to eliminate areas that fall outside desired population ranges or do not have adequate transportation services.

Site Specifications	+2 Years	+5 Years	+10 Years
1 BASIC UTILITIES REQUIREMENTS			
Electricity -- Million KWH/Year	8 - 10	16 - 20	20 - 25
Electricity -- Thousand KWH/Day	32 - 40	64 - 80	80 - 100
Natural Gas -- Million Cu. Ft./Year	80 - 100	160 - 200	200 - 250
Natural Gas -- Thousand Cu. Ft./Year	0.3 - 0.4	0.6 - 0.8	0.8 - 1.0
Process Water -- Million Gallons/Year	150	300	350
Process Water -- Thousand Gallons/Day	600	1200	1400
2 PROBABLE PERSONNEL REQUIREMENTS			
Personnel:	300 - 350	700 - 750	850 - 950
60% Metal working -- relatively high skills 15% to 20% Machine operators; Lathe operators; Tool repair; Electricians 20% to 25% Clerical staff; supervisory Working: 250 days/year; 2 shifts/day; 16 to 20 hours/day			
3 RAIL NEEDS -- Rail cars per day	10	20 - 30	20 - 40
4 GENERAL			
Buildings Sq. ft.	400,000	700,000	850,000
Land: Approx. 40 - 60 acres clear of flood problems with good road access.			

Figure 14-1. Quantitative site specifications for a secondary steel mill. These are primarily concerned with utilities and service demand. From: Systematic Planning of Industrial Facilities, Vol. II, by Richard Muther and Lee Hales, Management and Industrial Research Publications.

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[1] For a more comprehensive list of factors see: New Project File & Site Selection Checklist, by Conway Research, Inc., Norcross, Georgia. An early edition of this comprehensive checklist also appears by permission as an appendix in Systematic Planning of Industrial Facilities (SPIF), Volume II, cited above.

SELECTING A COMMUNITY

Typical Objectives	Possible Factors to Measure
• Low material supply cost	– Cost per unit of raw material – Annual inbound freight costs
• Low distribution cost	– Delivered cost per unit – Annual outbound freight costs
• Adequate labor supply	– Number of potential workers within given commuting distance – Unemployment rate – Days lost to strikes
• Low labor cost	– Average hourly wages by category – Fringe benefits – Average workweek and local holidays
• Mild climate	– Degree-days by month – Average monthly temperatures – Average monthly humidity
• Adequate community services	– Hospital beds per thousand – Fire classification

SELECTING A SPECIFIC SITE

Typical Objectives	Possible Factors to Measure
• Proximity to labor force	– Commuting times to given points – Concentration of workers
• Adequate site size	– Useable acres
• Proximity to community services	– Response and driving times
• Proximity to utility services	– Distance to connecting points – Costs to hook-up, per service
• Frequency of transport service	– Pickups, switches per day – Latest pickup times
• Low land cost	– Cost per acre

Figure 14-2. Measurable objectives for community location and site selection. From: Systematic Planning of Industrial Facilities, Vol. II.

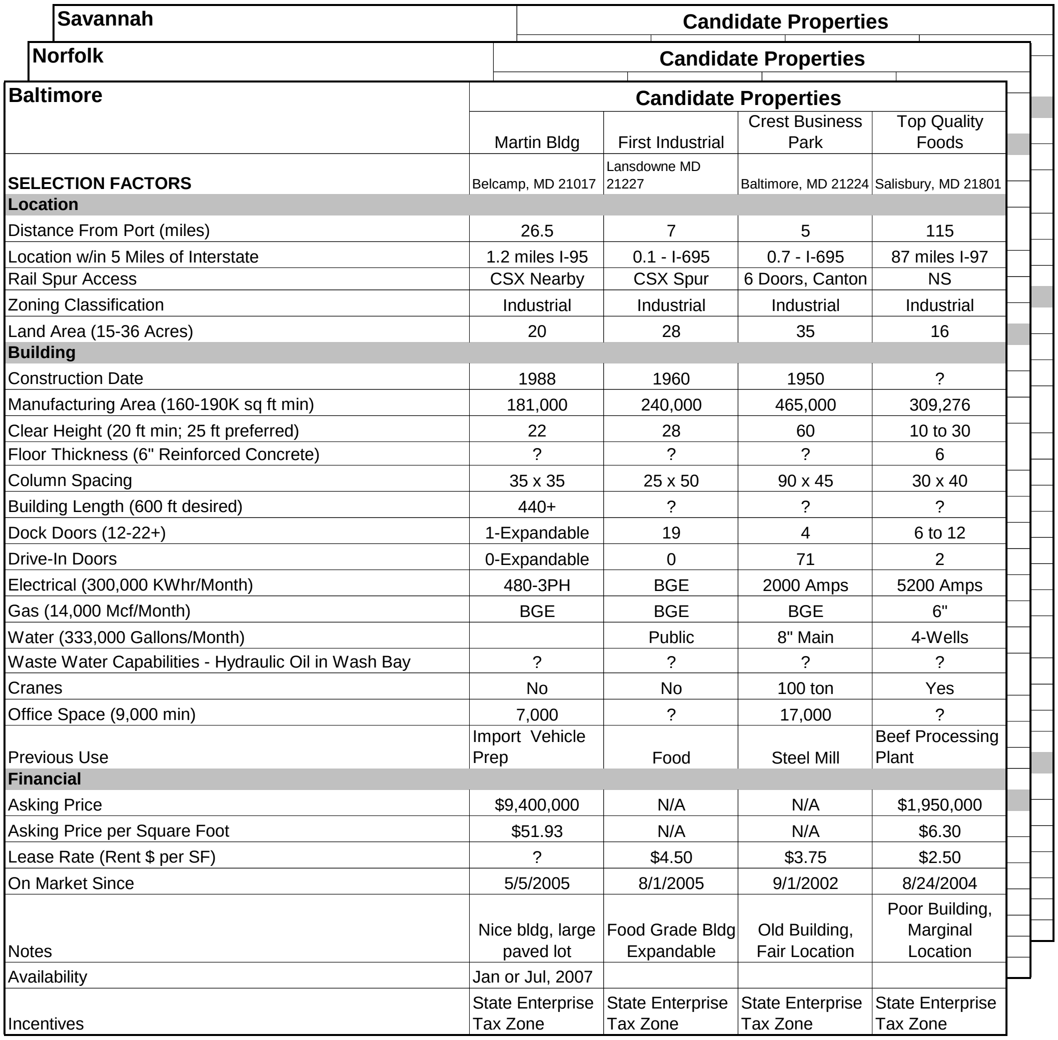
Prospective regions and communities within them are usually obvious in a specific situation. They will generally reflect the “pulls” of customer and market demand, material supply, labor supply, transportation hubs and ports, or special considerations such as financing, tax abatement or trade regulations. The company’s existing locations and their available capacities will also influence the possibilities.

Information on candidate locations can usually be obtained from national, state and local development agencies, chambers of commerce, public utilities, and railroads. Much statistical and descriptive information about communities is available on the Internet and can be searched fairly quickly within areas and regions of interest.

Prospective sites can be identified quickly on the World Wide Web, where the planner will find thousands of industrial properties and buildings throughout the world. These postings by industrial realtors and developers will typically include photos and basic data about each property (size, zoning, utilities…), and occasionally even drawings. A few will include asking price or rent. Once identified, surrounding areas may be explored using Google Earth or other geographic information systems.

Screening the adequacy of transportation service is more difficult and often requires contacting prospective carriers for schedules and rates. Similarly, realtors and local development agencies may need to be contacted for property prices, taxes, and potential incentives.

Outside consultants or realtors are often retained to perform initial screening, especially when the company lacks a staff with this kind of experience. Results of a typical screening exercise appear in Figure 14-3.



Savannah **Candidate Properties**

Norfolk **Candidate Properties**

Baltimore	**Candidate Properties**			
	Martin Bldg	First Industrial	Crest Business Park	Top Quality Foods
SELECTION FACTORS	Belcamp, MD 21017	Lansdowne MD 21227	Baltimore, MD 21224	Salisbury, MD 21801
Location				
Distance From Port (miles)	26.5	7	5	115
Location w/in 5 Miles of Interstate	1.2 miles I-95	0.1 - I-695	0.7 - I-695	87 miles I-97
Rail Spur Access	CSX Nearby	CSX Spur	6 Doors, Canton	NS
Zoning Classification	Industrial	Industrial	Industrial	Industrial
Land Area (15-36 Acres)	20	28	35	16
Building				
Construction Date	1988	1960	1950	?
Manufacturing Area (160-190K sq ft min)	181,000	240,000	465,000	309,276
Clear Height (20 ft min; 25 ft preferred)	22	28	60	10 to 30
Floor Thickness (6" Reinforced Concrete)	?	?	?	6
Column Spacing	35 x 35	25 x 50	90 x 45	30 x 40
Building Length (600 ft desired)	440+	?	?	?
Dock Doors (12-22+)	1-Expandable	19	4	6 to 12
Drive-In Doors	0-Expandable	0	71	2
Electrical (300,000 KWhr/Month)	480-3PH	BGE	2000 Amps	5200 Amps
Gas (14,000 Mcf/Month)	BGE	BGE	BGE	6"
Water (333,000 Gallons/Month)		Public	8" Main	4-Wells
Waste Water Capabilities - Hydraulic Oil in Wash Bay	?	?	?	?
Cranes	No	No	100 ton	Yes
Office Space (9,000 min)	7,000	?	17,000	?
Previous Use	Import Vehicle Prep	Food	Steel Mill	Beef Processing Plant
Financial				
Asking Price	$9,400,000	N/A	N/A	$1,950,000
Asking Price per Square Foot	$51.93	N/A	N/A	$6.30
Lease Rate (Rent $ per SF)	?	$4.50	$3.75	$2.50
On Market Since	5/5/2005	8/1/2005	9/1/2002	8/24/2004
Notes	Nice bldg, large paved lot	Food Grade Bldg Expandable	Old Building, Fair Location	Poor Building, Marginal Location
Availability	Jan or Jul, 2007			
Incentives	State Enterprise Tax Zone	State Enterprise Tax Zone	State Enterprise Tax Zone	State Enterprise Tax Zone

Figure 14-3. Excerpt from a screening report on new plant sites. Data was in gathered in one week without travel -- largely from the Internet, by telephone, and follow-up email. Aerial photos, building photos, and drawings were also obtained but are not shown here.

Transportation and Other Special Studies

Transportation costs – inbound and outbound – are typically key factors in plant location, although their significance is often overrated relative to differences in labor and material costs. The circumstances of each project determine how much study is required and what approaches to take. The most certain is to ask several prospective carriers for rate quotes on specific volumes and routes. An example is shown in Figure 14-4. When the company's own trucks provide the transport, develop actual costs per trip, mile or kilometer from accounting records.

Some planners use mathematical network planning models that compute the number of trips and then apply an expected cost factor. This factor may be based on a rate quote or actual experience, or it may be a mathematical function of distance and average cost with possible allowances for backhaul. Some models assume that transportation rates and costs are a linear function of distance and/or demand. In reality, transport costs are not linear, but in many cases, this is "true enough" to give useful results. As can be seen in Figure 14-4, rates can vary significantly among carriers so averages may be misleading.

When the location planning is within a single community, transportation cost analysis becomes more specific and make take a form like that shown in Figure 14-5.

Inbound Transportation Rate Quotes								
All Rates are for non-overweight, non-oversized, non-hazardous commodities								
	SE Motor Freight	JAX Haulers	ABC	Martin Express	Carolina	Distance in Miles per Round trip	Lowest $/Mile Round trip	Savings - Lowest vs. Highest Quote
Charleston to Fairfax								
Container Rate	$ 300		$ 550	$ 350	$ 375			
Fuel Surcharge (%)	20%		31%	25%	22%			
Total Container Rate	**$ 360**	**$ 700**	**$ 721**	**$ 438**	**$ 458**	180	$ 2.00	**50%**
Flatbed Rate					$ 480			
Fuel Surcharge (%)					22%			
Total Flatbed Rate		**$ 700**	**NA**	**NA**	**$ 586**	180	$ 3.25	**16%**
Charleston to Augusta								
Container Rate	$ 375		$ 550	$ 460	$ 420			
Fuel Surcharge (%)	20%		31%	25%	22%			
Total Container Rate	**$ 450**	**$ 800**	**$ 721**	**$ 575**	**$ 512**	312	$ 1.44	**44%**
Flatbed Rate					$ 545			
Fuel Surcharge (%)					22%			
Total Flatbed Rate		**$ 800**	**NA**	**NA**	**$ 665**	312	$ 2.13	**17%**
Savannah to Fairfax								
Container Rate	$ 275		$ 550		$ 300			
Fuel Surcharge (%)	20%		30%		22%			
Total Container Rate	**$ 330**		**$ 715**	**NA**	**$ 366**	174	$ 1.90	**54%**
Flatbed Rate								
Fuel Surcharge (%)								
Total Flatbed Rate				**NA**	**NA**	174	$ 3.31	**NA**
Savannah to Augusta								
Container Rate	$ 375		$ 550		$ 375			
Fuel Surcharge (%)	20%		30%		22%			
Total Container Rate	**$ 450**		**$ 715**	**NA**	**$ 458**	266	$ 1.69	**37%**

Figure 14-4. Truck transport rates from the ports of Charleston and Savannah to prospective plant locations. Note the wide ranges among prospective carriers.

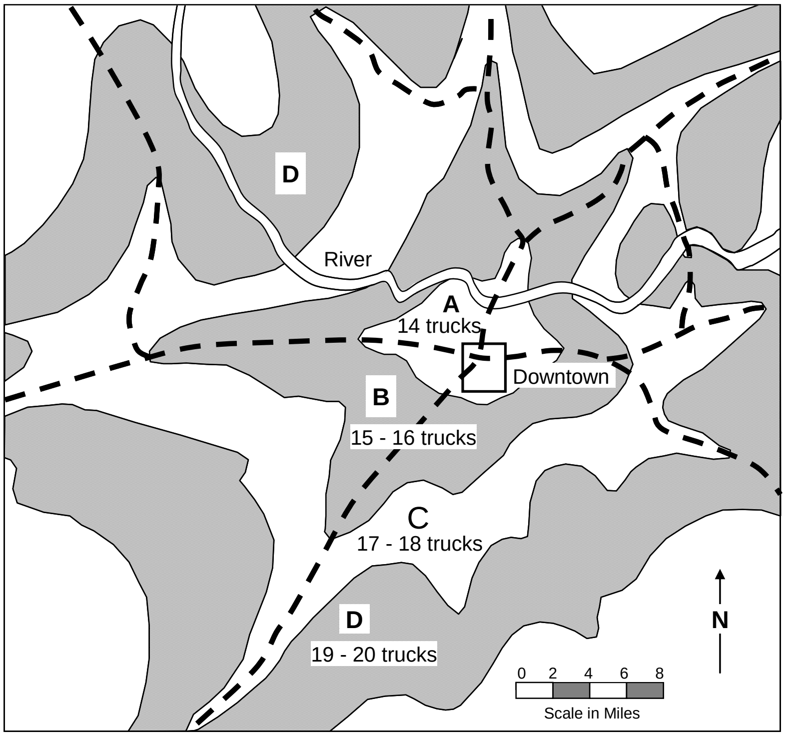


Figure 14-5. Location and trucking costs. Before building a new warehouse, a distribution company made this study of how the number of over-the-road trucks depended on the site location. The figure shows that a location in zone A nearest the downtown area would require 14 trucks. On the other hand, any site in zone D would require 20 trucks, a difference of six trucks or approximately $480,000 per year. Notice how the zone lines tend to follow the major highways, which are shown by dotted lines. By comparing the difference in trucking cost and the cost of land in the different districts, it is possible to select the district(s) which give(s) the optimum cost of land and trucking.

The total trucking time per day was derived as follows: The warehouse receives truckloads from a number of freight terminals and delivers to different shopping centers located throughout the area. The trucking time per day to each of the freight terminals or shopping centers is:

$T = N*(L+(2D/V))$ where:

T = Trucking time per day (hours)
N = Number of trips per day
L = Loading and unloading time per trip (hours)
D = Distance between warehouse and freight terminal or shopping center (miles)
V = Average travel speed (miles per hour) on this route

The total trucking time per day, which is used to decide the number of trucks needed, is the sum of the total time from the warehouse to and from each terminal and each shopping center. This is simplified, for in most cases two additional conditions have to be included.

(a) Delivery trucks with less than a full load for one destination will visit more than one shopping center per trip.
(b) Trucks may first deliver to a shopping center (s) and then pick up a load at the freight terminal on the return journey to the warehouse.

Such studies with special conditions are best performed with various forms of linear programming using network modeling software. A method for planning and executing such modeling studies is described in the booklet: *Simplified Systematic Network Planning* by Chandrashekar Natarajan and Lee Hales, VDM Verlag Dr. Müller.

Similar studies involving research and data collection include: Costing for outside warehousing and logistics services or other contract services; cost of van service for employees; average or cumulative distance and commute times between prospective sites or public transit routes and current employees' homes…

"Go See" for Ground Truth

At some point in every location study it becomes necessary to go and see prospective communities and sites to get first-hand information – what cartographers and analysts of aerial photography call *ground truth*. This refers to information that can only be obtained on location. In addition to simply viewing and touring, the planner should meet with plant managers and personnel directors in the area, local officials, and others to validate published data and to gather information and impressions not available in published reports.

Economic Analysis

Site visits will verify and add to published data on wages, taxes, land costs, utility costs, and other economic factors. These data, together with transportation and special study results, should now be sufficient to identify locations with the lowest cost or greatest profit potential. A simple cost comparison like that shown in Figure 14-6 may be sufficient to identify the best location. But more often, planners will construct projected profit-and-loss statements or conduct various forms of return-on-investment analysis. The same techniques and forms used to compare layout costs in Chapter 10 may be used here for location cost comparisons.

	Alternative Site Locations Annual Costs in $US x 1000			
Category	A	B	C	D
Labor	7800	10010	10610	15220
Transportation	2620	2400	2350	2160
Taxes	500	890	1030	1490
Fuel & Utilities	190	240	310	410
	11110	13540	14300	19280

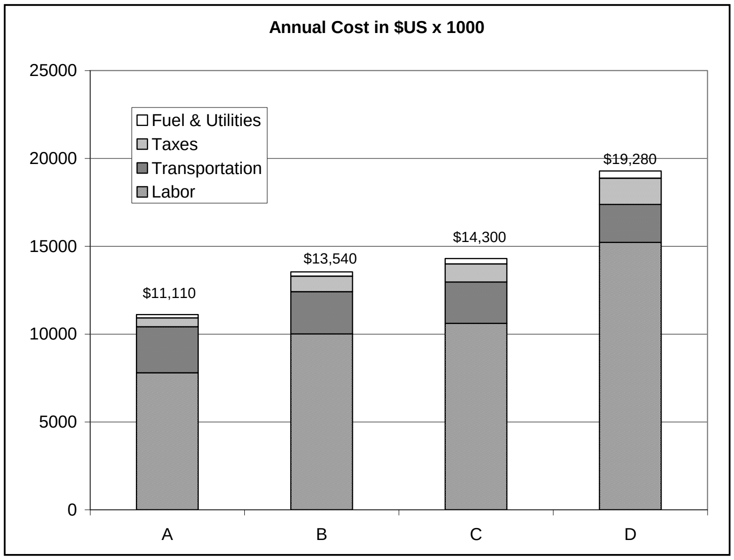


Figure 14-6. Simple comparisons like this one are often sufficient to identify locations with the lowest costs. Here, Location A is lowest cost; Location D highest. Locations B and C are effectively the same given the likely error in forecasts and estimated costs. The selection of B and C should probably rest on evaluation of intangible factors. With most of the cost differences due to labor, the planners should check these estimates carefully and confirm directly with employers in the areas.

The following major cost categories will usually be sufficient to compare alternative locations and identify those with the best economics.

1. Capital for land and construction, or rent.
2. One-time costs, especially for plant re-location, but also recruiting, training, and learning curve.
3. Materials – raw material and purchased component price differences.
4. Labor – adjusted for local fringe benefits, holidays, sick leave, absenteeism, turnover, and productivity. On international selections do not overlook the often considerable costs of housing, and paying expatriate managers and their families' trips home, and the like.
5. Taxes – all kinds at all levels.
6. Transportation – inbound and outbound, including fees and other expenses associated with customs clearance, consolidations, storage, and expediting.
7. Management and staff travel to and from off-shore locations – corporate information technology, human resources, engineering, etc.
8. Utilities – power, water, fuel.
9. Telecommunications – voice and data.
10. Financing – interest rates, allowances, and concessions.

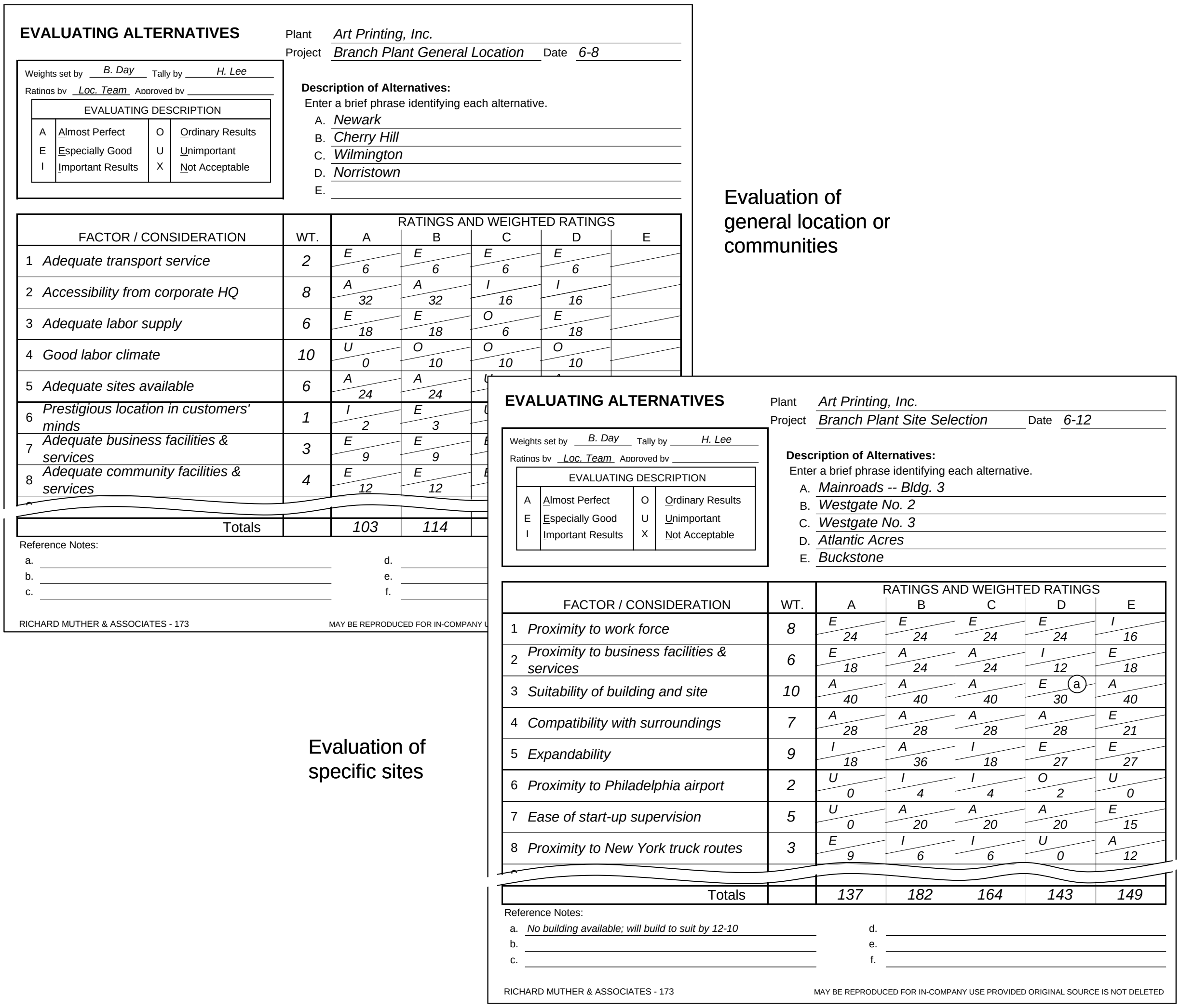
Some locations may require more inventory investment than others due to their distance from supply and demand and variability in transportation time. This is manifest in terms of larger pipeline inventories and/or safety stocks. When valuing inventories, be sure to account for any differences in cost of goods due to sourcing, or to material and labor if manufactured within the company. Lost sales due to stock-outs may also be a factor worth comparing if locations may result in different availabilities.

The planner should be aware of any recent increases in each cost category and consider the long-term cost trends in all comparisons. This is especially true when comparing sites in less developed regions and so-called low-cost countries. Note that the worth of any expected tax concessions, government aid, or special financing arrangements should be considered at this point, even though they may not be firmly committed. Such special arrangements may be the only significant source of economic difference among competing locations.

Always remember that cost estimates are just that and some may be off by 5% to 10% in either direction. The volume forecast may have this much error or more. Therefore, locations with total cost differences of less than 10% should probably be considered more or less the same, given the estimates and assumptions involved.

Intangible Considerations

Intangible or non-economic considerations may be just as important as economics when selecting the best location. And they are typically the deciding factors when costs are comparable. The weighted-factor method explained in Chapter 10 is the best way to compare the intangible features of competing locations. Examples of its use appear in Figure 14-7. Factors should reflect specifications developed at the outset plus any considerations that may have emerged during the search.



EVALUATING ALTERNATIVES

Plant *Art Printing, Inc.*
Project *Branch Plant General Location* Date *6-8*

Weights set by *B. Day* Tally by *H. Lee*
Ratings by *Loc. Team* Approved by

EVALUATING DESCRIPTION

A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:
Enter a brief phrase identifying each alternative.
A. *Newark*
B. *Cherry Hill*
C. *Wilmington*
D. *Norristown*
E.

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1 *Adequate transport service*	*2*	*E* *6*	*E* *6*	*E* *6*	*E* *6*	
2 *Accessibility from corporate HQ*	*8*	*A* *32*	*A* *32*	*I* *16*	*I* *16*	
3 *Adequate labor supply*	*6*	*E* *18*	*E* *18*	*O* *6*	*E* *18*	
4 *Good labor climate*	*10*	*U* *0*	*O* *10*	*O* *10*	*O* *10*	
5 *Adequate sites available*	*6*	*A* *24*	*A* *24*	*U*		
6 *Prestigious location in customers' minds*	*1*	*I* *2*	*E* *3*	*U*		
7 *Adequate business facilities & services*	*3*	*E* *9*	*E* *9*	*E*		
8 *Adequate community facilities & services*	*4*	*E* *12*	*E* *12*	*E*		
Totals		*103*	*114*			

Reference Notes:
a.
b.
c.
d.
e.
f.

RICHARD MUTHER & ASSOCIATES - 173 MAY BE REPRODUCED FOR IN-COMPANY U

Evaluation of general location or communities

EVALUATING ALTERNATIVES

Plant *Art Printing, Inc.*
Project *Branch Plant Site Selection* Date *6-12*

Weights set by *B. Day* Tally by *H. Lee*
Ratings by *Loc. Team* Approved by

EVALUATING DESCRIPTION

A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:
Enter a brief phrase identifying each alternative.
A. *Mainroads -- Bldg. 3*
B. *Westgate No. 2*
C. *Westgate No. 3*
D. *Atlantic Acres*
E. *Buckstone*

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1 *Proximity to work force*	*8*	*E* *24*	*E* *24*	*E* *24*	*E* *24*	*I* *16*
2 *Proximity to business facilities & services*	*6*	*E* *18*	*A* *24*	*A* *24*	*I* *12*	*E* *18*
3 *Suitability of building and site*	*10*	*A* *40*	*A* *40*	*A* *40*	*E* ⓐ *30*	*A* *40*
4 *Compatibility with surroundings*	*7*	*A* *28*	*A* *28*	*A* *28*	*A* *28*	*E* *21*
5 *Expandability*	*9*	*I* *18*	*A* *36*	*I* *18*	*E* *27*	*E* *27*
6 *Proximity to Philadelphia airport*	*2*	*U* *0*	*I* *4*	*I* *4*	*O* *2*	*U* *0*
7 *Ease of start-up supervision*	*5*	*U* *0*	*A* *20*	*A* *20*	*A* *20*	*E* *15*
8 *Proximity to New York truck routes*	*3*	*E* *9*	*I* *6*	*I* *6*	*U* *0*	*A* *12*
Totals		*137*	*182*	*164*	*143*	*149*

Reference Notes:
a. *No building available; will build to suit by 12-10*
b.
c.
d.
e.
f.

RICHARD MUTHER & ASSOCIATES - 173 MAY BE REPRODUCED FOR IN-COMPANY USE PROVIDED ORIGINAL SOURCE IS NOT DELETED

Evaluation of specific sites

Figure 14-7. Examples of the weighted-factor method for community and site selection. Plans separated by less than 12% to 15% should be judged comparable and probably selected on the basis of a cost comparison.

One caution is in order regarding the use of long checklists and the weighted-factor approach. When using a great many factors, there is a tendency to lose sight of the relative importance that should be placed on each. Consider for example the factor of “proximity to labor” and let it be twice as important as “adequate community facilities” (schools, churches, etc.). If eight factors are used to measure adequacy of community facilities and only two for labor proximity, then care must be taken when assigning weights to insure that community facilities do not overly influence the outcome.

Always expect that “hidden factors” will be present among the evaluators and decision-makers. These typically stem from the unstated personal preferences of executives for a specific location.

Ultimately the choice of location is a matter of compromises. There is seldom a perfect location for a perfect layout available at a perfect price.

Site Selection

Within a given community, the selection of a site follows the same comparison of "wanted" with "available." But the factors are more specific and a more detailed analysis is made. For sites within the *same* community, many factors change their definition – transportation may now become trucking, for example. And factors like community attitude and physical climate tend to disappear from the evaluation entirely.

The trucking cost analysis in Figure 14-5 is a typical example of a local study. Similar investigations are made for all elements of expenditure. The cost comparison worksheets described in Chapter 10 can be applied here just as in evaluating alternative communities. Likewise, the weighted-factor method shown in Figure 14-7 can be used again to select a specific site.

Common Pitfalls in Finding New Sites

Finding a new site is an infrequent activity for most companies. Consequently, few managers in a project will have prior experience. A brief review of the common oversights and mistakes listed below may be instructive when confronting a location project for the first time.

1. Failure to clearly specify what is needed.
2. Looking for specific sites too soon – a waste of time and potential source of ill will when the community has been not chosen.
3. Misunderstanding of cost relationships.
4. Misunderstanding taxation and tax exposure.
5. Overestimation of labor supply.
6. Improper estimation of labor cost – focusing on wage rate, while neglecting productivity, work standards, and labor history.
7. Failure to identify local land use and growth patterns negative to the company's long-term interests.
8. Purchasing too small a site – underestimating plant and yard space needed; failing to anticipate growth or allow for future product and market opportunities.
9. Overlooking the impact of environmental regulations.
10. Overlooking limited support services – machining, plating, repair, express freight, warehousing, printing, catering…
11. Underestimating moving costs.
12. Overlooking "quality of life" factors such as good schools, medical care, etc., and losing good people as a result.
13. Incomplete soil tests.
14. Prejudices or preferences of key executives governing the selection, instead of impartially gathered facts.
15. Failure or unwillingness to recognize changes or shifts in market areas, transportation methods, raw materials, and other major cost reduction elements.

Land-To-Building Ratio

A typical mistake – No. 8 in the list of pitfalls – is selecting a site that is too small. This is true in times of both expanding economy and recession. Perhaps it is because managers who see the need for new facilities do not want to scare their directors with too large a request. Perhaps it is because top managements as a whole are concerned with current problems and not doing the kind of long-range planning they probably should. In any event, no company should “go in fresh” with too small a location.

Future land and space constraints can limit market share and profit potential and may result in the need to move the facility again, or establish costly off-site activities. In most situations the cost of land is relatively small compared to the total investment. Yet its unavailability, once a company is committed to a site, hinders the operation from then on and eventually causes premature abandonment of the company's investment.

Actually, much of the extra land "required" is protection – insurance against future increased capacity requirements and also against neighboring property owners who buy and build around the site. Agricultural or vacant sites outside of industrial parks can become surrounded by residential community in a surprisingly short time. When this happens the plant that originally started the area's development often finds itself an obnoxious or at least out-voted member of the new community.

A number of land requirements are notoriously overlooked by managements and layout planners alike. These include:

1. Site access on two or three, or maybe all four sides.
2. Ability to drive all around the plant within its property boundaries.
3. Room to bring in future roadways or rail sidings, to spot waiting vehicles.
4. Yard storage.
5. Space for supporting-service facilities: water tower, cooling pond, filter beds, and similar facilities for reclaim, waste treatment, and storm water retention; central distribution or collection of various kinds.
6. Buffer space with neighbors.

In North America – where land is readily available and relatively inexpensive – the stated policy of many larger manufacturing companies has come to read something like this: "New sites for plant facilities should have a ratio of usable open land to under-roof, built-upon land of ten to one." Five to one for large manufacturing plants is probably a minimum. On the other hand, the typical ratio for warehouses and distribution facilities is much lower and may approach the minimums specified in municipal zoning codes.

Companies are typically unable to “bank” open land for long-term growth in China and other countries where land is controlled by government authorities, or in Japan, or Northern Europe and Scandinavia, where land is scarce and expensive. In such locations, the land-to-building ratio will be at a minimum – typically not more than 3:1 or 4:1 at the time of initial construction.

When speaking of land-to-building ratio, "Building" is ground area under structure or roof, not the area of usable floor space. "Land" is the open ground area, not the total site. The ratio wanted by any company at a particular time varies significantly. And from industry to industry, there are many extremes.

The problem of too little space is not confined to new sites; we discussed it earlier when balancing area requirements versus area available. (See Chapter 7.) The same type of space balancing is involved in finding where to put the layout to be planned.

It must be remembered that planning is even less specific in the Location phase than in Phase II. Frequently, the planner gets a "feel" of the amount of space needed and then gets agreement from the important people involved. The planner can calculate to death trying to get some figures to stand behind, when actually there may not be an effective way to achieve any degree of accuracy. As a result, one is likely, in Phase I, to use the ratio-trend-and-projection or the converting method of space determination.

Overlapping Phases

We have pointed out earlier that Phase I, Location, of the SLP framework of phases should overlap Phase II. Before choosing a specific location, therefore, the planner must know what kind of a general overall layout can be fitted into or onto the location. This is particularly true when there is limited flexibility in the location, such as in existing buildings.

This means that the planner does in fact have to know what can be done layout-wise with a location if it is selected. For example, in Figure 14-8 any of the existing buildings would satisfy the space requirements, but the rail siding affects the general overall layout possible within each building. This means making a rough overall layout of what could be done layout-wise for the three alternative locations as a part of deciding on the best location.

This raises the question of whether to work from the outside in or the inside out. Some industrial engineers believe in starting at each workplace. Improve the methods there; expand to an improved department layout; and build this up to an overall layout which can be used as a basis for plant-location or building-selection studies. They quote the principles "plan the layout around the machinery and equipment" and "plan the building around the layout" as their support.

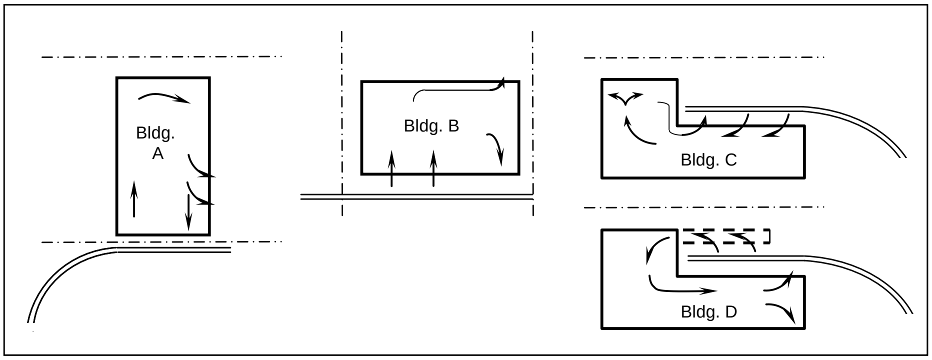


Figure 14-8. Alternative locations and the effect of rail siding access on each insofar as what can be done with the general overall layout of each location. Buildings A and B give a pretty good layout. Building C/D doesn't lend itself as well to the operation and therefore should probably be passed by as a prospective location, assuming other considerations are equal.

To be sure, a good program of methods improvement may be needed. It might well be a lot more productive of reduced costs than a relayout of the area. In fact, in a company where no attention has been given to methods work recently, it is not uncommon to save both the cost of relayout and the need for expansion by a good program of improving operating methods. Certainly, at the time a new layout is made, the planner should not miss this golden opportunity to sweep away old, bad practices and get rid of loose, poor methods.

On the other hand, if the planner waits for a full methods study program, and then a detailed layout, and then an overall plan, before moving ahead with location, in all likelihood the project will be set back too far to help the immediate need. As a matter of fact, waiting for the perfect methods may mean never getting to the bigger layout project.

If, however, by “methods” is meant the selection of the process used to produce the products and the selection of the type of operating machinery and equipment, these must be known before proceeding with layout planning. Recalling the key input data, (R) routing or process, and its sequence and equipment must be known before an effective flow of materials can be planned.

Or, if "methods" are taken as work simplification analysis, then certainly eliminating operations, combining them, or changing their sequence will influence routing, flow-of-materials analysis, and, therefore, the layout.

Actually, the framework of phases does follow the two principles quoted a few paragraphs above. It says further, "Start with the whole, and work to the details." And the pattern demands, "Plan the ideal and from it the practical." Start with rough measurements and estimates and refine these as the ground becomes more certain and the end objectives plainer. Rough tools and techniques are used for early planning and fine ones for later, more accurate details. Decisions are made in each phase, each phase overlapping into the next phase as warranted, but full details are postponed until the basic direction is reasonably defined.

As Figure 1-6 illustrated, the planner deals with more intangibles and less specific details and techniques in Phase I than elsewhere in layout planning work. For example, space requirements used to solve a location problem are estimated and seldom as detailed as figures calculated according to number of machines multiplied by space per machine (as in Chapter 7).

On the other hand, where ample space is available so the plan can be fitted and adjusted within it in many different ways, the planner can move ahead with overall planning – even get into detail planning – before the location is actually settled.

Occasionally, it is true, full details are preplanned. For example, where typical buildings or office layouts are more or less standardized for use by branch shops, laboratories or offices, several optional layouts can be prepared to meet the conditions of each likely location. See Figure 14-9. This is a practical way of reducing the cost of planning. But even here, it is necessary after the location is determined, to select the layout that best fits overall and then adjust the details to meet local conditions.

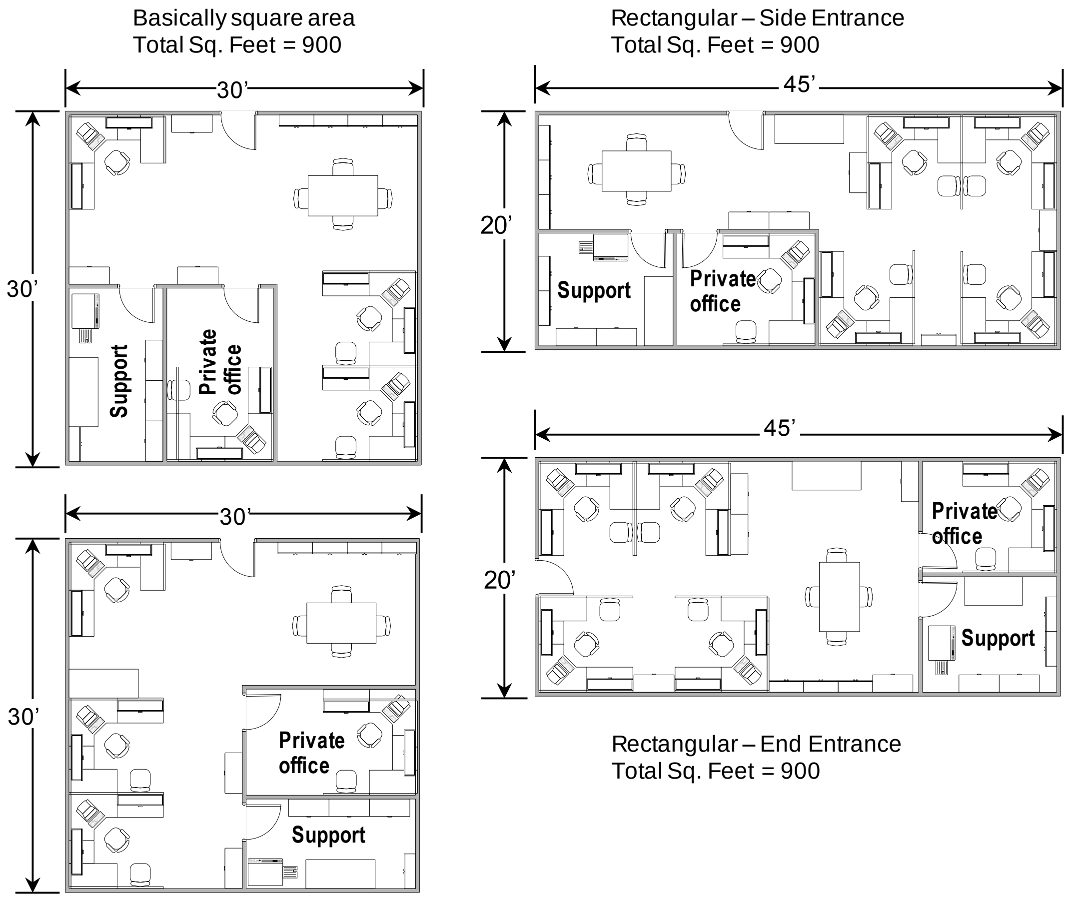


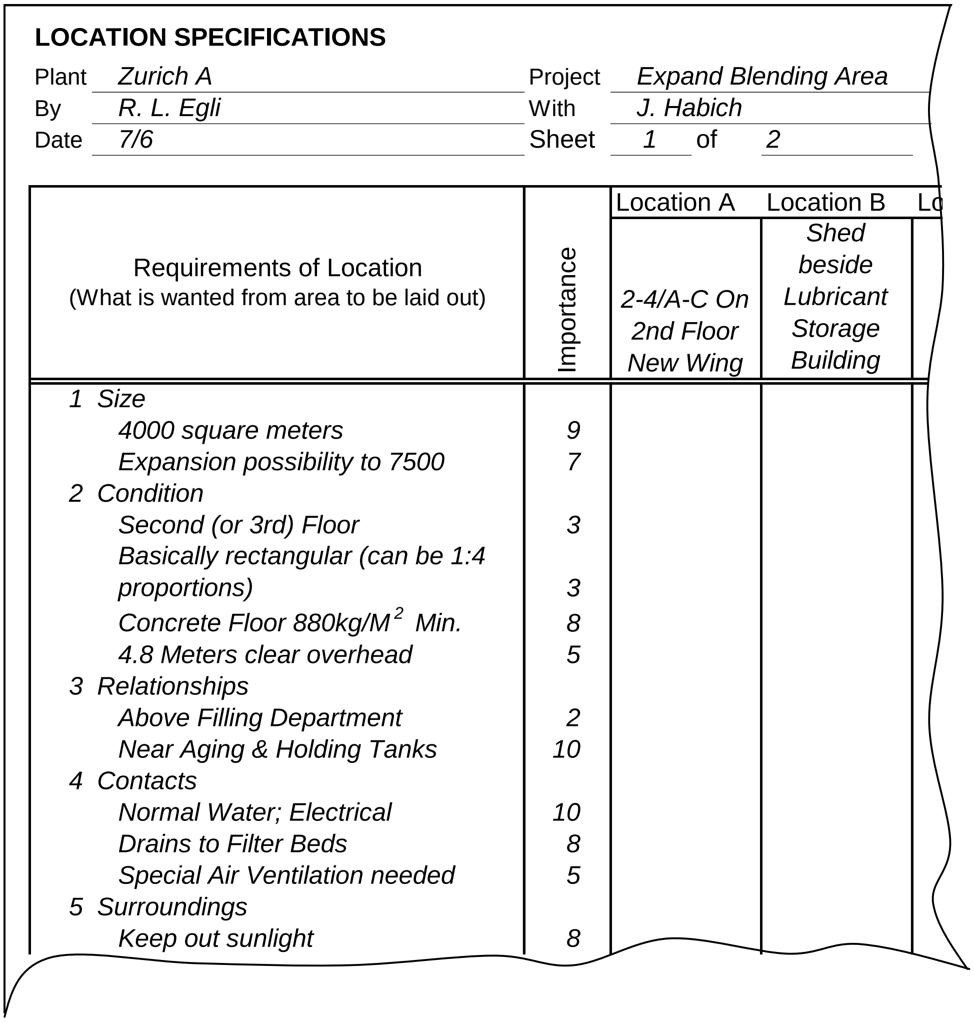
Figure 14-9. Typical preplanned standardized layouts. These are developed for branch sales offices. Layouts like this are planned long before the location is selected. Then quick, brief adjustments only become necessary when the specific office area is being considered or after it is selected for lease. Standard laboratory layouts are similar, when laid out around modular casework and benches.

Locations on Existing Site

The problem of locating the area to be laid out more often than not falls within the confines of an existing site.

When relocating a department or small area, take the same approach as with plant location: Establish what is wanted (requirements); determine what is available; analyze to decide what is most suitable.

As with larger location problems, set up a list of *requirements* or specifications. Figure 14-10 shows such a list, using the same classifications of factors listed earlier in this chapter. The importance of each factor in the selection of the desired location is called out in the column next to the factor description. Available locations are then considered and rated in adjacent columns. The form explained in Chapter 10 for evaluating alternatives by factor analysis could be used here equally well.



LOCATION SPECIFICATIONS

Plant *Zurich A* Project *Expand Blending Area*
By *R. L. Egli* With *J. Habich*
Date *7/6* Sheet *1* of *2*

Requirements of Location (What is wanted from area to be laid out)	Importance	Location A	Location B	Lo
		2-4/A-C On 2nd Floor New Wing	*Shed beside Lubricant Storage Building*	
1 Size				
4000 square meters	*9*			
Expansion possibility to 7500	*7*			
2 Condition				
Second (or 3rd) Floor	*3*			
Basically rectangular (can be 1:4 proportions)	*3*			
Concrete Floor 880kg/M^2 *Min.*	*8*			
4.8 Meters clear overhead	*5*			
3 Relationships				
Above Filling Department	*2*			
Near Aging & Holding Tanks	*10*			
4 Contacts				
Normal Water; Electrical	*10*			
Drains to Filter Beds	*8*			
Special Air Ventilation needed	*5*			
5 Surroundings				
Keep out sunlight	*8*			

Figure 14-10. Location Specifications set up to serve as requirements in considering various possible areas where expanded blending area can be put. Note that this list follows the "What is wanted" section of the text: items are filled in; their importance to the project is weighed; and each prospective location available can then be rated against this list of specifications to select the most suitable. This is similar to the factor analysis method of evaluating alternative layouts.

Determining what is *available* (or can be made available) within the existing site does not involve the extensive search necessary for locating a new site. But essentially the same sequence is followed:

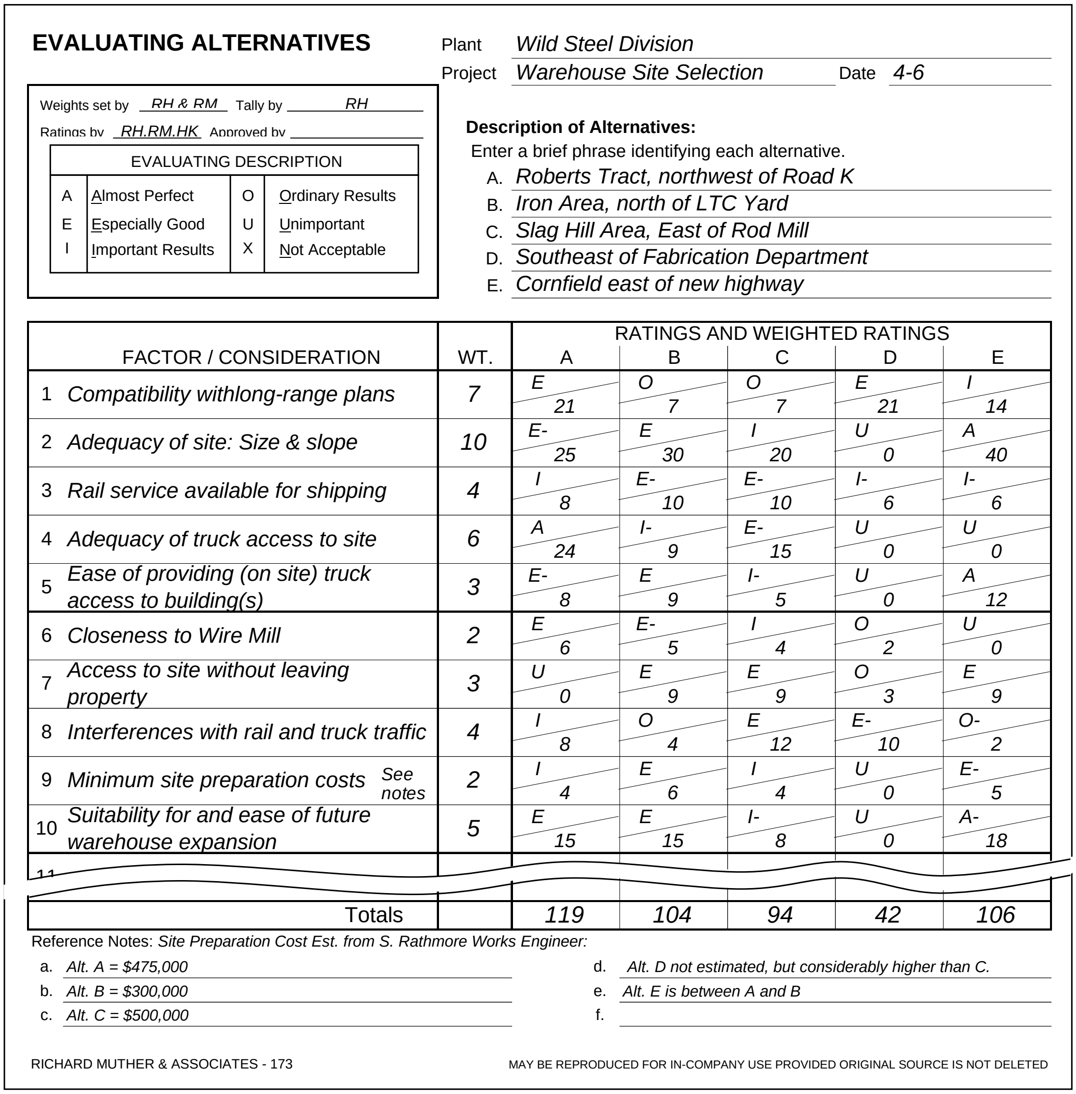
1. Finding possible locations that reasonably meet the requirements
2. Matching the requirements against each possible location
3. Determining the restrictions or limitations and screening out all but the logical alternative locations

Point 3 is important. Every location has some restrictions or limitations on its use or availability. These must be established before a potential location can be considered truly "available."

We have already touched upon the methods of determining the most suitable location:

1. Advantages versus disadvantages, for rough or screening decisions
2. Factor analysis, for intangibles or when lacking adequate financial figures
3. Cost comparison (and justification) for final decision or when reasonably accurate and complete cost figures are on hand

A fairly typical example of on-site location selection appears in Figure 14-11.



EVALUATING ALTERNATIVES

Plant *Wild Steel Division*
Project *Warehouse Site Selection* Date *4-6*

Weights set by *RH & RM* Tally by *RH*
Ratings by *RH,RM,HK* Approved by

EVALUATING DESCRIPTION

A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:
Enter a brief phrase identifying each alternative.
A. *Roberts Tract, northwest of Road K*
B. *Iron Area, north of LTC Yard*
C. *Slag Hill Area, East of Rod Mill*
D. *Southeast of Fabrication Department*
E. *Cornfield east of new highway*

	FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS A	B	C	D	E
1	*Compatibility withlong-range plans*	7	E 21	O 7	O 7	E 21	I 14
2	*Adequacy of site: Size & slope*	10	E- 25	E 30	I 20	U 0	A 40
3	*Rail service available for shipping*	4	I 8	E- 10	E- 10	I- 6	I- 6
4	*Adequacy of truck access to site*	6	A 24	I- 9	E- 15	U 0	U 0
5	*Ease of providing (on site) truck access to building(s)*	3	E- 8	E 9	I- 5	U 0	A 12
6	*Closeness to Wire Mill*	2	E 6	E- 5	I 4	O 2	U 0
7	*Access to site without leaving property*	3	U 0	E 9	E 9	O 3	E 9
8	*Interferences with rail and truck traffic*	4	I 8	O 4	E 12	E- 10	O- 2
9	*Minimum site preparation costs* *See notes*	2	I 4	E 6	I 4	U 0	E- 5
10	*Suitability for and ease of future warehouse expansion*	5	E 15	E 15	I- 8	U 0	A- 18
11							
	Totals		119	104	94	42	106

Reference Notes: *Site Preparation Cost Est. from S. Rathmore Works Engineer:*

a. *Alt. A = $475,000*
b. *Alt. B = $300,000*
c. *Alt. C = $500,000*
d. *Alt. D not estimated, but considerably higher than C.*
e. *Alt. E is between A and B*
f.

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Figure 14-11. Evaluation of 5 alternative on-site locations for a new warehouse. The building cost will be more or less the same in all locations. Only the site preparation costs will differ. These have been roughly estimated and rated on a comparative basis as Factor 9. The intangible factors are fairly typical for this kind of location selection.

Frequently, the location problem on an existing site is one of juggling or "playing checkers" with areas. Thus, relocating one department or area can start a chain reaction of rearrangements with attendant costly disruptions. And, the more divided the space, such as with multi-story buildings or buildings with fixed or load-bearing walls, the problem of finding suitable fits of areas is even greater. This kind of shuffling of space is illustrated in Figure 14-12. The figure also illustrates the importance of logically planning future space needs to avoid frequent and serious relocation problems.

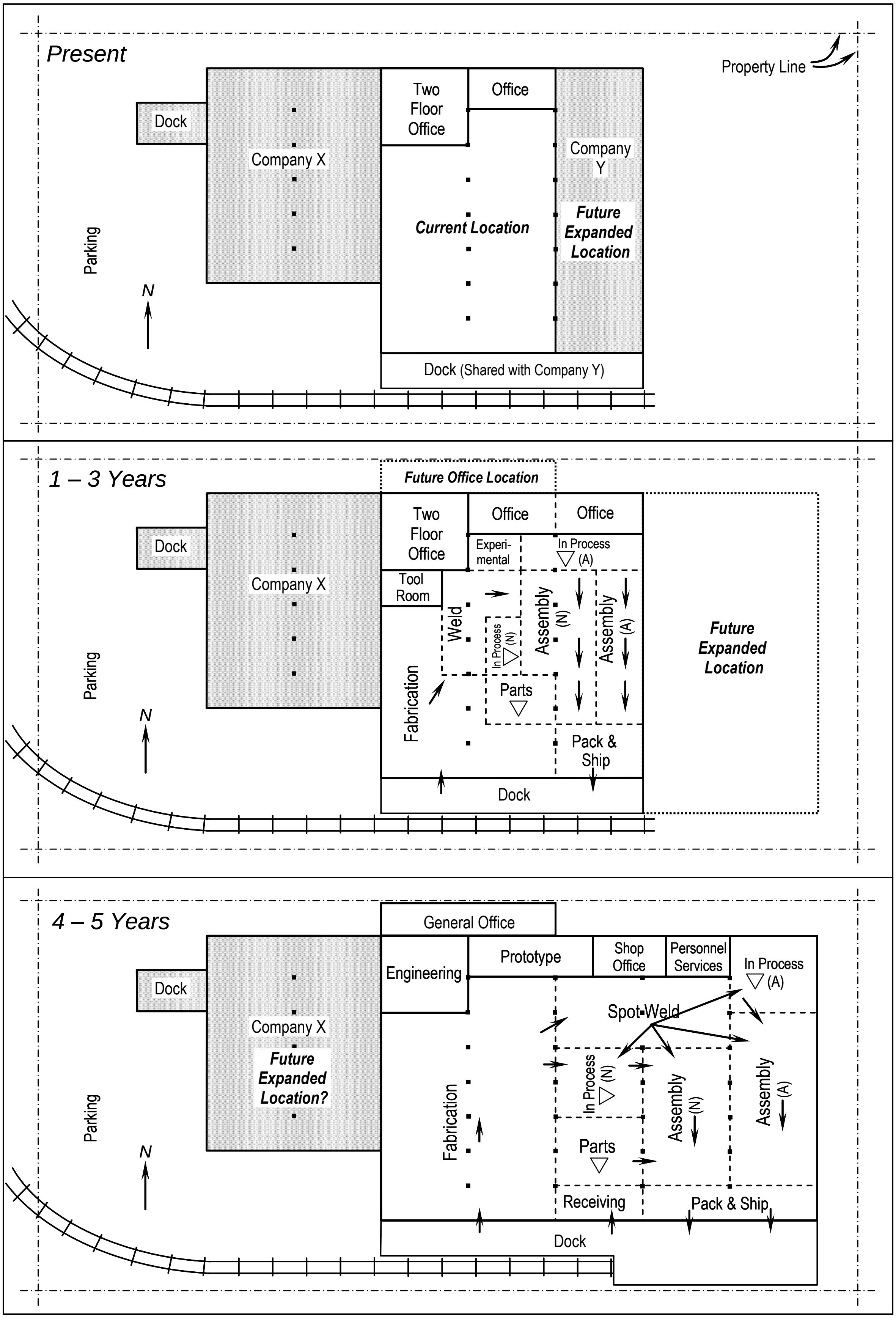
We again point out that what is a "location" problem for a departmental area is a "rearranging of the general overall layout" problem for a building of several departments. That is, what is a Phase I problem for one area to be laid out, is a Phase II rearrangement for the overall plant or building. Similarly, placing an individual desk is a location problem as to the desk alone, but it is part of a Phase III rearrangement of the office in question.

Figure 14-12. Shows the problem of adjusting locations as a company looks ahead and plans future growth on its present site.

The top layout shows the present building features and property lines. The company's current location is in the center of the building with Company X and Company Y located respectively in the West and East portions of the building.

The middle and bottom layouts show what can be done with the layout and flow pattern for two future periods. In Years 1 – 3, space occupied by Company Y is absorbed. In Years 4 – 5 the building is expanded. Contemplated expansion (not shown) for 10 years in the future, incorporates the area now used by Company X.

Planning future area locations provides for logical property development at a minimum of expense, and often prevents a company from being "boxed in". Equally significant is the question of what can be done to make effective layout plans as new locations (areas to be laid out) become available or as management plans its negotiations to make added areas available.


Present
Property Line
Dock
Company X
Two Floor Office
Office
Company Y
Current Location
Future Expanded Location
Parking
N
Dock (Shared with Company Y)
1 – 3 Years
Future Office Location
Dock
Company X
Two Floor Office
Office
Office
Experi-mental
In Process ▽ (A)
Tool Room
Weld
In Process ▽ (N)
Assembly (N)
Assembly (A)
Future Expanded Location
Parking
N
Fabrication
Parts ▽
Pack & Ship
Dock
4 – 5 Years
General Office
Dock
Company X
Future Expanded Location?
Engineering
Prototype
Shop Office
Personnel Services
In Process ▽ (A)
Spot Weld
In Process ▽ (N)
Assembly (N)
Assembly (A)
Parking
N
Fabrication
Parts ▽
Receiving
Pack & Ship
Dock

Chapter 15

Installation

Installation of the layout is Phase IV of the framework of phases. Phase IV is like Phase I in that the SLP pattern of procedures does not apply to it. Also, it, too, may not fall under the responsibility of the layout planner. Ordinarily, it is chiefly the work of the plant engineering or maintenance group.

Planning for the installation will have begun as early as Phase II as overall layouts are prepared. “Ease of installation” is almost always a factor or consideration when selecting the best plan, so the planners will have discussed the installation sequence and any problems associated with each alternative. Occasionally a plan will be rated “X” and rejected on this factor alone. In Phase III, a more detailed discussion and evaluation will occur with respect to the equipment layouts within each activity-area. So by Phase IV, the major elements of each area’s installation and any problems should already be clear. This represents the overlapping of Phases III and IV.

A good way to develop the major elements of the installation plan is to place or tape sequence-numbered notes on a drawing of the selected layout. It may also help to do this on an up-to-date drawing of the existing layout. This should be a group activity involving the layout planners, operating people and plant engineering or maintenance group. If there will be significant interruptions to production, the inventory planner should also be involved. Examples appear in Figure 15-1. Actions thus identified in Phases II and III become the basis for more thorough installation planning in Phase IV. Here, we identify, sequence, assign and schedule the specific tasks associated with each piece of equipment to be installed and any other actions that need to take place.

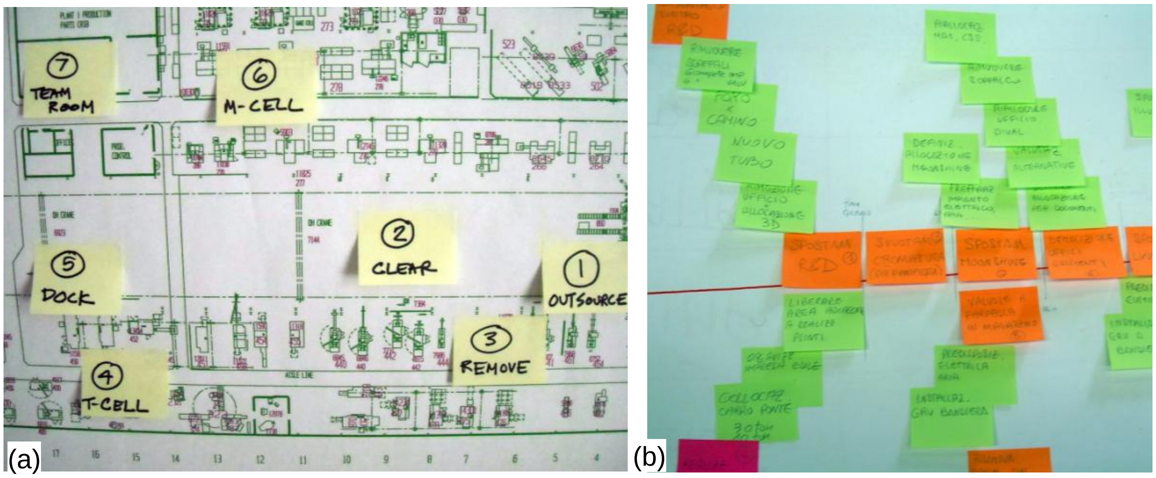


Figure 15-1. Using sticky notes to develop installation plans. (a) Identifying the sequence of actions in a plant rearrangement. (b) Detailed sequence for the installation of one rearranged area. Tasks are described on color-coded notes. Colors indicate responsible departments. This is a highly visual group exercise with people from all affected departments.

Scope of the Installation

On small, simple rearrangements, the operators themselves may make the installation, using no more than a handwritten task list on a flip chart or white board. But large, complex installations often require a variety of skilled trades – carpenters and painters, millwrights, electricians, riggers and haulers, plumbers… Each requires time and labor and their work may need to be preceded by or interleaved with that of the others. Detailed instructions and schedules, and usually an expense budget will be needed.

The fact that machinery and equipment is to be moved offers a real opportunity to make other changes and improvements in the operation. This is the time to take such steps as the following:

1. Repair, rebuild, or repaint equipment.
2. Add new fittings, attachments, feeds, deliveries.
3. Initiate new working methods, procedures, controls.
4. Abandon bad operating practices of all kinds.
5. Convert to new materials or new product specifications.
6. Realign the manpower assignments, balancing, skills, and time standards.
7. Incorporate better safety practices.
8. Repair the floors, walls, ceilings, and do other major maintenance work.
9. Realign supervisory responsibilities.
10. Housekeeping, removal of unnecessary items from the floor, and implementation of visual management: signage, color codes, display boards, shadow boards for tools, markings, floor-striping with paint and/or tape

Where such actions are desirable, they must be built into the schedule and assigned to the appropriate individuals or teams.

Installation Make-Ready

The physical act of picking up, moving, and placing the machinery and equipment in its new location is only part of Installation. *Make-ready* and *follow-up* are also important. The preparation for the physical move is the really big job. Included in the make-ready may be securing final approval and appropriation of money for the expenditure (with the necessary installation costs as back-up information); preparing installation plans and drawings; arranging for changes in the building or the auxiliary service lines and utilities; scheduling the move; and notifying everyone involved.

Similarly, the *follow-up* steps, after the move, are important and time-consuming. They involve hooking up the equipment; try-out; release to the operating people; and cleaning up the areas-both new and old.

A necessary part of the request for financial appropriation is backing it up with cost information – a breakdown of estimated costs for the installation of the new layout. Not that costs are overlooked in Phases II and III – no, cost information is necessary there, too. In fact, the planner may obtain the installation funds when getting Phase III approval . . . or the funds for footings and structure at Phase II approval, if the project is rushed. However, if new construction, major renovation, or costly new equipment is involved in the project, a more definite, more accurate cost breakdown can be made after the detail plans and installation drawings are prepared.

As an aid to management in deciding whether to proceed with the layout, the planner may update and formalize for presentation earlier cost analyses. The planner itemizes the savings that are expected as the result of the new layout, as well as the capital investment and expenses of the installation. The analysis should be factual and on a measurable basis so that results and estimates can be compared after the installation. Still, in many cases it is necessary to list the intangible results expected which are not included in the actual expenditure or savings figures.

Figure 15-2 shows a method of compiling estimated installation costs. This sheet – or these figures, along with their back-up information – together with investment sheets for any capital equipment involved in the new layout, is the basis for the appropriation or allocation of funds.

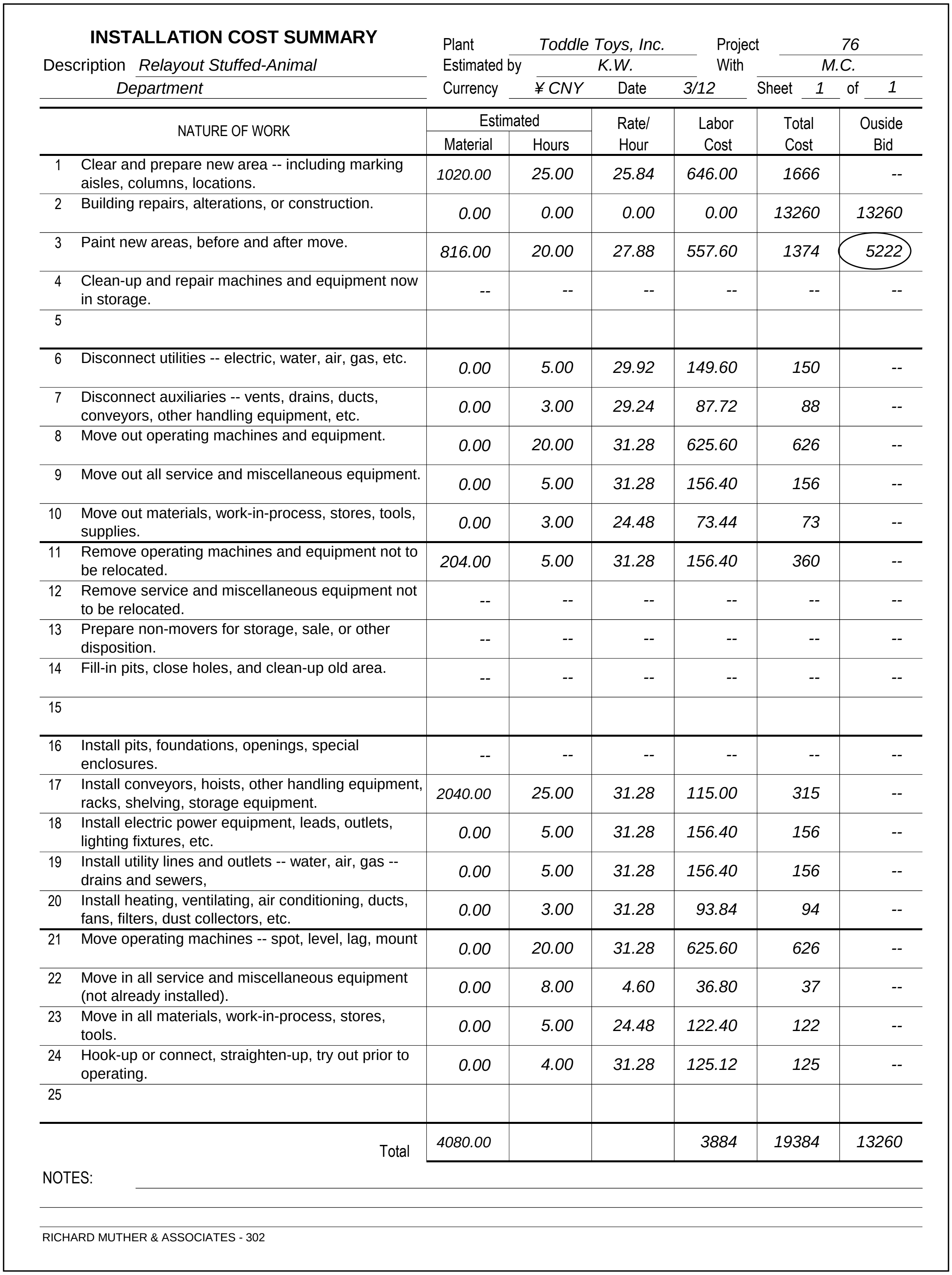
Because the events prior to making the actual moves are so significant, an Installation Coordination Worksheet has been developed. Figure 15-3 shows this. The form is designed to serve as a check list of items likely to be overlooked, as a guide in installation planning, and as a status check. Establishing what is to be done, when it is needed, and who is to do it, achieves the biggest part of coordinating the installation. Therefore, make definite assignments for the completion of each step, calling out when it should be done and who is responsible for the action. This means names and dates on each line of the form. Then make periodic status checks to be sure the new installation goes in on time and with a minimum of disturbance.

Installation Drawings

The ability to pass instructions along to the various persons concerned with the installation is important. It can best be accomplished with installation drawings and written instructions.

The development of the detail layout is explained in Chapters 11, 12 and 13. Regardless of how the layout was drawn and visualized during its planning, at installation time it will always be made available as a paper document – printed, plotted or photocopied. Every such "drawing" should show north direction (N), the scale being used, identification of the plant or building, and the sheet or panel if the drawing covers only a portion of the plant or installation. The date of reproduction and the revision level of the layout should also be included. These are minimum requirements.

If not already included, the installation drawings should include symbols for utilities, walls, doors, and other building features that may have been omitted on equipment layouts. These symbols are typically available in electronic drawing software or illustrated in architectural reference books.



INSTALLATION COST SUMMARY

Description *Relayout Stuffed-Animal Department*

Plant *Toddle Toys, Inc.* Project *76*

Estimated by *K.W.* With *M.C.*

Currency *¥ CNY* Date *3/12* Sheet *1* of *1*

	NATURE OF WORK	Estimated		Rate/ Hour	Labor Cost	Total Cost	Ouside Bid
		Material	Hours				
1	Clear and prepare new area -- including marking aisles, columns, locations.	*1020.00*	*25.00*	*25.84*	*646.00*	*1666*	--
2	Building repairs, alterations, or construction.	*0.00*	*0.00*	*0.00*	*0.00*	*13260*	*13260*
3	Paint new areas, before and after move.	*816.00*	*20.00*	*27.88*	*557.60*	*1374*	*5222*
4	Clean-up and repair machines and equipment now in storage.	--	--	--	--	--	--
5							
6	Disconnect utilities -- electric, water, air, gas, etc.	*0.00*	*5.00*	*29.92*	*149.60*	*150*	--
7	Disconnect auxiliaries -- vents, drains, ducts, conveyors, other handling equipment, etc.	*0.00*	*3.00*	*29.24*	*87.72*	*88*	--
8	Move out operating machines and equipment.	*0.00*	*20.00*	*31.28*	*625.60*	*626*	--
9	Move out all service and miscellaneous equipment.	*0.00*	*5.00*	*31.28*	*156.40*	*156*	--
10	Move out materials, work-in-process, stores, tools, supplies.	*0.00*	*3.00*	*24.48*	*73.44*	*73*	--
11	Remove operating machines and equipment not to be relocated.	*204.00*	*5.00*	*31.28*	*156.40*	*360*	--
12	Remove service and miscellaneous equipment not to be relocated.	--	--	--	--	--	--
13	Prepare non-movers for storage, sale, or other disposition.	--	--	--	--	--	--
14	Fill-in pits, close holes, and clean-up old area.	--	--	--	--	--	--
15							
16	Install pits, foundations, openings, special enclosures.	--	--	--	--	--	--
17	Install conveyors, hoists, other handling equipment, racks, shelving, storage equipment.	*2040.00*	*25.00*	*31.28*	*115.00*	*315*	--
18	Install electric power equipment, leads, outlets, lighting fixtures, etc.	*0.00*	*5.00*	*31.28*	*156.40*	*156*	--
19	Install utility lines and outlets -- water, air, gas -- drains and sewers,	*0.00*	*5.00*	*31.28*	*156.40*	*156*	--
20	Install heating, ventilating, air conditioning, ducts, fans, filters, dust collectors, etc.	*0.00*	*3.00*	*31.28*	*93.84*	*94*	--
21	Move operating machines -- spot, level, lag, mount	*0.00*	*20.00*	*31.28*	*625.60*	*626*	--
22	Move in all service and miscellaneous equipment (not already installed).	*0.00*	*8.00*	*4.60*	*36.80*	*37*	--
23	Move in all materials, work-in-process, stores, tools.	*0.00*	*5.00*	*24.48*	*122.40*	*122*	--
24	Hook-up or connect, straighten-up, try out prior to operating.	*0.00*	*4.00*	*31.28*	*125.12*	*125*	--
25							
	Total	*4080.00*			*3884*	*19384*	*13260*

NOTES:

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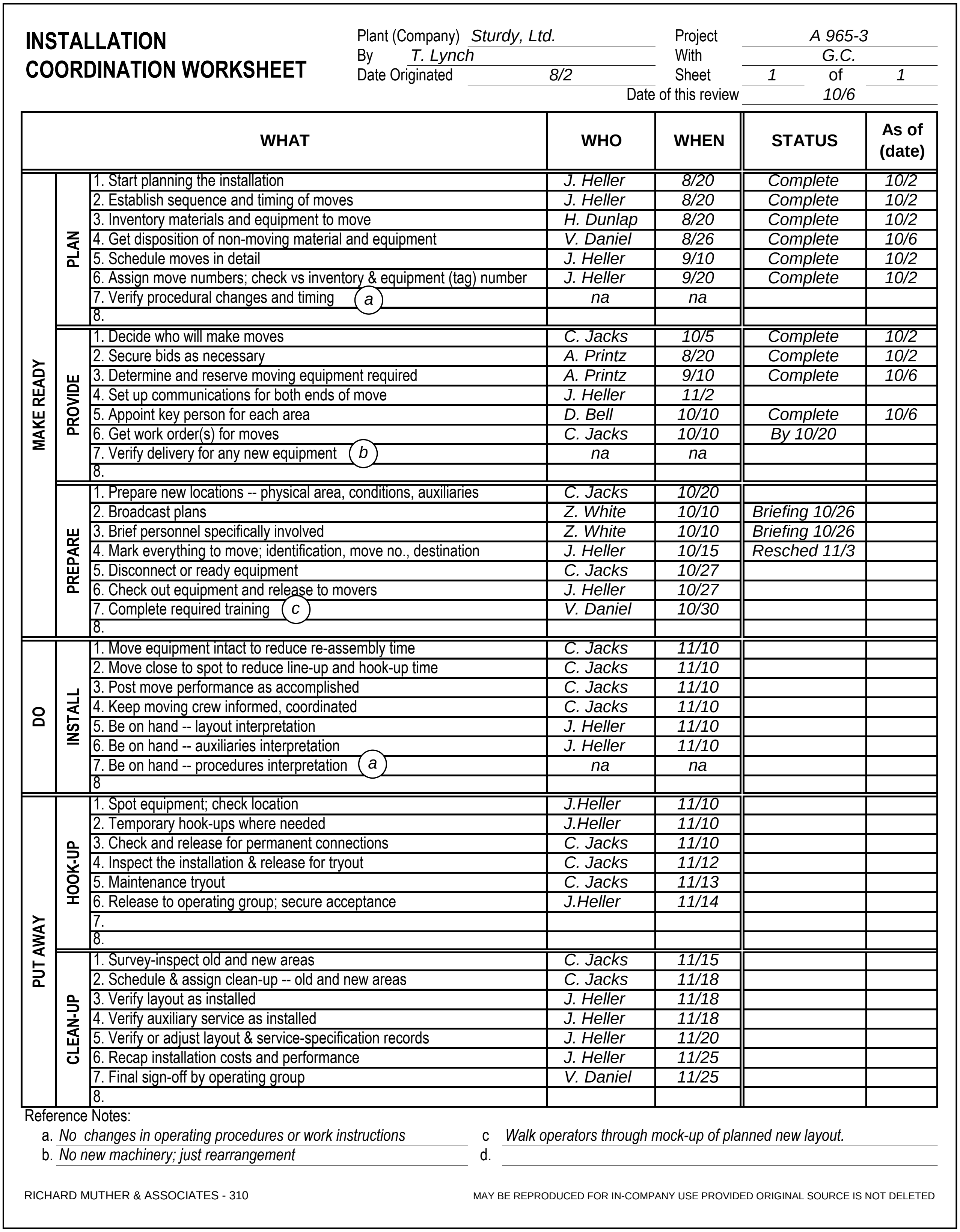
Figure 15-2. Estimated installation costs for a small departmental rearrangement of a toy factory. The form is subdivided into specific steps by nature of work to be done. This example shows the recording of an outside bid (line 2) – used when it is not practical or economical to do the job with company people. On the other hand, the outside bid can be compared with the company estimate (line 3). The circled outside bid for painting indicates that it was not accepted. The sum in the total cost column uses the outside bid for building repairs and the company estimate for painting.



INSTALLATION COORDINATION WORKSHEET

Plant (Company) *Sturdy, Ltd.*
By *T. Lynch*
Date Originated *8/2*
Project *A 965-3*
With *G.C.*
Sheet *1* of *1*
Date of this review *10/6*

		WHAT	WHO	WHEN	STATUS	As of (date)
MAKE READY	PLAN	1. Start planning the installation	J. Heller	8/20	Complete	10/2
		2. Establish sequence and timing of moves	J. Heller	8/20	Complete	10/2
		3. Inventory materials and equipment to move	H. Dunlap	8/20	Complete	10/2
		4. Get disposition of non-moving material and equipment	V. Daniel	8/26	Complete	10/6
		5. Schedule moves in detail	J. Heller	9/10	Complete	10/2
		6. Assign move numbers; check vs inventory & equipment (tag) number	J. Heller	9/20	Complete	10/2
		7. Verify procedural changes and timing ⓐ	na	na		
		8.				
	PROVIDE	1. Decide who will make moves	C. Jacks	10/5	Complete	10/2
		2. Secure bids as necessary	A. Printz	8/20	Complete	10/2
		3. Determine and reserve moving equipment required	A. Printz	9/10	Complete	10/6
		4. Set up communications for both ends of move	J. Heller	11/2		
		5. Appoint key person for each area	D. Bell	10/10	Complete	10/6
		6. Get work order(s) for moves	C. Jacks	10/10	By 10/20	
		7. Verify delivery for any new equipment ⓑ	na	na		
		8.				
	PREPARE	1. Prepare new locations -- physical area, conditions, auxiliaries	C. Jacks	10/20		
		2. Broadcast plans	Z. White	10/10	Briefing 10/26	
		3. Brief personnel specifically involved	Z. White	10/10	Briefing 10/26	
		4. Mark everything to move; identification, move no., destination	J. Heller	10/15	Resched 11/3	
		5. Disconnect or ready equipment	C. Jacks	10/27		
		6. Check out equipment and release to movers	J. Heller	10/27		
		7. Complete required training ⓒ	V. Daniel	10/30		
		8.				
DO	INSTALL	1. Move equipment intact to reduce re-assembly time	C. Jacks	11/10		
		2. Move close to spot to reduce line-up and hook-up time	C. Jacks	11/10		
		3. Post move performance as accomplished	C. Jacks	11/10		
		4. Keep moving crew informed, coordinated	C. Jacks	11/10		
		5. Be on hand -- layout interpretation	J. Heller	11/10		
		6. Be on hand -- auxiliaries interpretation	J. Heller	11/10		
		7. Be on hand -- procedures interpretation ⓐ	na	na		
		8				
PUT AWAY	HOOK-UP	1. Spot equipment; check location	J.Heller	11/10		
		2. Temporary hook-ups where needed	J.Heller	11/10		
		3. Check and release for permanent connections	C. Jacks	11/10		
		4. Inspect the installation & release for tryout	C. Jacks	11/12		
		5. Maintenance tryout	C. Jacks	11/13		
		6. Release to operating group; secure acceptance	J.Heller	11/14		
		7.				
		8.				
	CLEAN-UP	1. Survey-inspect old and new areas	C. Jacks	11/15		
		2. Schedule & assign clean-up -- old and new areas	C. Jacks	11/18		
		3. Verify layout as installed	J. Heller	11/18		
		4. Verify auxiliary service as installed	J. Heller	11/18		
		5. Verify or adjust layout & service-specification records	J. Heller	11/20		
		6. Recap installation costs and performance	J. Heller	11/25		
		7. Final sign-off by operating group	V. Daniel	11/25		
		8.				

Reference Notes:
a. *No changes in operating procedures or work instructions*
b. *No new machinery; just rearrangement*
c *Walk operators through mock-up of planned new layout.*
d.

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MAY BE REPRODUCED FOR IN-COMPANY USE PROVIDED ORIGINAL SOURCE IS NOT DELETED

Figure 15-3. Installation Coordination Worksheet is used to assign responsibilities and check status of installation planning. This sheet shows the timing established for each step in coordinating a move. Along with the due times go assignments to specific individuals for the completion of each step. A status report is issued periodically (information on the right side of the form) to prevent detail "fall downs" from affecting the completion date scheduled for the entire project.

Another method of instructing the various parties is to print only the relevant “layers” of the plan, each for a particular function or trade such as electrical, mechanical, and the like. This is easy if the layout has been properly prepared with electronic drafting software and each function assigned to a separate layer. If drawn by hand, the planner must create an overlay for each function using registration symbols for alignment when printed. Overlays should be printed on acetate or other transparent or semi-transparent material, with the equipment layout and building features typically on the base sheet.

If 3-D electronic modeling has been used, the planner can get full "mileage" from it by printing various images or creating video sequences to instruct, train, and generally orient operating people and installation crews. This is one of the big advantages of 3-D modeling. While rarely used today, physical models and photographs thereof can play the same role, depending upon their detail and accessibility to the installers.

Locating Equipment

There are basically two ways to aid installers in lining up machines and equipment. One is to print the layout planning grid sheet or to superimpose a grid on the layout drawing. This allows anyone to count the number of grid lines and convert it to distance. The other way is to mark the dimensions on all copies of the layout drawing. Either method allows the machine to be located in the proper position.

Providing the installation people with the actual dimensions has proven to be more accurate, though it is more time-consuming for layout planners. Figure 15-4 shows various methods of lining up equipment. Obviously, it would be difficult for the installation crew to place such machines accurately if dimensions were not given. Moreover, when black-line grids are used, the grid lines show through clear templates, causing confusion and making interpretation difficult. Remember that when setting up to visualize detail layout plans, the total system of documentation must be considered: equipment templates, base building features, overlays for various functions, reproduction method, and incorporation of installation instructions.

Tasks, Work Orders and Written Instructions

Each major element or action in an installation plan will require completion of several tasks, often by different skilled trades, departments, and contractors. Instructing them clearly and concisely usually requires written explanations in addition to physical prints, plots and/or photocopies of the layout drawings. Often, preparing these written instructions helps to identify, sequence and schedule all the tasks to be done, and may uncover some oversights.

One of the simplest aids to clear understanding of the installation work to be done is to post in the new area a copy of the written work instructions and colored identification of the various items on the layout drawing. This display should be attached to something firm, and mounted up off the floor or on the maintenance supervisor's desk. Significant items should be colored for easy visualization; this is simple to do and very often extremely helpful.

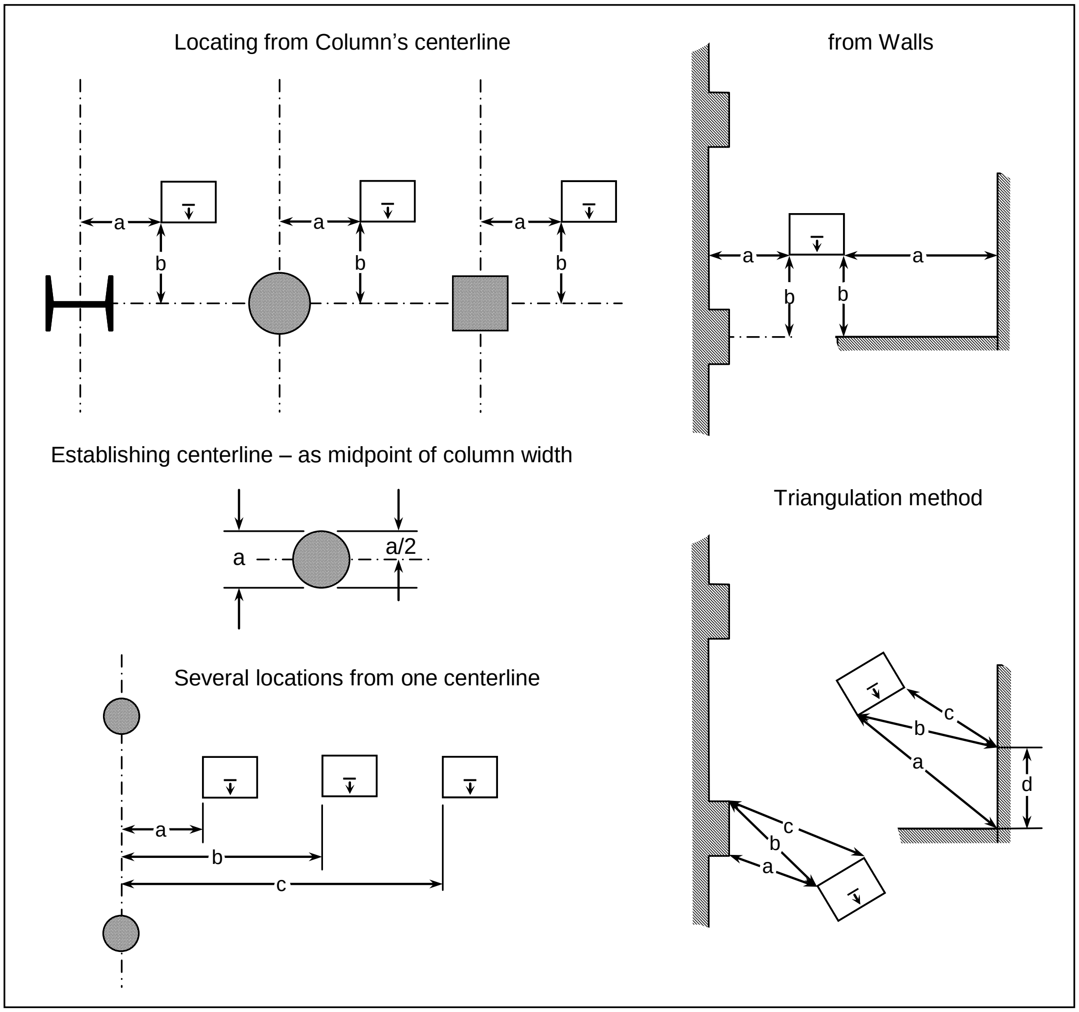


Figure 15-4. Methods of indicating machinery and equipment placement. The centerline method is most commonly used in locating equipment. It may be necessary to dimension to both sides of the machine (or machine template) if the reference point is not clearly defined.

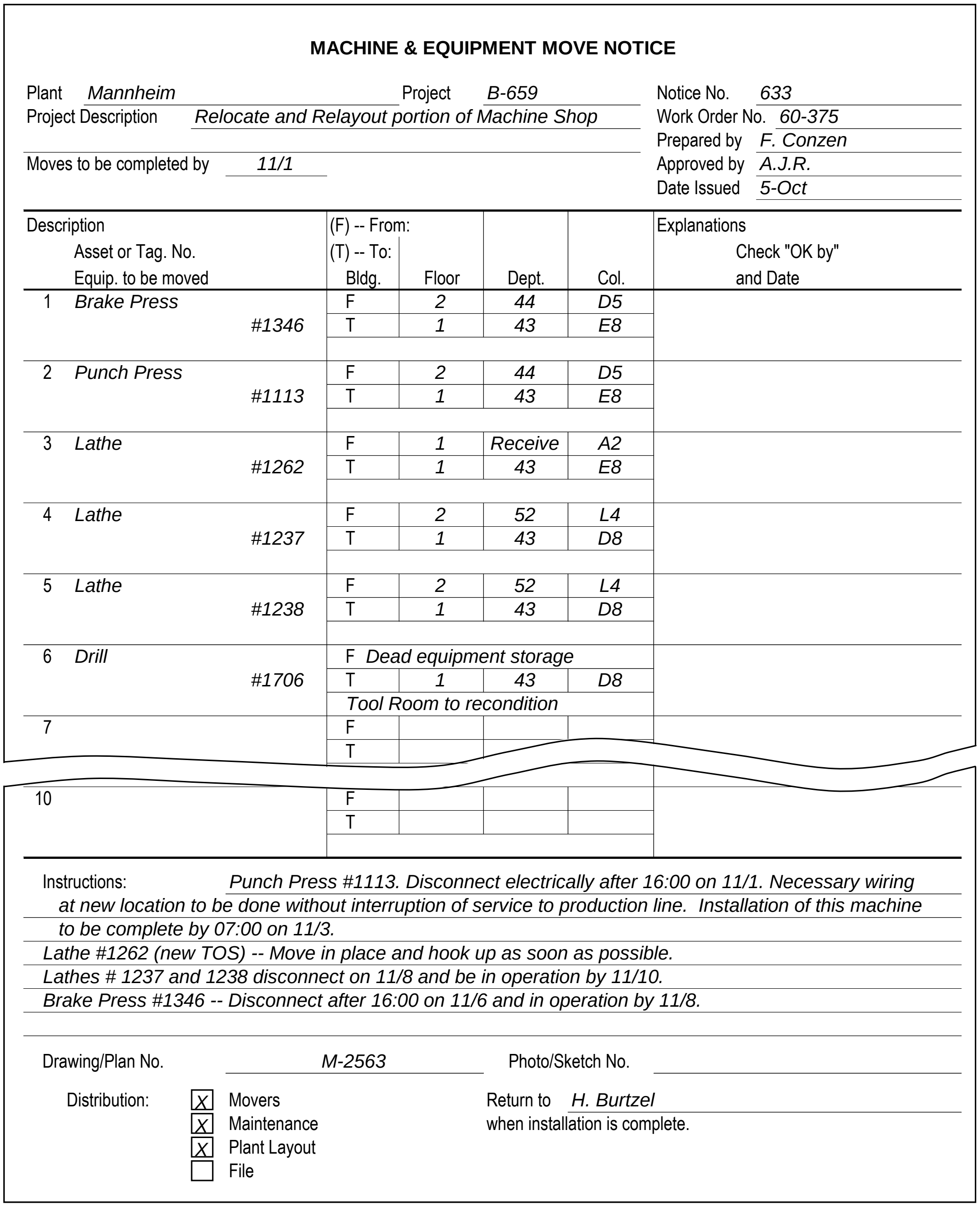
The use of triangulation requires three dimensions to be specified for proper location of equipment.

Machines can also be located from aisle markers as if the measurements were given with respect to a wall. Here, the outside edge of the aisle marker is customarily used as the measurement line.

Note that for large, interconnected systems such as in automotive body assembly shops, all equipment locations are typically referenced to a single master column. This is because there is too much variability in actual building column placement to use multiple columns as reference points.

Written instructions are best communicated with some type of work order covering each element. Each plant has its own design of form and procedure for preparing and issuing work orders. However, Figure 15-5 shows one form of move notice that can be used effectively within any work order system.

The Installation Instruction Summary, Figure 15-6, is another example that includes more detail about utilities and which department or skilled trade will be responsible for each aspect of the installation. The item numbers on this form can be keyed to similar numbers marked on the layout plan. This makes it easier to find the piece of equipment under consideration and a copy of the form can be posted next to the layout in the area being installed.



MACHINE & EQUIPMENT MOVE NOTICE

Plant *Mannheim* Project *B-659*

Project Description *Relocate and Relayout portion of Machine Shop*

Moves to be completed by *11/1*

Notice No. *633*

Work Order No. *60-375*

Prepared by *F. Conzen*

Approved by *A.J.R.*

Date Issued *5-Oct*

	Description Asset or Tag No. Equip. to be moved		(F) -- From: (T) -- To: Bldg.	Floor	Dept.	Col.	Explanations Check "OK by" and Date
1	*Brake Press*		F	*2*	*44*	*D5*	
		#1346	T	*1*	*43*	*E8*	
2	*Punch Press*		F	*2*	*44*	*D5*	
		#1113	T	*1*	*43*	*E8*	
3	*Lathe*		F	*1*	*Receive*	*A2*	
		#1262	T	*1*	*43*	*E8*	
4	*Lathe*		F	*2*	*52*	*L4*	
		#1237	T	*1*	*43*	*D8*	
5	*Lathe*		F	*2*	*52*	*L4*	
		#1238	T	*1*	*43*	*D8*	
6	*Drill*		F *Dead equipment storage*				
		#1706	T	*1*	*43*	*D8*	
			Tool Room to recondition				
7			F				
			T				
10			F				
			T				

Instructions: *Punch Press #1113. Disconnect electrically after 16:00 on 11/1. Necessary wiring at new location to be done without interruption of service to production line. Installation of this machine to be complete by 07:00 on 11/3.*

Lathe #1262 (new TOS) -- Move in place and hook up as soon as possible.

Lathes # 1237 and 1238 disconnect on 11/8 and be in operation by 11/10.

Brake Press #1346 -- Disconnect after 16:00 on 11/6 and in operation by 11/8.

Drawing/Plan No. *M-2563* Photo/Sketch No.

Distribution:
- ☒ Movers
- ☒ Maintenance
- ☒ Plant Layout
- ☐ File

Return to *H. Burtzel* when installation is complete.

Figure 15-5. Move Order used in conjunction with a work order system. Each item of machinery or equipment is identified on one line; from and to locations are placed opposite; and instructions entered below. Space at right is for follow-through notes such as installation delays, movers' explanations, and completion sign-off.

Figure 15-6. The Installation Instructions Summary is a condensed way of issuing instructions. The item number is keyed to the layout plan for easy reference. Description refers to the equipment being moved. A check or an X in the columns under Utilities indicates services that must be provided or removed. The Electrical column calls out the electrical requirements. The columns labeled Millwrights-Mechanical and Electricians will hold a brief description of the work each trade is to perform. The remainder of the form allows room for instructions or special assignments for other people involved with the installation.

INSTALLATION INSTRUCTIONS SUMMARY

Description *Relayout of Kitchen*

Plant *Nortot*
By *O.M. Cramer*
Date *11/10*

Project *343*
With *D.F. Addis*
Sheet *2* of *2*

ITEM No.	DESCRIPTION MACH./EQPT. No.	MOVE	UTILITIES						MILLWRIGHTS-MECHANICAL	ELECTRICAL						ELECTRICIANS	OTHER WORK -- (Code who and describe) C - Carpenters M - Methods S - Safety Engr. F - Fire Marshall P - Plant Engrg. * - Outside Contractor	
			Air	Water	Gas	Drain	Vent	Steam		Volts	Phase	KVA	Amps	H.P.			WHO	WHAT
1	Sink D-1	-- --	--	✓	--	✓	--	--	Reorient									
2	Food Prep. Table D-2	A-5 B-10	--	--	--	--	--	--	Relocate	110			15			Install	C	Revise table per drawing T6538
3	Steamer (Stag) D-3	A-5 B-10	--	✓	✓	✓	✓	✓	Relocate	110			15			Hook up		
4	Proof Box D-4	A-7 B-10	--	--	--	--	--	--	Relocate after repairs	110			15			Install		
5	Bake Oven D-5	A-7 B-10	--	--	✓	--	✓	--	Relocate								F	Check for fire regulations
6	Portable Mixer D-6	A-7 B-10	--	--	--	--	--	--	Relocate	110			15			Install		
7	Range F-7	C-5 B-12	--	✓	✓	--	✓	--	Relocate								F	Check for fire regulations
8	Range F-8	C-5 B-12	--	✓	✓	--	✓	--	Relocate								F	Check for fire regulations
9	Portable Slicer F-10	C-5 B-12	--	--	--	--	--	--	Relocate	110			15			Install	S	Certify present guards
10	Exhaust Hood	-- --					✓		Rearrange and tie-in with 3,5,7,8									
11	Partition	A-5 76															C	Disassemble and salvage

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To accompany Drwg. Nos. *M-29548*

Work Order *60-936*

Builders and suppliers of new machinery and equipment should be instructed to mark the centerline of each machine – typically on the front and one side of the base. These centerlines (and other agreed reference points) should appear on up-to-date, correct drawings submitted at some appropriate time before installation. Ideally, the drawings will contain all of the layout detail and information listed earlier in Figure 12-1.

Who Should Make the Move

The layout planner or analyst may plan and coordinate the installation, although more often than not, someone else is responsible for this phase. The physical installation usually falls to the maintenance group. For large or complex jobs, outside movers and installation contractors are frequently called in. On the other hand, for simple relayouts, operating personnel themselves often make the change-over.

Whenever the installation work is divided among two or more groups, the work of each group should be dearly defined. In addition to its own assignments, each group should have information on what the other group is supposed to do. In this way, one group cannot "assume" that another group will cover a certain portion of the job because it does not happen to be listed on the instructions of the first group.

Actually, most firms make their own layout installations for the following reasons:

1. The cost is likely to be less when the company has its own installation crew. This is especially true if operating people are idle anyway and can be used effectively, although their effectiveness is often very limited.
2. The maintenance men become familiar with the installation when they put it in and, therefore, find it easier to maintain and repair.
3. There is less need for elaborate paper work on contracts, prints, specifications, installations drawings, and the like – that is, less staff work.
4. Where speed and time are important, as in the case of hurried changeovers, it is frequently not practical to wait for an outside contractor.
5. By having the company's own personnel do the installation work, the presence of maintenance staff is consequently ensured in case of emergency.

Advantages of using outside installation contractors include:

1. Contractors are often more skilled and familiar with layout installation work and techniques; they have the proper equipment and can do a safe, efficient job.
2. Frequently a company does not have a qualified or adequate maintenance group to handle the rather infrequent task of layout installation. For new layouts, there may be no company employees available at all.
3. A company's own construction and maintenance crews will have many other details to attend to during a relayout, and may not have time for installation.
4. Labor union agreements may restrict the use of company personnel.
5. The installation can be a long drawn-out sequence, or a continuous process plant may have to be kept operating, in which cases, outside crews are practical.

Where outside contractors are employed, it is often practical and usually wise to have one or more company personnel work closely with them. Again, be sure to spell out for both groups which details of the installation each will do.

When to Move

Where new construction is planned, or the plant will be relocated, or the layout is part of a larger “system” such as an assembly line, the timing of the layout installation will be largely determined and controlled by others. When the timing is discretionary, the planner should schedule the move during periods of low production or changes in product, process, or equipment. Scheduling moves in this manner helps avoid interruptions in shipping schedules, losses in production time, and disrupting effects on employees.

It is usually impossible to find a time which will completely satisfy all parties. An attempt can be made to maintain production schedules during the move. Or, the move can be made on weekends, holidays, vacations, or during seasonal lulls when production is normally down. It is often advisable to suspend operations and make the move all at one time, rather than tangle with everyone during the move.

When the move time is critical, the installation phase can dictate the schedule for the entire planning project, earlier work being scheduled against the "on stream" or "in operation" dates. Regardless of the planning schedule(s), the installation work should have a specific schedule – finely broken down and closely controlled – especially when closely synchronized and complex construction, utilities, and equipment are involved. Critical path analysis and scheduling are most meaningful under such conditions.

Once the schedule is set, it is often better to go ahead than to hold up if everything is not quite ready. That is, make the installation before being ready with every layout detail. If the installation were postponed until everything was completely ready, the move might never be made. And if we tolerate delays, we may find in the future our installation planners never will meet schedules.

When the move takes place, the layout planner must be on the floor, or at least readily available, for consultation with the movers. No matter how well the layout planning has been done, there are layout adjustments at installation time. Therefore, the planner must be available to answer questions, interpret plans, inspect for completeness, and secure as early a resumption of production as possible.

Regarding changes, the policy should be firmly established that the installation people can not deviate from the prints and work orders. The layout planner or installation coordinator can make changes on the prints or work orders and must sign and date such changes before the installation group can honor them.

Making the Move

If a small move is being made, move things closest to the door first. This clears space. And if the equipment can be moved in one load, the first item in the vehicle is the last item out. But it is probably much more important that the new areas are set up and completed in orderly sequence – so let this objective control the sequence of moves.

Before the move, pillars or columns should be clearly identified, preferably by painted letters and numbers on each. This allows ready orientation for equipment spotting. Also, paint, tape, or otherwise mark aisles before starting the move. This prevents the movers from setting equipment in the aisles and clogging the flow of other equipment. Besides, most of the equipment will be located with respect to the columns and aisles.

Whenever floor space is clear, the location of each piece of equipment in the new layout should be marked on the floor. The equipment can be moved as close as practical to the point where it is to be used. Then it can be lined up with a minimum of further moving.

Making a relayout is often not unlike a game of checkers. One move may call for a move into a spot presently occupied by some other piece of equipment. Hence the sequence of moves must be planned, perhaps even with extra moves merely to clear space.

Condition Employees for Change

Prior to the move, operating and supporting-service supervisors should be briefed. Their understanding of the installation plans can materially aid a smooth move. By having prints, photos, or perhaps a 3-D physical model available to them, supervisors can explain to their employees what is going to happen and where each worker will be located in the new set-up. Actually, thorough training of operating people may payoff handsomely, depending on the nature of the project and the relative "newness" of product, process, and personnel.

Keeping employees "in the know" improves morale, especially during the time when there is a certain amount of disruption. And, of course, don't overlook personnel staff; give out new locker numbers, explain the new parking or time-clock procedure which has developed as a result of the new layout. New practices of this type, when improperly introduced to employees and supervisors, can give a black eye to the entire layout project – with the layout planner frequently catching most of the blame.

Release to Production

Machinery and equipment should be checked over and tried out before being released by maintenance to the operating departments. Figure 15-7 shows a form helpful in this *installation check-out*. It is used to certify that the piece of equipment is installed and functioning properly. This form has a place for each craft to check off the work it has completed. It includes a place for the safety engineer to sign, indicating that the machine conforms to the plant's safety regulations.

Figure 15-7. The Installation Record serves as a progress sheet of each piece of equipment's installation. By checking-off and/or writing-in as necessary, the sheet gives work assignments and completion due dates at left, installation completion sign-offs at right, and acceptance of the installation below. The sheet will be kept with the machine until its installation is completed and accepted. Any reason for delays in installation or hook-up can be entered in the comments section or as a footnote. Return of the form to the issuing office indicates completion of this machine's installation. If an electronic document management system is available it may perform the same functions without the paper form.

INSTALLATION RECORD

Mach. or Eqpt. No. 5
Mach. /Eqpt. Type *16" Wire Drawing Mach.*
Mfgr. *Federal Wire Rope Corp.*
Size/Model
Signif. Identification *7-B -- 7-H*

Plant *St. Louis* Project *60-36*
Bldg. *B* Area *1st floor* Dept. *L*
Nearest Column Location *E 5*
Sheet issued by* *J. Rothman*
Date issued *12/7* Date returned

MECHANICAL, MAINTENANCE, MILLWRIGHTS

Level *Yes* Resp. *A. Butts* Due *12/15*
Lag Resp. Due
Mount Resp. Due
Resp. Due

Complete (sign) A. Butts
Date 12/15
Comments Everything OK

ELECTRICIANS

Power *440 3 phase* Resp. *L. Carter* Due *12/17*
Control *X* Resp. *L. Carter* Due *12/17*
Lights *X* Resp. *L. Carter* Due *12/17*
Connect spooler Resp. *L. Carter* Due *12/18*

Complete (sign) L. Carter
Date 12/18
Comments OK

PIPING & SHEET METAL

Water *X* Resp. *F. Royer* Due *12/17*
Steam Resp. Due
Drains Resp. Due
Comp. Air *X at front* Resp. *F. Royer* Due *12/17*
Gas Resp. Due
Coolant, Lube Resp. Due
Hoods, Ducts, Fans Resp. Due
Resp. Due

Complete (sign) F. Royer
Date 12/17
Comments Will need new valve installed when available.

PAINT and CLEAN-UP

Paint Resp. Due
Clean-Up *X* Resp. *G. Art* Due *12/18*
Resp. Due

Complete (sign) G. Art
Date 12/18
Comments OK.

SAFETY

Guards *X* Resp. *J. Wolf* Due *12/18*
Fire Regs. Resp. Due
Fumes, Acids Resp. Due
Resp. Due

Complete (sign) J. Wolf
Date 12/18
Comments Old style guards - replace with new style soon as available.

OTHER INSTALLATION WORK SIGN-OFF

Resp. Due
Resp. Due
Resp. Due
Resp. Due

Complete (sign)
Date
Comments

FINAL ACCEPTANCE (by installation coordinator or operating supervision)

Name *H. Sharp* Title *Layout Engineer* Sign H. Sharp Date 12/19
Comment Working OK
Name *J. O'Conner* Title *Dept. Supervisor* Sign J. O'Conner Date 12/19
Comment O.K.

(After final acceptance, return this sheet to person originally issuing it. See above.)

NOTES, Special Instructions, Reasons for Delay

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* Return this sheet to person originally issuing it, after final acceptance

Follow-Up

For the sake of future layout projects and adequate space control, the planner should follow up the layout to see that it is correct and functioning as planned. Check with the people using the new layout to determine what gripes may have developed. Immediate attention to these details will aid in making the new layout successful and at the same time develop the reputation of the layout planning group.

If the layout is not functioning as planned, the layout engineer must analyze the problems. The operating people may have misunderstood what was intended. The plan may have called for something impractical. Or for some reason, the service people cannot or will not follow the procedures, or use the equipment as intended. This is a serious reflection on the layout planner, and requires immediate attention. If the layout is wrong the planner should OK the change. After all, some oversights are to be expected; it is too costly to plan every detail perfectly. If the layout plan is right and the operating people cannot be induced to work it as planned, the layout engineer may have to involve "higher ups" in the organization.

When the layout project is wrapped up, it is wise to make a post-installation audit of the savings and costs that were estimated. This increases the accuracy of installation estimating and gives a sounder basis for future operating-cost estimates. Also, where relayouts are frequent, the layout plans should be updated so an exact record of the current layout is always available for future use.

Chapter 16

Managing Layout Projects

In this final chapter, layout projects are considered from the standpoint of the person responsible for supervising plant layout activities and from the viewpoint of the individual charged with the responsibility for a specific project. The reader is addressed here accordingly.

Management Interest

The degree of management attention to facilities layout varies with the relative amount of the capital investment involved, with the extent of owner or stockholder interest, and with the degree of change in products, processes, and sales volume. Top management is generally interested in Phases I and II of layout planning but delegates to others execution and approval of Phases III and IV.

However, as explained in the Introduction to Part Four, the rearrangement of a small departmental area has a Phase I and a Phase II, but they may be of no interest at all to top management. Moreover, what is a major Phase II problem for a branch plant may have little or no significance from the viewpoint of top management at headquarters.

Therefore, as shown in Figure 16-1, the degree of management attention is *relatively* greatest in the early phases and less important in the later phases of layout planning. On the other hand, the total hours involved in layout planning increases with each phase. There are more people involved and more time is spent in the later phases. But, since the work is generally at lower levels of the total employee group, management delegates the planning and control of these hours to others.

In general, more important deliberations by fewer, high-level management personnel will take place in the early stages of projects while the reverse will be true later in the project.

Organization

The organization for layout planning depends on a host of factors. When staffed with full-time layout planners, about 60% of industrial plants place them in Industrial Engineering, or Plant Engineering, or their equivalents.

In highly engineered process plants, people with highly technical experience meld the layout planning right into the process planning. For office areas, on the other hand, where fixed investment is not high and rearrangements are easy to make, skills in procedures analysis, as well as an understanding of layout planning, may be of value. Where there is no formal layout planning function, the planning falls to the manager of each operating area: office manager, superintendent, service manager, assistant to one of these, or some other person designated for the job.

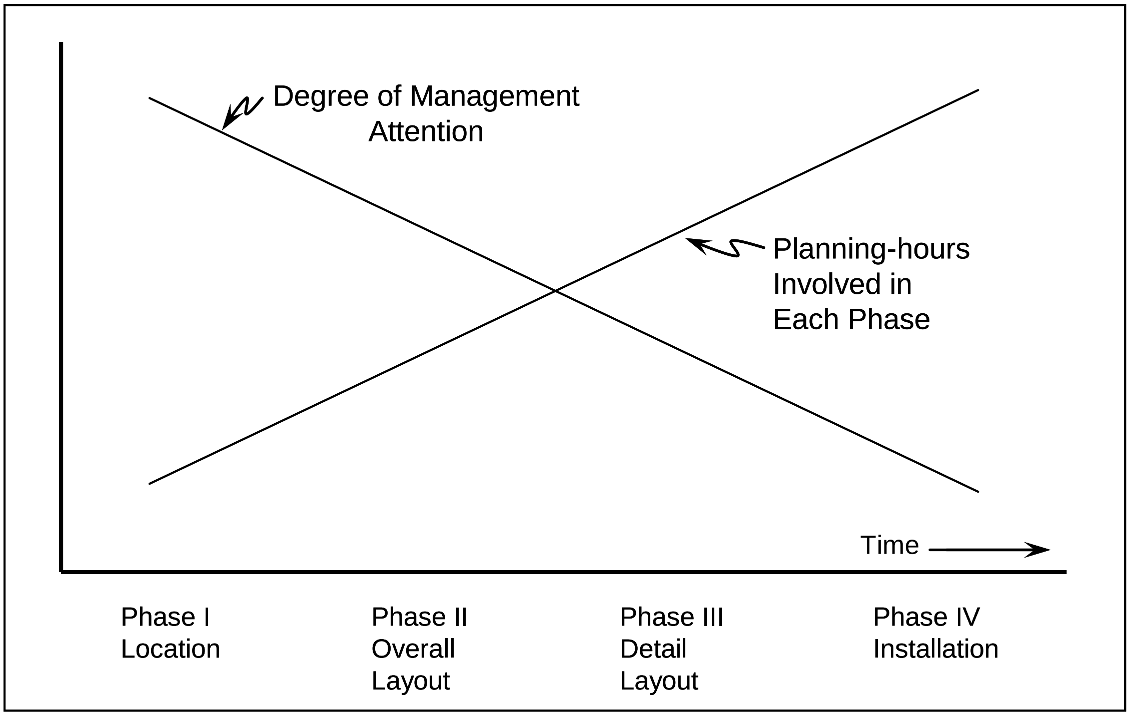


Figure 16-1. Management interest and total man-hours vary with layout-planning phases. Management deliberates more on the more-important early phases, and delegates and spreads the work of detail planning and installation.

The main point is to have somebody responsible for planning the layout and to equip this person with the know-how necessary to do it well. This person's position in the organization structure is more academic perhaps than it is significant. Teams, committees, and other investigating groups or outside consultants can and should definitely participate, and with good overall benefits; but for best results, one person, or group with a designated person in charge, should be responsible for getting the layout planning executed.

When layout planning is left to each department or function and undertaken only occasionally, the facility's overall layout will eventually suffer. Expedient and apparently good area decisions will preclude more effective layouts when the layout is viewed as a whole. Further, when planning is undertaken only intermittently by departments and functions, it is rarely performed in a systematic manner. Thus the quality of the area plans themselves can typically be improved when one group or person is responsible for the planning process.

In this connection, a word should be added about the common practice of layout planning during "continuous improvement" events or as quality improvement projects. In the absence of training in layout planning, leaders of such events and projects often rely on the standard project management structure of their company improvement program. While better than no structure, these are typically generic and do not recognize the fundamentals of *relationships*, *space* and *adjustment*, and the benefits of their orderly application. Teams following generic project methods often are unaware of and fail to apply proven tools and techniques that would yield better layouts and results. In some cases, the improvement programs are simply prescriptive with respect to layout: “Always use the U-shaped flow pattern… Put everything into manufacturing cells… No more than four hours of floor storage,” etc. Such prescriptive approaches kill ideas and consideration of relevant and potentially better alternatives.

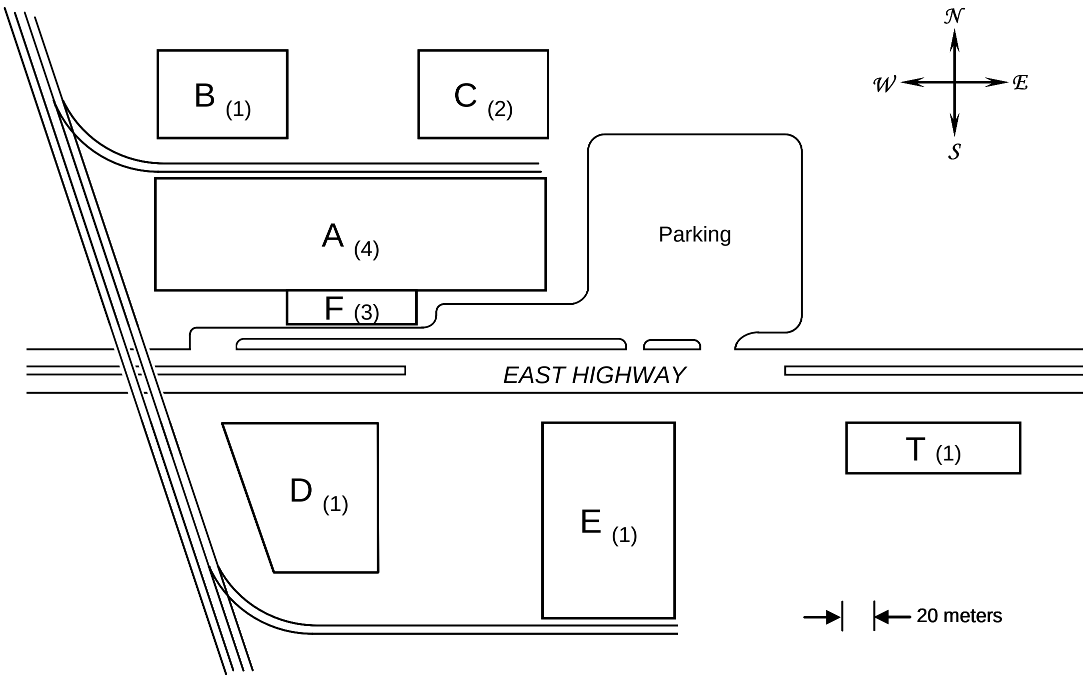
Leading practitioners of lean manufacturing, continuous improvement (Kaizen) and Six Sigma (quality) improvement have discovered that Systematic Layout Planning (SLP) is a highly-effective method for running short, team-based layout planning events and projects – and better than their standard structures for operations improvement planning. Several multinational corporations have added SLP to their corporate programs as an alternate procedure for layout projects or workshops. The most experienced SLP users in these companies have demonstrated the consistent ability to develop and evaluate multiple plant layouts in a week or less. Appendix IX explains how to run layout planning as a one-week “Kaizen event” using SLP.

Get Ready for Planning

Getting set up properly for layout planning is important. Too often, the person or team responsible for the project is handicapped by lack of working space or suitable materials, by ignorance of the total company program, or by lack of recognition or authority. The planner should get set up with suitable and sufficient materials. Get an adequate place to work, with table-top area or wall space to spread out plans. For quick plotting of charts, forms, block layouts and individual activity-area plans, much time can be saved with a letter-size, color ink jet plotter right in the planning room. The expense of this plotter and ink cartridges will be minor compared to the time lost by the planners going to and from remote printers and plotters.

Get an overall layout of the site or a set of building plans which identifies the buildings and floors and the assignment of current departmental areas. Such plans need not be greatly detailed, but they should show major features of the site or buildings. An example of such an orientation plan is shown in Figure 16-2. In detail relayouts, detailed plans of existing structures and utilities are used – and, in the average company, they are notoriously inaccurate if they are available at all.

Make it easy for the layout planner to get the necessary information: projected input data – product designs (P), anticipated sales forecasts (Q), the process routing (R), supporting services (S), and timing considerations (T). The planner needs to know what changes are expected in these during the life of the layout. And, the planner should know about any long-range master plans for the site, buildings, or space allocated, so that the layout is integrated with the larger space planning program for the company. If these are not available see that other division officers or department managers involved are alerted to the fact that they will be expected to supply such information to the layout planner. Failure to plan or to communicate the basic criteria or specifications to which the layout must be designed is one of the most common oversights by top management in initiating layout planning projects. Knowing this, the planner should not hesitate to develop his or her own input data and submit it to others for approval.



FACTORY			OFFICE		
Department	Bldg.	Floor	Department	Bldg.	Floor
Large Press	A	1	Accounting	F	1
Small Press	A	1	Billing	F	1
Screw Machines	B	1	Engineering	F	3 & 4
Gear Shop	B	1	Payroll	F	1
Assembly Dept.	A	2 & 3	Cafeteria	A	Bsmt.
Tool Room	C	1 & 2	Plant Engineering	F	Bsmt.
Heat Treating	D	1	Purchasing	F	1
Experimental	C	3 & 4	Industrial Engineering	F	2
Forge Shop	E	1	Tool Design	C	2
Test Range	T	1			

Figure 16-2. Overall orientation plan to aid layout planning. This diagram of the buildings involved and list of allocated floorspace is valuable to the layout planner while working to adjust and rearrange space. The planner should always have at hand – or at least obtain early in the project – this record of existing departmental space and where it is located. Here the buildings are indicated by letter and the number of floor levels (including basement) by number in parenthesis.

Facilities Planning

The term *facilities planning* is sometimes used almost interchangeably with plant layout. Some companies use facilities planning to describe Phases I and II of major projects, and plant layout to mean Phase III only. In academic circles, “facilities planning and design” has replaced what was once called “plant layout and material handling.” But what is taught is still mostly plant layout and materials handling analysis, plus mathematical modeling of logistical networks. The architectural, civil and

and plant engineering aspects of industrial facilities planning are generally not addressed. Nor is the critical function of corporate real estate. Regardless of individual company or academic terms, facilities planning is a broader term and encompasses the total company program of real estate, buildings, process machinery, and utility equipment.

In reality, the layout and the material handling system are only parts of a total industrial or commercial facility. The total facility can be compared to a living organism. The different parts of the anatomy are different components of the facility. Figure 16-3 draws this comparison.

Following the concept of planning in phases, the layout planner integrates each of these components at each phase – overlapping the planning into the following phase as necessary. See Figure 16-4. But both the planner and the approver of the plans should recognize that all five components need to be considered as an integrated whole when each phase of planning is submitted for approval.[1]

For overall planning of these activities, a long-range capital investment budget is recommended. This not only forces management to plan ahead – which any reader of this book will subscribe to as being important – but also sets up an organized routine for screening and appraising various projects that must be justified in the competition for available investment money. For effective total facilities planning, this capital investment budget should be based on a five-year or ten-year plan of overall company action. The budget itself essentially reduces to dollars against a time schedule of anticipated plans for facilities alteration or expansion.

While all companies may not go so far as to follow the procedure set forth in Figure 16-5, some form of it is helpful – if not invaluable-to every organization expecting to grow or expand.

Doing the Planning

Once a project is activated, make sure it is defined and identified. Every project should have a descriptive name that is generally understood. Each project should probably also have some identifying project number, where a series of projects are involved. Moreover, a clear statement of the objective of the project – *what* is to be done and *why* – should be set down in writing and agreed upon.

Next, make clear *who* is to handle the project. This means a clear assignment of responsibility for the project. And, it should involve an understanding or indication of what other groups or individuals the layout planner must coordinate with; what the limits of the project are; and where the planner overlaps with others who must supply information or to whom results will be submitted.

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[1] The method of Systematic Planning of Industrial Facilities (SPIF) integrates the planning of all 5 components. Its structure builds on and extends that of Systematic Layout Planning (SLP). This method is fully described in Systematic Planning of Industrial Facilities (SPIF) Vol. I and II, by Richard Muther and Lee Hales. The SPIF method has been translated into Japanese and Chinese and used to plan many industrial facilities throughout the world.

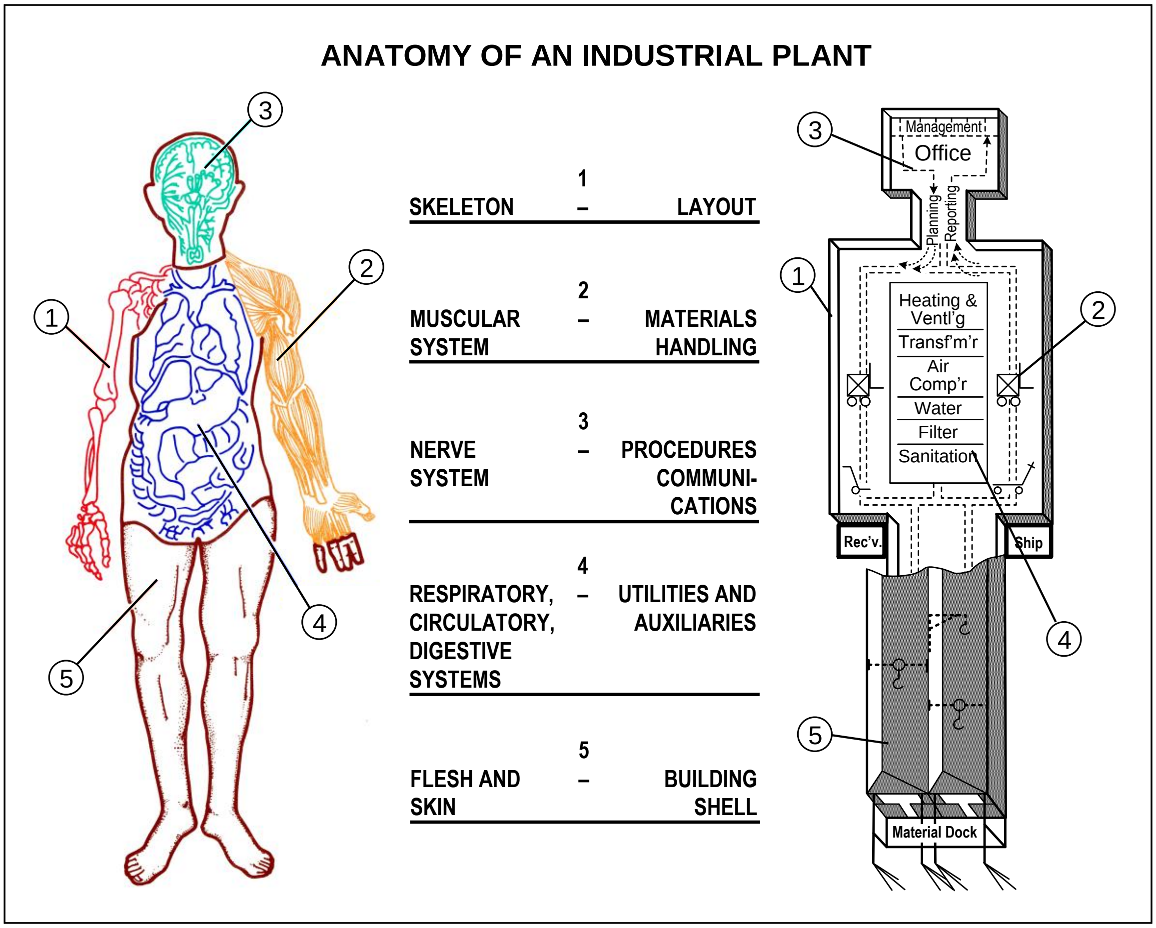


Figure 16-3. An industrial plant is a dynamic combination of physical systems. It may be likened to a living animal wherein each component system has its counterpart as a component of the industrial plant. The layout is only one of five components making up an industrial plant.

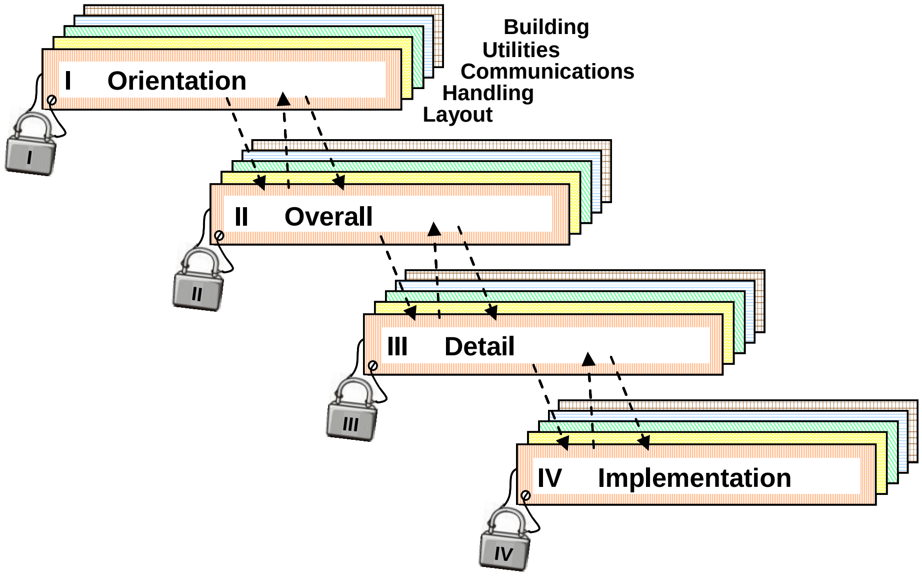


Figure 16-4. Industrial facilities planning in phases. The five components are planned in parallel and should be “locked together” at each phase. From: Systematic Planning of Industrial Facilities, Vol. I, by Richard Muther and Lee Hales, Management and Industrial Research Publications.

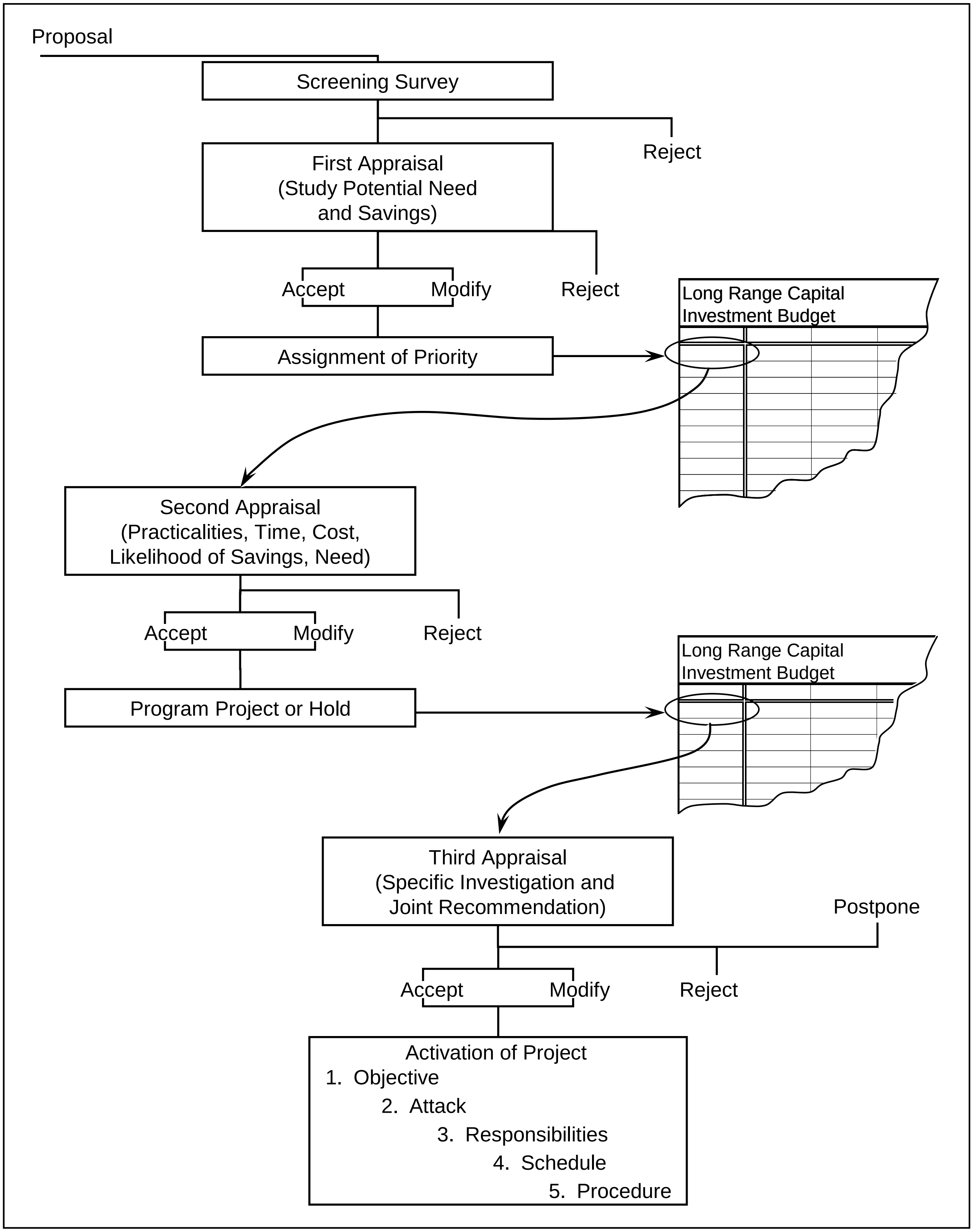


Figure 16-5. Screening and programming capital expenditures. Major layout projects – especially those involving new processes or new buildings – fall into the area of long range capital expenditure planning. They must first be worthwhile, then be compared with other requests for funds, and wait their turn for logical activation. Often, the layout will be planned through Phase II, general overall layout for screening or a first appraisal. Detail layouts are typically deferred until the second or third appraisal when more is known about the intended operations and to avoid wasted effort and expense.

PROCEDURE FOR STARTING ANY LAYOUT PROJECT WITH S L P

1. Establish in writing:
    a. The identification and description of the project.
    b. Its objective(s) and reasons why needed.
    c. Its breakdown in phases and appropriate steps.
    d. The name of the person responsible for the project.
    e. The time(s) when planning should be done and/or installation should be complete.

2. Determine where the project lies:
    a. In what phase?
    b. Are previous phases complete – fluid, fixed, approved?
    c. If not, how far along is each step in each phase?

3. Set a schedule for the project.
    a. The date for completion of each phase.
    b. The date for completing the appropriate steps.

4. Get, or verify, projected input data on P, Q, R, S, T.
    a. What is known?
    b. Is data approved by those in authority?
    c. If not, get basic input data.

5. Move into the appropriate step or box of S L P and follow forward from there.

Figure 16-6. Getting started on layout projects using SLP.

Every layout project should be scheduled. *When* the project should be done may be as significant as what is to be done and who is to do it. Scheduling alone can improve the performance of the layout planner, for most humans strive to meet the challenge of deadlines, especially ones they set or agree they can meet. Before proceeding with the project scheduling study, the reader should pause to examine Figure 16-6. It sets forth a procedure for starting any layout.

Probably the best way to schedule a project is to break it down into the four phases of layout planning; then subdivide:

Phase I into P, Q, R, S, T, and activities analysis
Phase II into steps (or Boxes) of the pattern
Phase III into the number of areas to be laid out in detail.

In this way, each project can be scheduled and its files kept according to this systematic breakdown.

There are no generally agreed upon time standards for layout planning. Under certain circumstances, an entire area can be laid out by one person in one day following the SLP methodology. On the other hand, under other conditions, a complete plant may involve several planners working more than a year just to execute one phase. Still, by reasoning out how much data is available, the phases involved, the steps of the pattern, the detailed areas involved, and the complexity of the installation, a project can be planned and scheduled according to a logical and systematic sequence of events.

Moreover, scheduling this way keeps the project within the SLP framework and pattern. Planners understanding SLP and using it to their advantage can work faster and more soundly. If a planner has to stop and think about which methods to follow and what materials to use, then time is lost. In the final analysis, if we save time in planning, we can afford or justify having a better person do the planning. A project scheduling worksheet with an example broken down by SLP phases is shown in Figure 16-7.

Recognize, however, that sometimes it is expedient not to follow the framework too strictly. For example, in crash programs it may be advantageous to move ahead with detailed layout plans before the general overall layout or even the location is agreed to. This usually results in much redoing of the detailed planning and is, therefore more costly. Still, if getting the total project accomplished on time is the most important consideration for the company, the extra cost is justified. By having more time to negotiate the site procurement or the lease arrangements, moreover, top management may have saved far more than the cost of the extra layout planning time.

Layout planners must realize that top management's common criticism of them is that the planning takes too long. Maybe management contributes to this. But planners too often drag out projects, meticulously seeking perfection. Most managers realize that engineers tend toward too much detail. Management may, therefore, do well to push projects along toward completion before all details are fully resolved.

On the other hand, a layout is not a good layout unless the operator who uses it also believes it is good. Therefore, it is best to involve the operating people in the development and evaluation of the plans. When this is not practical, or has not been done, be sure that reasonable time is allowed afterwards to let operating people sell themselves or become convinced of the benefits of the new layout. Then, they will support it as a "good layout" for the company.

Recording Data

For the layout planner, certain practical routines can avoid confusion and save time. As a matter of habit, the planner should identify every data or analysis worksheet. This identification should include:

1. Project name and/or identifying number
2. Name of person(s) preparing the worksheet
3. Date the worksheet is begun and dates of subsequent revisions or versions
4. Sheet number, in sequence for each step of the analysis or study (is helpful but not mandatory)

PROJECT SCHEDULE SHEET

Covering: *Chennai, Proj. 25731 Wax Paper Relayout*

Status as of: *22 Dec*

Distribution: *Continuous Improvement, Facilities, Ihuman Resources, Production, R. Kumar*

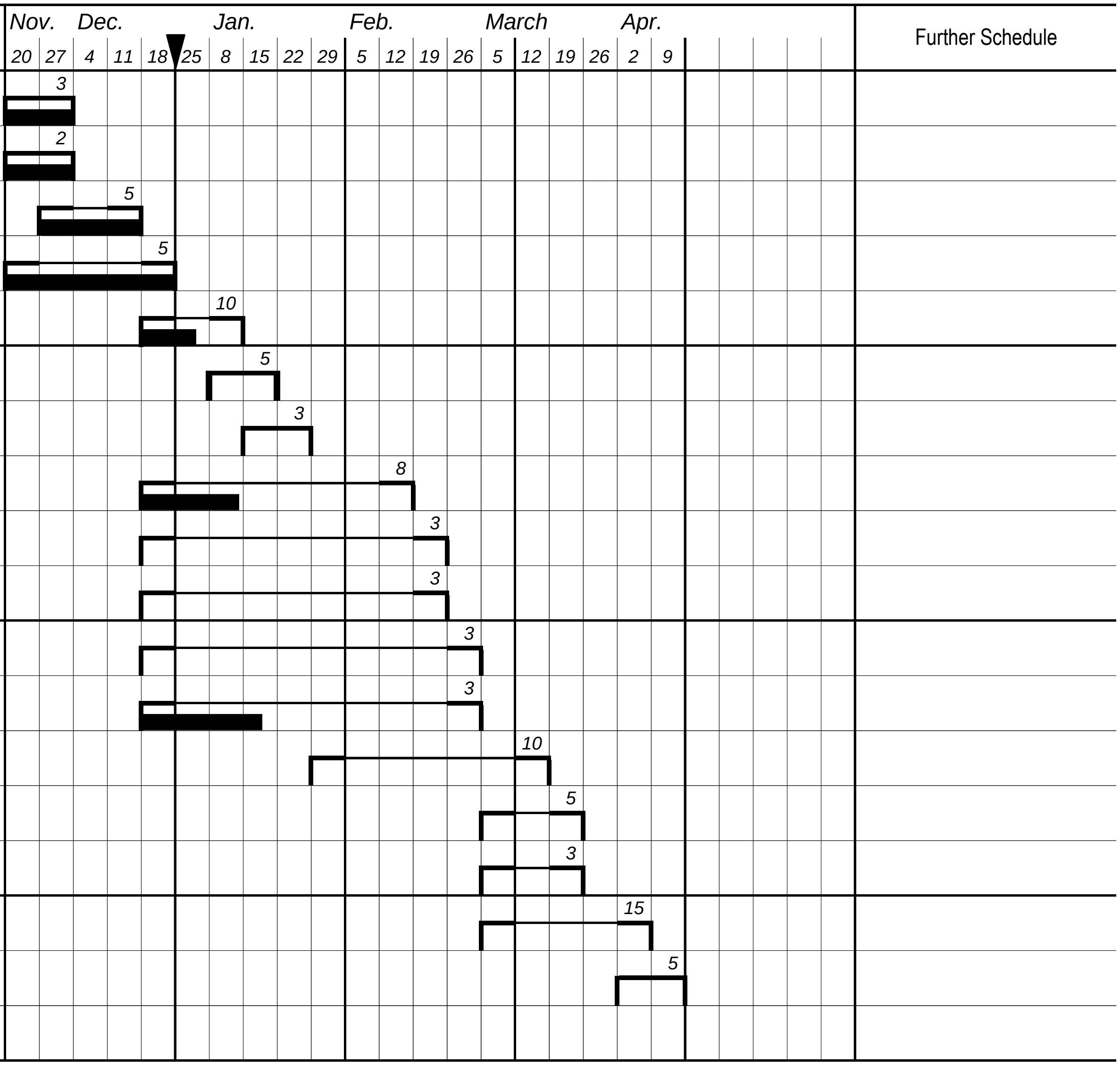
Originating Department: *Continuous Improvement*

Prepared by: *S. Ramakrishnan*

Date: *20 Nov.*

Sheet *1* of *3*

Task/Proj. No. and/or Description	Work to do; Action to take	Resp. of
1	*Establish location*	
2	*P-Q Analysis*	
3	*Flow of Material & Activity Relationship*	
4	*Space Allocated*	
5	*Alternative layouts*	
6	*Evaluation and Selection*	
7	*Approval of General Overall Layout*	
8	*Detail Layout:* *Wax Machines*	
9	*Wrapping Machines*	
10	*Boxing Machines*	
11	*Raw Paper Storage*	
12	*Finished Product Storage*	
13	*Service Areas*	
14	*Installation Cost Estimates*	
15	*Approval of Detail Plans*	
16	*Installation Drawings and Instructions*	
17	*Move and Cleanup*	
18		



Gantt Chart Code: ┌─ Date work scheduled to start ─┐ Date work scheduled to finish ┌─┐ Total time scheduled for work ▬ Amount of work done

(Each vertical period represents one unit of time. Use Gantt Chart Code or enter numbers and/or other indicators.)

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It is quite common in layout planning to have one project set aside in favor of another of higher priority. By the time the planner returns to the first original, he or she may have lost the ability to identify or understand the prior data. Or, if the planner is transferred or promoted, whoever inherits the project may be at a complete loss to identify what has been done, or whether or not the drawings and data even apply to the particular project. Much time and expense have been wasted by poor attention to identification, naming, version control and filing of worksheets.

Balance of Elements

One important guide to bear in mind in working with the great variety of features and people likely to be involved in any layout is a proper *balance* of all elements. It is easy to be led astray by statements based on preconceived thinking or personal preference of individuals likely to be affected by the layout. Their quick opinions based on too sudden or too early solicitation of their thinking may turn out to become stubborn "facts," merely because they were expressed or stated earlier.

Moreover, a common mistake is to overcorrect short-comings or limitations in an existing layout, when planning a new one. For example, perhaps the present layout has no adequate provision for maintenance personnel. This has become a major bone of contention for an outspoken maintenance supervisor. So in the new layout the planner goes overboard to provide access for maintenance personnel – at the same time perhaps wasting floor space and adding to housekeeping problems. The latter problems are taken for granted and not emphasized in the new layout planning because they were satisfactory in the original layout. Therefore, perhaps one of the most difficult mental adjustments for the layout planner is to maintain a realistic balance of all elements and factors affecting the layout plans.

Seeing the layout project in its entirety, which can be done with the SLP framework of phases and pattern of procedures, helps the planner give balanced attention to various elements. It helps capture the total picture – and with it a depth of perspective – for the planner can readily see just how any project fits into the larger framework and into the pattern of attack.

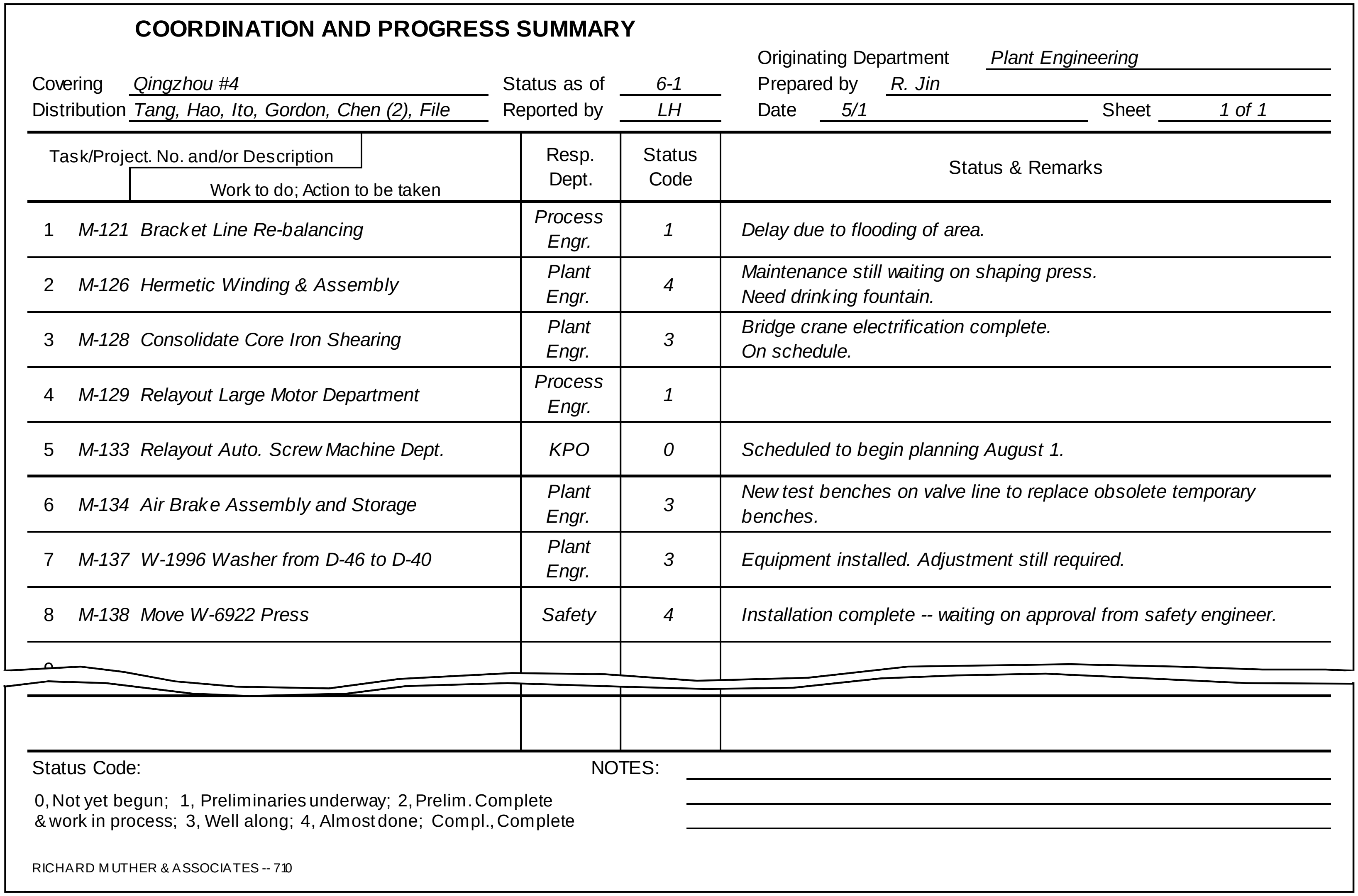
Similarly, middle and top managers should be cautioned about blaming "poor layout" for failure to produce competitively. Changes in layout can make dramatic savings. But frequently, the basic cause of high costs lies hidden in a poor production control system

---

Figure 16-7. The Project Schedule Sheet is especially effective for scheduling various steps of any layout project or a number of projects. The Gantt chart brackets show the span of calendar time allotted for each step. The number above the bracket indicates the number of planning days estimated to accomplish that step. Note that line 1 represents Phase I; lines 2 through 7 cover Phase II . . .

Periodically, as work is completed on each step, a heavier accomplishment line is filled in between the appropriate brackets. This is drawn from the left-hand bracket towards the right, thus showing the amount of work completed and still to be done.

As of 22 December, this project is running ahead of schedule except on lines 9, 10 and 11. A record can also be kept on the chart of the actual number of planner days spent. Thus, one sheet is used for both project scheduling and performance reporting.



COORDINATION AND PROGRESS SUMMARY

Originating Department *Plant Engineering*

Covering *Qingzhou #4* Status as of *6-1* Prepared by *R. Jin*

Distribution *Tang, Hao, Ito, Gordon, Chen (2), File* Reported by *LH* Date *5/1* Sheet *1 of 1*

Task/Project. No. and/or Description Work to do; Action to be taken	Resp. Dept.	Status Code	Status & Remarks
1 *M-121 Bracket Line Re-balancing*	*Process Engr.*	*1*	*Delay due to flooding of area.*
2 *M-126 Hermetic Winding & Assembly*	*Plant Engr.*	*4*	*Maintenance still waiting on shaping press.* *Need drinking fountain.*
3 *M-128 Consolidate Core Iron Shearing*	*Plant Engr.*	*3*	*Bridge crane electrification complete.* *On schedule.*
4 *M-129 Relayout Large Motor Department*	*Process Engr.*	*1*	
5 *M-133 Relayout Auto. Screw Machine Dept.*	*KPO*	*0*	*Scheduled to begin planning August 1.*
6 *M-134 Air Brake Assembly and Storage*	*Plant Engr.*	*3*	*New test benches on valve line to replace obsolete temporary benches.*
7 *M-137 W-1996 Washer from D-46 to D-40*	*Plant Engr.*	*3*	*Equipment installed. Adjustment still required.*
8 *M-138 Move W-6922 Press*	*Safety*	*4*	*Installation complete -- waiting on approval from safety engineer.*

Status Code:

0, Not yet begun; 1, Preliminaries underway; 2, Prelim. Complete & work in process; 3, Well along; 4, Almost done; Compl., Complete

NOTES:

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Figure 16-8. Keeping abreast of facilities installation. A periodic progress record informs the various interested parties of the progress being made on each layout installation project. Each project is listed as an aid in keeping the layout planners and the layout installers (in this case Plant Engineering) moving along together. Projects falling behind can be highlighted; the cause of delay and the party responsible for corrective action can be identified and reported.

poor services. Moreover, poor layout can be an overworked excuse by some weak managers. There is no sense in making a new layout, or relayout, or being concerned with how best to make it, if it is not necessary. We should look for other ways to "skin the cat" besides simply "planning a new layout."

Coordination of Projects

Every layout project involves coordination with other departments and people. In a small, one-project situation, it may be possible to keep these relationships in mind. But, as a general rule, it is best to get these relationships down on a coordinating sheet of some kind. This not only gives formal recognition to allied responsibilities, but also allows an *organized* method of reporting status. A self-policing type of form like that shown in Figure 16-8 can be of significant help in coordinating layout planning and installation when several groups are involved – as they practically always are.

Conclusion

In speaking of performance and accomplishment, Frederick W. Taylor, the recognized early leader of scientific management, has said "The greatest production results when each person is given a definite task to be done in a definite time and in a definite manner." Modern management theory would alter the statement to read:" … is given and accepts a definite … " or "is committed to … "

If Taylor’s statement is broken down and applied to managing layout projects, a relationship similar to that in Figure 16-9 is derived. By clearly specifying what is to be done, who is to do it, when it is to be done, by getting acceptance of the program for accomplishment, and by following an organized, systematic method of planning layouts, productivity of planning must improve.

“Greatest production results when…	Key Word	Application to Layout Planning Project
“each PERSON is given a	Who	Layout Planner
definite TASK to be done in a	What	Specific Project at Hand
definite TIME and in a	When	Project Schedule
definite MANNER.” *	How	Systematic Layout Planning
*Frederick W. Taylor		

Figure 16-9. Effective performance in executing of layout projects reduced to fundamentals of production output.

For greater success, you should organize your activities and conduct your projects with a clear-cut *what, who,* and *when.* Systematic Layout Planning can give you the *how.*

Appendices

Appendix I – Description and Tables for Mag Count

Various units are used in analyzing the intensity, or capacity, of materials movements. In a blast furnace operation, tons are commonly used to measure the amount of materials involved; in an oil refinery, barrels or gallons suffice; in a flour mill or grain-handling operation, tons again is adequate. Even in a warehouse of mixed items, truckloads or pallet loads may be adequate. The ton-mile, kilogram-meter, and the pallet-load-foot are then used to express the total work done in a given period of time – that is, the intensity of movement multiplied by the distances moved. And, of course, the actual time per trip or per distance traveled is highly important in the end result.

However, in diversified manufacture where a considerable variety of materials is involved, neither weight nor volume nor piece count alone truly measures the "transportability" of the material on a comparative basis. And, for overall layout planning – before any layout has been established and before the handling methods have been determined – there may be no agreed upon container or unit load that can be used as a common denominator. In these cases, the so-called "Mag" is a unit of real assistance.

"Mag" is an abbreviation for magnitude. It is a unit created to measure the transportability of materials. It measures the material, product, or material load for its difficulty-of-transport characteristics, largely independent of how it is to be moved or transported. When the mag count of any item is multiplied by the quantity of pieces moved per unit time, the intensity of materials movement, or intensity of flow, is established.

Obviously the mag concept has limitations, for the transportability of the piece or item itself may depend in part on the method of handling used, both in container and in handling equipment. Still, before these are known – as is true in practically all cases of theoretical analysis of flow – the mag can be an effective way to measure and compare the relative difficulty of the materials handling problem in a series of transportations involving highly diversified items.

Factors Affecting Transportability

There are many factors that can affect the ease or difficulty of transporting or handling materials. Basically, they can all be reduced to the following:

A. *Size* of the item
B. *Density* or bulkiness of the item *
C. *Shape* of the item
D. *Risk* of damage to the material, facilities, and employees
E. *Condition* of the item
F. *Value* or cost of the item (included only in certain cases, and usually included in factor E)

---

*The weight of the item is not included because, for any given material, weight is related to size. Density or bulkiness is therefore substituted for weight.

Because of these many factors, it is difficult to measure and compare the transport or handling effort for different materials. However, by classifying and rating these factors in a measurement system, the relative ease or difficulty of material transport can be quantified.

Definition of Mag

The Mag Count *establishes a base value for the size of an item and then reduces or increases this base value by means of modifying values for the other influencing factors.* Thus, the mag count of the item is derived. The magnitude of this end value is a measure of the transportability of the item in question.

By definition, one mag equals a piece of material that

a. can be held conveniently in one hand;
b. is reasonably solid;
c. is compact in shape and has some stacking qualities;
d. is slightly susceptible to damage; and
e. is reasonably clean, firm, and stable.

A typical example of one mag is a block of dry wood measured and roughly cut to 10 cubic inches in size – or a shade larger than two inches by two inches by two inches. Thus, if ten pieces of an item could be held conveniently in one hand, the item would have a value of approximately one tenth mag. One pack of twenty cigarettes or a typical small cell phone is one half mag; a piece requiring two hands cupped together to hold it conveniently has a value of approximately two mags. Starting with this crude, simple scale, a range of base values for typical benchmark items can be set up.

Note that the definition of base value in terms of what can be held in one hand does not mean that the transport will be made by hand. The handful measure is merely convenient and has nothing to do with the materials-handling method or equipment. Also, it does not refer to the number that can be picked up by one hand, but to the number that can be held in the hand on a non-prearranged or non-stacked basis.

The mag unit is used instead of actual cubic inches or cubic feet for several reasons.

1. There is a difference in units between the English and metric systems.
2. The "volume" is difficult to measure for very flat sheets or very long items.
3. There is not a linear relation between transportability – or handle-ability – and volume, so that a conversion or other calibration would be involved.
4. The use of actual cubic measurement would imply more accuracy in numbers than the precision to which items could be practically measured.

The Base Factor – Size

Figure 1 gives the benchmark values for the size of an item. Notice that the base value is not directly proportional to the volume or cubic size of the item.

Figure 2 shows typical items and their respective base values. In practice, any company can list its own typical and readily recognized items.

The Modifying Factors

Figure 3 gives the recommended modifying values. These factors are expressed in degrees, one degree equal to 25 per cent increase or reduction in the base value.

In terms of a formula, the mag count of any item equals:

$$A + [\frac{1}{4} \times A (B + C + D + E + F)]$$

or

$$A\left[1 + \frac{(B + C + D + E + F)}{4}\right]$$

where A is in mags and B, C, D, E and F are number of degrees positive or negative.

Example:

A four-drawer file cabinet, formed and welded, but unpainted and without drawers has a mag count as follows:

A	30 base value	D	0
B	-2 degrees	E	0
C	+1 degree	F	0

Total: 30 + [¼ X 30 (-1)] = 30 + [¼ (-30)] = 30 – 7½ = 22½, or

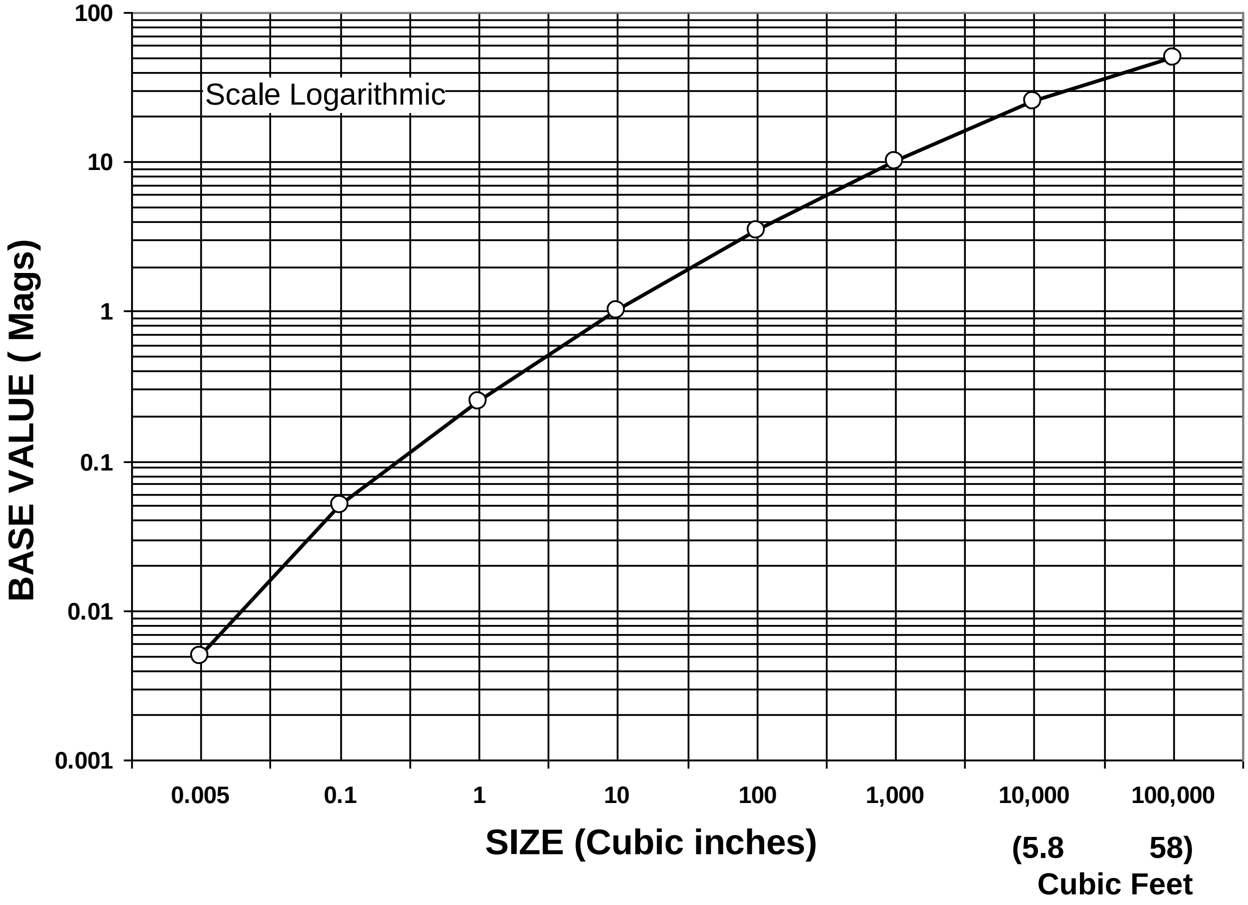
30[1+(– ¼)] = 30[¾] = 22½

This would probably be rounded off to 23 in practice.

Basis and Accuracy

Mag Count is a simple procedure. With a little practice, one can make the calculations in his head rather quickly. Some modifying factors do not apply at all for many items.

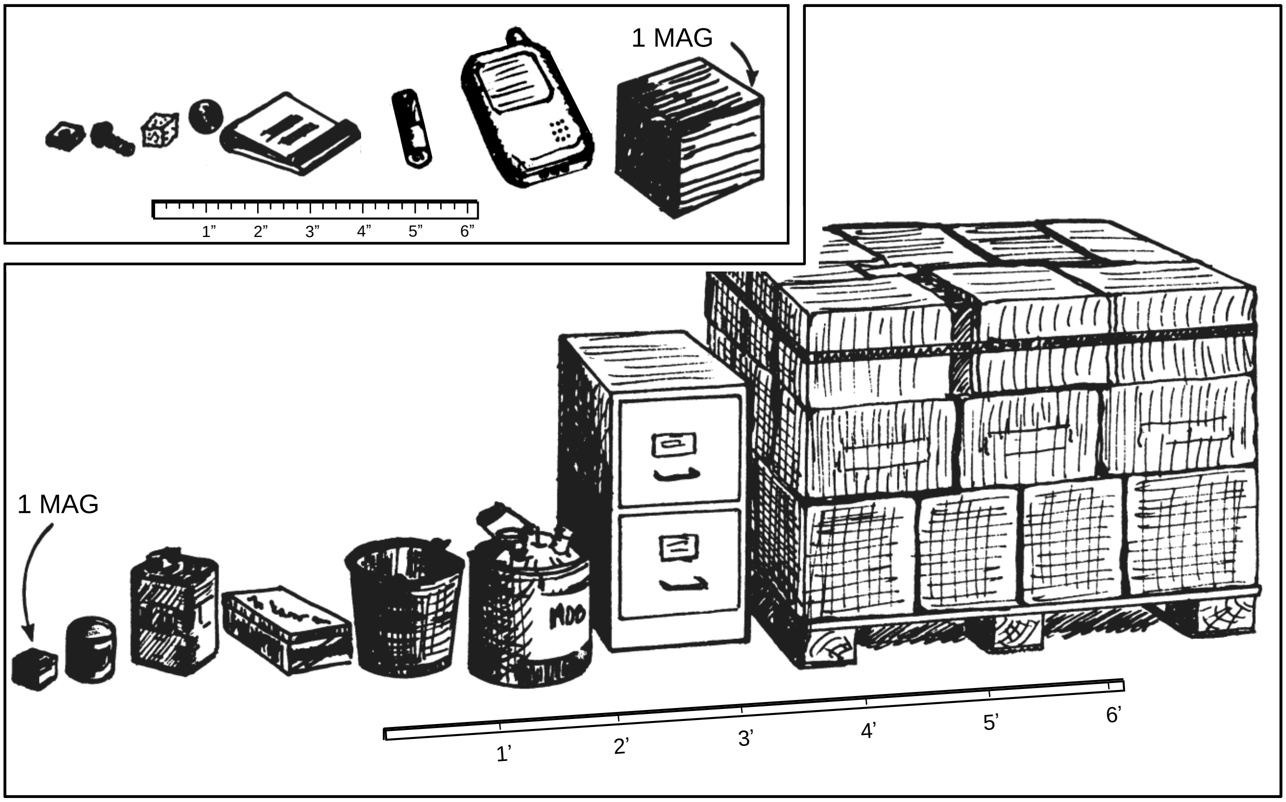
First time users of this measure of transportability must note that the mag



Curve showing relationship between size (volume) and base value. The base value is not directly proportional to the size; rather, it becomes relatively easier to transport an object per unit of its volume as it becomes larger. When measuring the volume, use outside dimensions and do not subtract for inside cavities or irregular contours.

Benchmark	Volume	Mag Count
	0.005 cubic inch	1/200
	0.1 cubic inch	1/20
	1.0 cubic inch	1/4
	10 cubic inches (approximately 150 cubic centimeters)	1 Mag
	100 cubic inches	3½
	1000 cubic inches	10
	10,000 cubic inches	25
	100,000 cubic inches	50

Figure 1. Base Value for Size-Factor A



Examples (*Items shown)	Base Value
Cotter pins 1/4" long	1/200
Washer 1/4" diam. hole	1/150
* Nut 7/16" x 3/16"	1/50
* Stove bolt 1/2" x 1/4"	1/50
* Sugar cube, small	1/16
* Glass marble	1/16
* Penny book of matches	1/6
* AAA Battery	1/4
* Cell phone	1/2
* Wood block approx. 2" x 2" x 2"	1
* Quart paint can	3
* Gallon container (incl. handle)	5
* Retail shoe box	6
* Household pail	9
Desk-type letter size file	11
* Five-gallon gasoline can	12
File drawer, filled	18
* Two-drawer file cabinet	24
4' x 4' standard wood pallet	28
Four-drawer file cabinet	30
Household bath tub	36
Pallet load (4' x 4'-low stack)	38
* Pallet load (4' x 4'-medium stack)	44
Pallet load (4' x 4'-high stack)	48

Figure 2. Examples of Size Values – Factor A.

Each “degree” is equivalent to 25% increase (or decrease) in the base value (Factor A)

DEGREE	B. BULKINESS OR DENSITY	C. SHAPE*	D. RISK OF DAMAGE	E. CONDITION
-3	---	Very flat and stackable or fully nestable* (Flat sheet of paper or metal)	---	---
-2	Very light and empty (Bulky sheet metal)	Readily stackable or nestable* (Pad of paper, soup bowl)	Not susceptible to any damage at all (Scrap iron)	---
-1	Light and bulky (Knocked-down corrugated carton)	Fairly stackable* or slightly nestable (Book, tea cup)	Susceptible to negligible or practically no damage (Compact casting)	---
0	Reasonably solid (Block of dry wood)	Basically square with some stacking qualities (Block of wood)	Slightly susceptible to some damage (Wood cut to dimensions)	Clean, firm, and stable (Block of wood)
+1	Fairly heavy and dense (Cored casting)	Long, rounded, or somewhat irregular (Sack of grain, short bar)	Susceptible to damage by crushing, breaking, scratching (Painted items)	Oily, flimsy, unstable or awkward to handle (Oily chips)
+2	Heavy and dense (Solid casting, forging)	Very long, spherical, or irregular (Desk-model telephone)	Very susceptible to some or susceptible to much damage (Computer monitor)	Covered with grease, hot, very flimsy or slippery, very awkward to handle
+3	Very heavy and dense (Die block, solid lead)	Extra long, curved, or highly irregular (Length of steel beam)	Highly susceptible to some or susceptible to very much (Glass crystal stemware)	(Tacky glued surface)
+4	---	Extra long and curved, or especially irregular (Formed tubing, wooden armchair)	Highly susceptible to very much damage (Acid in glass, explosives)	(Molten steel)

F. VALUE (or cost) of each item is not rated here because frequently it does not lead to variations in transportability within a plant, and because care in handling is already incorporated in the “risk of damage” factor. But if your situation requires a Value modifier, set your own zero and scale.

* When FLAT or NESTABLE items are commonly handled in a stack or nest, this unit stack or nest, and not the individual piece, should be used when measuring all six factors.

Figure 3. Modifying Factors and Add-On Values

count for each item may vary from operation to operation – as when a piece of sheet metal is formed, a product is painted, or a package is filled. Note also that when one item is assembled to another, its mag count ends and is included thereafter in the mag count of the assembled article.

Actually, the accuracy of this system is no closer than a range of 25 percent, so there is little reason not to round off the values. A half degree can be used for any of the modifying values if wanted, but this implies a greater precision in the modifying values than perhaps the base size value of the item itself involved.

Moreover, it is possible (though it seldom occurs) to calculate a negative mag count, which is realistically impossible. In this case, the lower limit is arbitrarily set as 25% of the A value.

In this same connection, it should be recognized that the mag count system is itself not based on scientific research or mathematical analysis. Rather, it was developed by practical materials handling and plant layout engineers, representing three different countries, to meet a specific need on a particular project. Later, it was further reasoned through and refined.

One application of mag count is explained in Figure 4. It is typical of cases where there are diversified products or materials which have to be moved – especially when significant changes in the product and, therefore, in its transportability, take place during the process. This is where mag count has its greatest use: in diversified fabrication and assembly, where no universal handling equipment and containers are employed. Mag Count fills the need for a common unit of measuring the transport characteristics of materials and of quantifying them in a realistic way.

Adaptation and Extension of Mag Count Concept

The Mag Count is based on a unit of such size that it can be conveniently held in one hand. There are many industrial situations, however, in which the physical sizes of the objects being moved are appreciably larger. Palletized materials, large tote boxes, containers, and crated goods are typical. In projects where these relatively larger loads predominate, it is often practical and convenient, when making an analysis of materials flow, to select, for Factor A (size), a larger "base unit," one closer in size to that of the objects being handled. The analyst then has a more meaningful yardstick for measuring the comparative size of the materials. Moreover, the findings can be explained to other people associated with the project in terms they can more readily understand.

Macromag

The Mag Count concept lends itself readily to such adaptations. Indeed it may be less important to have a definite base value than to grasp the very real significance of (a) the shape of the curve of Factor A (size) and (b) the impact or influence of the other factors (density or bulkiness, shape, risk of damage, and condition – the latter

One application involved a firm producing kitchen, restaurant, and hospital utensils. The fabricating shops had to be relocated. In planning the new layout, engineers found that most of the diverse products followed different routings or paths of flow. Therefore, process groupings of equipment were in order and the layout was planned on a basis of the intensity of flow between each pair of process departments.

A From-To Chart (Cross Chart) was made and postings for each transportation were entered thereon. Here is how the engineers determined the intensity of movements between the various departments.

Item: Nine-inch diameter
metal mixing bowl.

Routing:
Shear
Press
Trim

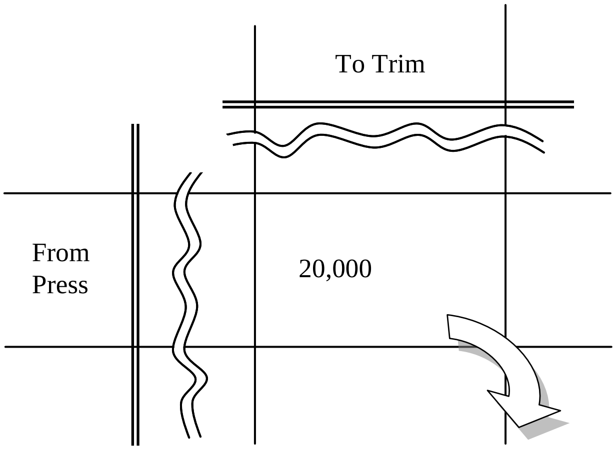
Plan-for Quantity:
10,000/year

Mag Count for move
"From Press to Trim"
A = 4 Mags
B = -2 degrees
C = -1 degree
D = 0
E = +1 degree
F = ---

Net Modifier =
-2 degrees

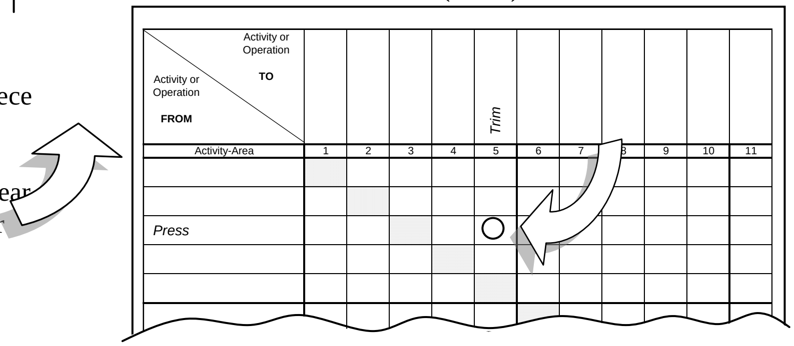
Mag Count = 4 + [¼ x 4 (-2)]
= 4 - 2 = 2 mags/piece

Intensity of movement
= 2 x 10,000 pcs./year
= 20,000 mags/year



Mag Count times plan-for quantity was entered on From-To Chart in its respective "box" as a measure of the movement between the two departments, so far as that item was involved.

From-To (Cross) Chart



The total entered amounts were then posted to a final From- To Chart, representing the total intensity of flow between all departments for all items.

Figure 4. Application of Mag Count.

including the value factor). It is logical, therefore, for planners and analysts to use their standard shop boxes or industrywide containers as base values, and then proceed to apply the other Mag Count factors. This leads to intensity-of-flow (magnitude per period of time) measurements in terms of "equivalent shop boxes per day," "equivalent palletloads per month," and the like.

A typical adaptation is to convert to a cubic meter as the base size unit. Experienced planners have used the term *Macromag* when measuring transportabilities based on this size unit.

A *Macromag* is thus equivalent to a cube of wood one meter on each side. In English units, this approximates a block 40 x 40 x 40 inches in size. Such a block approximates 44 *Mags.* If the Macromag is then called "1" on the size scale, the other factors can be applied to it just as they would when the Mag is used as the base value.

Application of Macromag to an Actual Industrial Project

The planning of a new factory layout for a manufacturer of steel office furniture called for an analysis of the proposed materials flow in the new plant. The relatively large size of many of the parts to be manufactured led to the selection of the Macromag (one cubic meter) as the base value for unit size. Size measurements of materials and containers used throughout the proposed plant were expressed in the metric units of cubic decimeters (1 cubic meter = 1000 cubic decimeters) and converted via equation to Macromags. The equation relating base value of transportability in Macromags and size in cubic decimeters has been determined empirically to be:

$$\text{Log}_{10}\ (\text{Macromags}) = -0.03553\ (\log_{10} \text{dm}^3)^2 + 0.51104\ (\log_{10} \text{dm}^3) - 1.21336$$

With this equation, a table of secondary benchmarks was established. These were plotted in the form of a curve, as shown in Figure 5.

In this project, as with most similar applications, the physical properties of the Macromag unit other than its size (i.e. density, shape, risk of damage, condition and/or value) were taken to be basically the same as the original wooden Mag block. This had numerous advantages. One cubic meter of very heavy wood with a specific gravity of 1 weighs 1 metric ton (1000 kilograms), which is the order of magnitude of many loads commonly encountered in materials handling. Thus the Macromag has both size and weight characteristics which are quite typical for industry.

In addition, use of a base unit whose other physical characteristics were the same as those of the Mag block, permitted the Table of Modifying Factors to be used unchanged.

These facts made it possible to draw up a direct-reading table (Figure 6) to help the analyst quantify each of his typical existing transport units (containers).

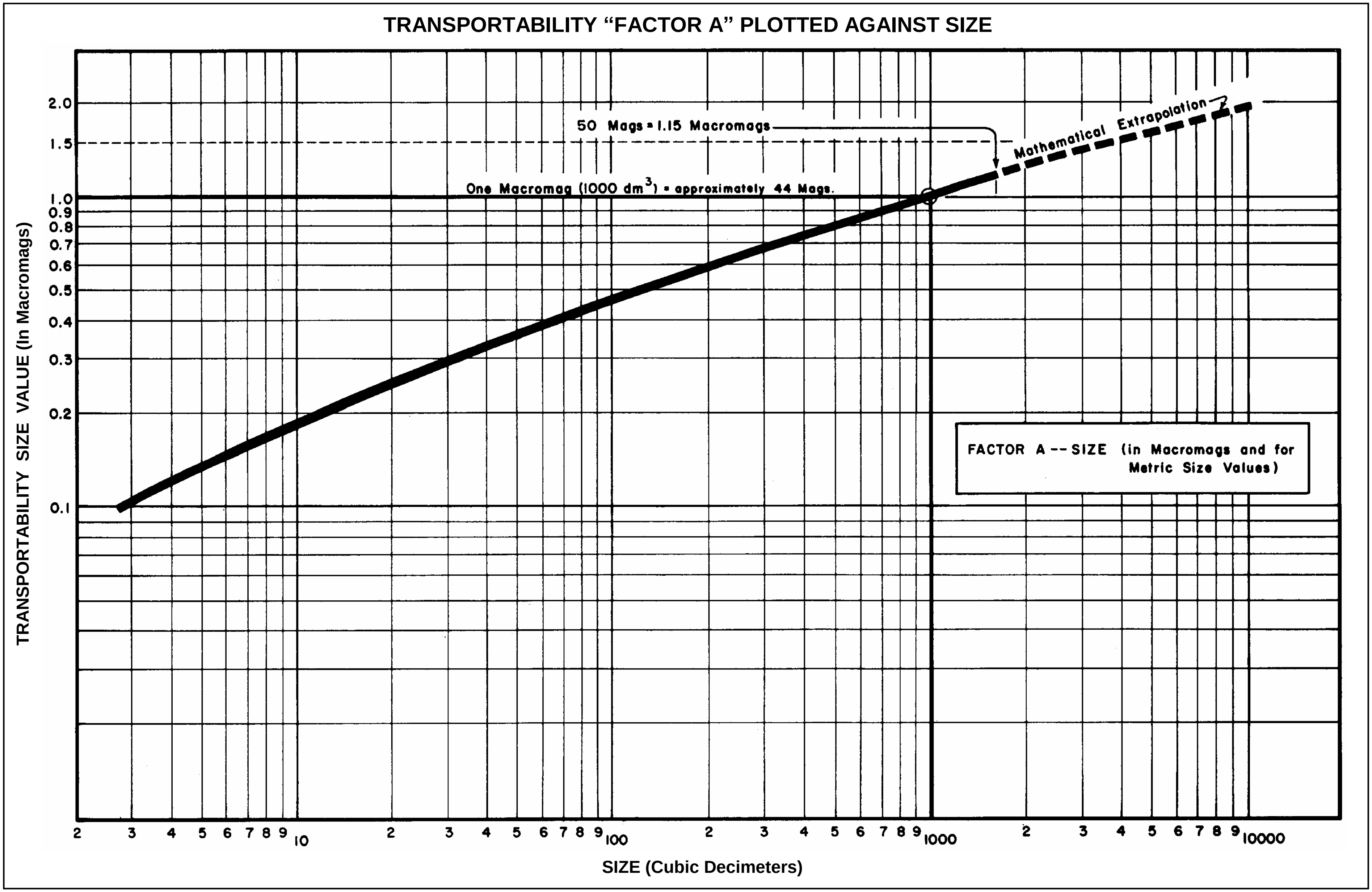
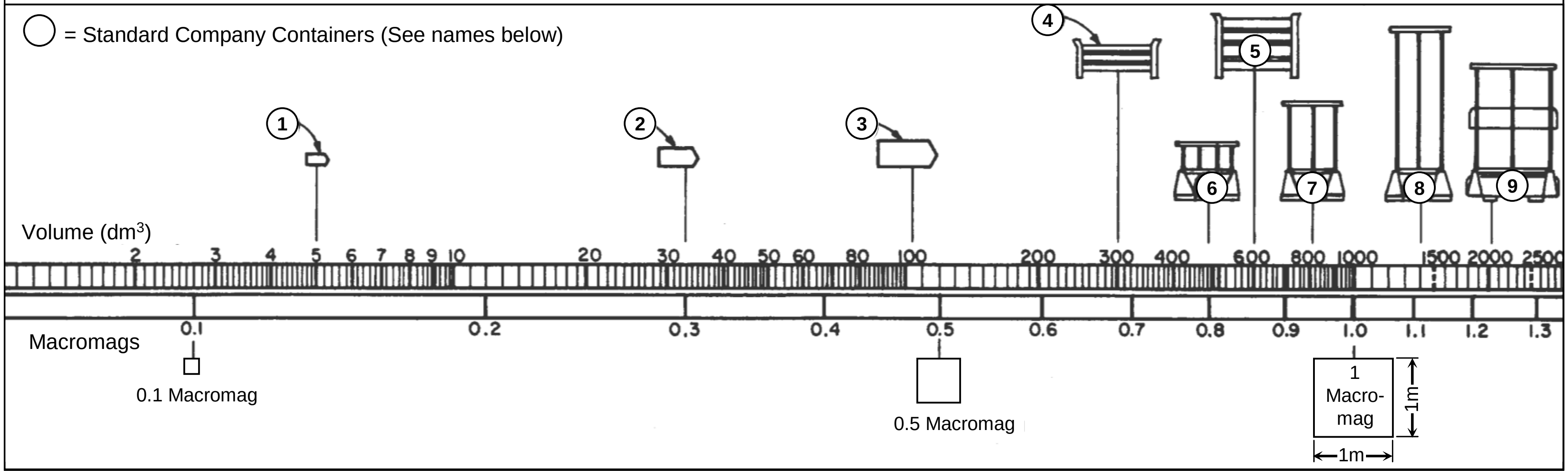


Figure 5. Transportability "Factor A" Plotted Against Size

DIRECT-READING CHART FOR SIZE FACTOR IN MACROMAG UNITS



Modifying Factors

B. Bulkiness or Density

C. Shape

D. Risk of Damage

E. Condition (including value)

The Macromag values for the Base Size Factor A, derived from the above chart, are modified to incorporate the influence of Factors B through E at left. Use the same modifiers and add-on values tabulated in Figure 3 of Appendix I.

Calculation Example

Coil of sheet steel
O.D. = 1.00m = 10.0 dm (radius = 5.0 dm)
Width = 1.25m = 12.5 dm
Volume = π x (5)^2 x 12.5 = 982 dm^3
Size Factor A = approximately 1.0 Macromag
Density Factor B = +2 degrees
Shape Factor C = +1 degree
Risk Factor D = ±0 degree
Condition Factor E = ±0 degree
Total = +3 degrees = +75 percent

Transportability Value = 1.0 x 175% = 1.75 Macromags

Further Typical Examples of Modifying Factors

B. Bulkiness or Density

-2	degrees	Empty standard desk body
-1	"	Knocked-down cartons
0	"	Wood spacers
+1	"	Pallet of Part No. 72691
+2	"	Coil of steel
+3	"	Stack of flat steel sheets

C. Shape

-3	degrees	Desk covers (stacked)
-2	"	Waste baskets (unpacked)
-1	"	Drawer front panel
0	"	Two-drawer file cabinet
+1	"	Coil of steel
+2	"	Bracing rods
+3	"	Lengths of angles & shapes
+4	"	Executive chair (unpacked)

D. Risk of Damage

-2	degrees	Scrap from presses
-1	"	Heavy steel plate
0	"	Unpainted drawer panel
+1	"	Painted drawer panel
+2	"	Plate glass inserts

E. Condition (Ignore Value)

0	Unpainted drawer panel
+1	Oily steel sheet
+2	Freshly pickled sheet
+3	Freshly glue-coated desk top

Standard Company Containers (as sketched above)

1. Small Rackable pan
2. Assembly bench stack pan
3. Large tote pan
4. Low skid box
5. High skid box
6. Low carrier frame
7. Medium carrier frame
8. Extra high carrier frame
9. Large carrier frame

Figure 6.

Visualizing Flow in Mag Count Measurement

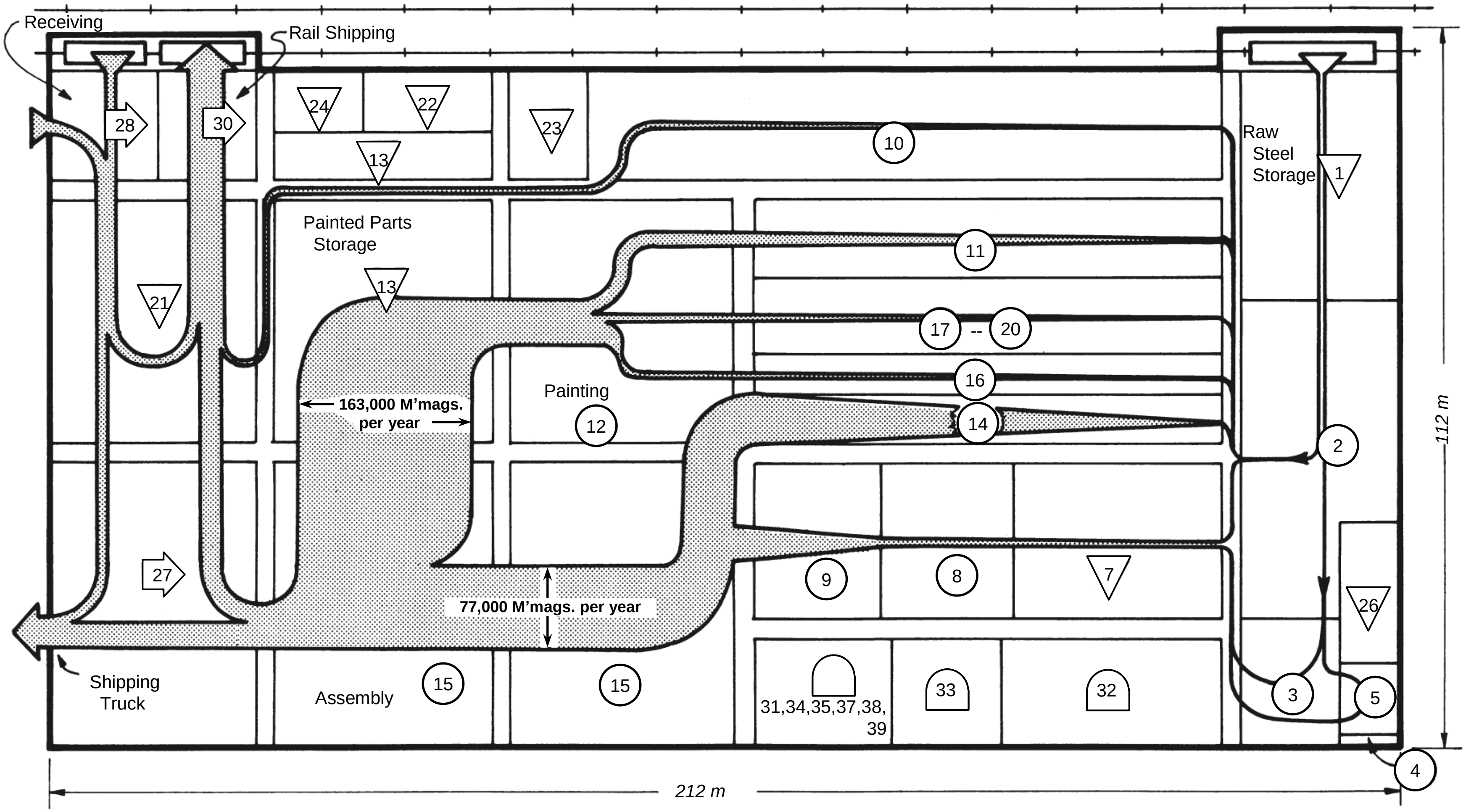
Besides helping to construct a realistic layout, the concept of Mag Count can be used in checking or explaining the flow plan. For example, when the layout planning for the office-furniture factory was completed, the materials flow in Macromags was superimposed on the proposed layout plan. The resulting diagram, shown in Figure 7, exhibits the following interesting characteristics:

1. As the sheet steel passes through the plant, its form changes progressively from a simple compact steel coil, to relatively complex formed and painted furniture components. During this process, the tonnage moved from department to department does not change markedly. However, the size, shape, risk of damage, and condition are altered as each item progresses through the production process. The progressive changes in the corresponding materials flow intensities, expressed in Macromags and shown on the diagram by the width of the flow line, reflect the real changes in the amount of transport effort required to handle the product. If tons or numbers of pieces were the basis for measuring the flow, these changes would be revealed only in a limited way, if at all.
2. Note the large increase in the major flow lines (as the parts emerge from painting) and the reduction in flow intensity when the drawers are assembled into the main desk body and the combined assembly is packed (thereby reducing the "risk of damage" factor of its transportability).

The above application of the Macromag and its measurement of "transportability," demonstrates how this unusual yardstick can provide a more realistic picture of the transport effort than calculations based on size, weight or piece count alone.

Modification for Weight-Based Items

Often a company has good data as to the weights of its materials, but because of the various sizes, shapes, and conditions of its end products, it can still benefit from mag count measurements. A rubber company that mixes its raw material but then molds or extrudes endless varieties of shapes and sizes is a typical example. It keeps its mixing records by weight. Often it is easier to weigh an item than to establish its cubic size. In such cases, the analyst should start with weight as his base value and convert via density estimates (representing an add-on or deduct for bulkiness or density) to reach a modified Mag (or Macromag) – to which Factors C, D, and E can then be applied.

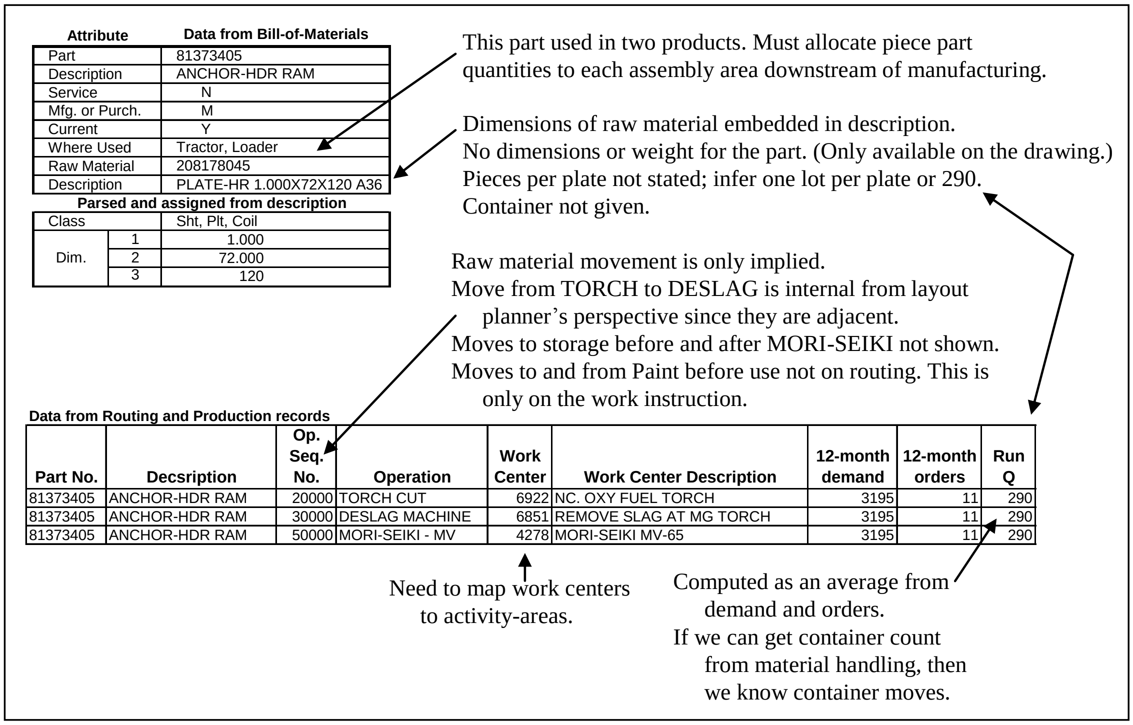


MATERIAL FLOW INTENSITY (IN MACROMAGS)
SUPERIMPOSED ON PROPOSED LAYOUT PLAN

Figure 7.

Appendix II – Data Sources for Flow Analysis

The layout planner must piece together flow-of-materials information from several sources and be ready to use judgment and rough estimates when data is limited or unavailable. Electronic records are useful for flow analysis since they can be extracted, sorted and manipulated in spreadsheets and databases such as Microsoft Excel® and Access®. See Figure 1. When extracting such data always be sure to understand their sources and precise meanings. And watch out for corruption of the data or errors during the extraction.



Attribute	Data from Bill-of-Materials
Part	81373405
Description	ANCHOR-HDR RAM
Service	N
Mfg. or Purch.	M
Current	Y
Where Used	Tractor, Loader
Raw Material	208178045
Description	PLATE-HR 1.000X72X120 A36

Parsed and assigned from description

Class		Sht, Plt, Coil
Dim.	1	1.000
	2	72.000
	3	120

This part used in two products. Must allocate piece part quantities to each assembly area downstream of manufacturing.

Dimensions of raw material embedded in description.
No dimensions or weight for the part. (Only available on the drawing.)
Pieces per plate not stated; infer one lot per plate or 290.
Container not given.

Raw material movement is only implied.
Move from TORCH to DESLAG is internal from layout planner's perspective since they are adjacent.
Moves to storage before and after MORI-SEIKI not shown.
Moves to and from Paint before use not on routing. This is only on the work instruction.

Data from Routing and Production records

Part No.	Decsription	Op. Seq. No.	Operation	Work Center	Work Center Description	12-month demand	12-month orders	Run Q
81373405	ANCHOR-HDR RAM	20000	TORCH CUT	6922	NC. OXY FUEL TORCH	3195	11	290
81373405	ANCHOR-HDR RAM	30000	DESLAG MACHINE	6851	REMOVE SLAG AT MG TORCH	3195	11	290
81373405	ANCHOR-HDR RAM	50000	MORI-SEIKI - MV	4278	MORI-SEIKI MV-65	3195	11	290

Need to map work centers to activity-areas.

Computed as an average from demand and orders.
If we can get container count from material handling, then we know container moves.

Figure 1. Electronic data from engineering and production systems. Each note above identifies one or more difficulties in converting the available data into a meaningful flow analysis. The example above shows the challenges for just one of 10,000 active piece parts moving through the layout. Each part averages 4 machining operations. Incoming moves from receiving, moves to and from storage and paint, and moves to sub- and final assembly were not available in electronic routing files.

Managing Scope

In simple batch processing such as a flour mill, flow analysis is straightforward and only a few data are needed. But in large plants making and assembling thousands of piece parts into many diverse products, flow analysis can easily become a time consuming, data processing exercise – some would say boondoggle – that gives precisely wrong flow estimates to the third decimal place. Sound estimates may be more useful with less effort.

To keep the quest for data under control, remember that in overall *plant* layout, the primary purpose of flow analysis is to establish the relative closeness desired between pairs of activity-areas. This can usually be accomplished with a sample or subset of parts or items, or by grouping hundreds or even thousands of items into a few material classes and then estimating the aggregate movement for each class. With these approaches, flow in complex facilities can be analyzed with little more effort than is needed for simple plants making only a few end items from a few parts and materials.

Later, with overall layouts in hand, flow analysis guides detail layout of stations, machines and equipment within each activity-area. Here, part-specific movement between individual operations is useful and often necessary, but not in every area. Often, the flow pattern (straight-through, U-flow, circular) and the operational sequence are obvious, without the need for part-routing and item-specific flow analysis. Even when hundreds or thousands of items pass through an area, the planner rarely needs to examine them all to arrive at an effective flow of materials and layout.

Another purpose of flow analysis and use of flow data is to plan material handling methods and to estimate the amount of material handling effort and cost associated with each plan. Here, some detail is appropriate and useful. But it need not overwhelm if the planner continues to work with groups and/or samples of all the items involved.

What to Measure

Flow analysis must always distinguish between *moves, trips* and *flow intensities*. A move is the act of moving one or more items from place to place. A trip accomplishes one or more moves. Intensity quantifies the *volume moved per period* in some meaningful way – typically taking into account mass, difficulty and risk.

In layout planning, expressing intensity in moves or trips can be problematic since both presume the material handling methods. Thus, the number of moves and trips is subject to changes in:

Movement <u>system</u> – direct point to point with empty return, route with drop-offs, route with drop-offs and returns, movement of kits or assembled orders, etc.
Handling <u>equipment</u> – fork truck, tugger, push cart, person, bridge crane, jib crane, conveyor, pipe, etc.
<u>Transport unit</u> – batch, run or lot size; loose or unitized; container type and capacity, etc.

If the handling methods are largely known and fixed, then moves and/or trips are a sound reflection of material flow and may be used to establish closeness desired. But if the project scope includes potential changes in methods, the planner should base closeness relationships on the measured flow of products and materials themselves, without presuming a method. This will make the *facilities planning* more manageable by separating relationship-setting and layout planning from the selection of handling methods. Under this approach, handling methods are considered and/or set in Section 4 of the SLP Pattern as modifying considerations. Or, they may be planned in a separate, parallel project using Systematic Handling Analysis (SHA) as described in Appendix X.

Sources of Data on Products and Materials themselves.

Chapters 3 and 4 and Appendix I described the five physical characteristics of materials that govern their transportability – size (dimensions), weight or density, shape, risk, and condition. The planner needs to consider them all when establishing flow intensities. The best source of electronic data for these characteristics are bill-of-materials records, or recipes or batch sheets in process industries.

Dimensions (length, width, height, thickness, diameter) may be in separate fields, but often must be parsed from a text description of the item. Weight – if available – will typically have its own field. However, related information on material type or gauge in metal working may also be embedded in the text description.

Finding recorded information on an item's shape (stackability, nestability, awkwardness) is rare. However, the item's name or description may occasionally be helpful in identifying problematic parts. For example, in the manufacture of machinery, terms such as "plate, angle, gusset, cover, shaft, and roller" can conjure reasonable expectations as to shape and, in some cases, size and weight). Occasionally, part numbers themselves may be significant and indicate features or where used. Or a combination of part number and name may be useful – for example, to flag painted or plated parts or others with special conditions.

Sources of Data on Quantities (Production Volume)

The production lot size or run quantity, the standard purchase quantity, and the usage per unit of finished product are typically found in the bill-of-materials. For manufactured parts, the container or contained quantity is highly useful, but unlikely to be found on the bill-of-materials. It may be available in a materials or container management "system" of some kind – perhaps only a spreadsheet maintained by the material handling department.

Aggregate part, item or material usage is typically available from historical production records or from a forecast. Some care must be taken when selecting the historical or future period to use. In highly seasonal operations, it is wise to select a period that includes the peak. If product-mix has changed, confine or cull the historical period to reflect the current mix. Of course, if the future product mix will differ radically from the past (or present), using production history is probably a mistake.

Typically the bill-of-materials records must be married to the production history or forecast. Of course, this will be a problem if bills-of-material are not yet available for the new forecasted items. If sourcing policies will change, adjust the data to include only those items that will likely be made.

Dividing aggregate usage by lot size gives the number of lots or production runs, or receipts. This may be helpful in estimating the number of times an item is moved, especially if standard containers and quantities are also available from records.

Sources of Data on Routings, Moves and Trips

Detailed part routings define a part's processing, from work-center to work-center, or operation to operation. These can usually be obtained in electronic form from the same engineering and production systems as the-bills-of-material. In practice, a lot of work will be needed to use these records for layout planning. First, the work centers in the routings must be mapped to the planner's activity-areas. Often they do not reflect the current shop floor reality – machines no longer in use, different naming, alternate routings, latest outsourcing and outside processes. Sometimes the routings themselves may be too general to help. But if they can be made useful and married to the production usage and run data above, the planner can approximate the movements of parts through the facility. An example of how to do this using Microsoft Excel® appears in Appendix III. Converting moves to flow intensities may still require factoring for characteristics and transportability if the items are diverse and dissimilar.

A better source of move data may be the warehouse, inventory management or material handling dispatching systems. See Figure 2. When present, these systems typically record pick-up and delivery transactions, including part number moved, material handler (and by inference the equipment type) and time of day. These “move ticket” records represent actual routings and moves, and may indicate the number of trips. However, they are usually limited to moves made by material handlers and only to moves made to and from controlled inventory locations. Moves by production workers and other flows of interest will still have to be estimated or determined.

Date	Time	Operator ID	Part. No.	Description	Location ID	Drop Zone ID	Qty.
6/17/2009	8:20:08	1016	700161210	HUB WA	P4-23-06	S1-04	100
6/17/2009	8:21:12	1023	6832406	CRANK-DOUBLE	P1-08-02	S2-01	120
6/17/2009	8:21:19	1019	700121551	HUB-CAM	P4-23-06	S1-04	100
6/17/2009	9:23:10	1016	208191	SPROCKET 6 TOOTH	P1-07-05	S1-06	75
6/17/2009	9:27:04	1016	527441	CAM-TENSION,ROLL,LH	P2-02-02	S1-04	157

Operator 1016 makes some moves with a forklift and some with a tug and cart. The data does not show which. The planner can only know which was used on each move by inference from the size of the part being moved and/or from Location ID.

Need to map location and zone IDs to activity-areas.

Tag/label quantity (one per container)

Figure 2. Typical information from a material handling control system. Captured from the handler scanning bar coded labels on containers and at pick-up and drop-off points.

If the plant uses a signaling system to replenish parts for production areas and if the signals are saved in an electronic file, these may help to establish moves and flow intensities. Such “kanban” systems typically also contain the standard replenishment quantity and container.

Assembly plant flow analysis

In assembly plants, bill-of-material records show which parts are consumed at each station and in what quantity per end unit. Even in the absence of electronic replenishment records or move tickets, flow intensities to assembly stations can be quickly established by applying the planned build rate to standard part usage. For purchased parts, the planner may need to infer the upstream receiving and storage routes and moves. For manufactured parts, the engineering and production systems typically will contain the information needed to determine their routes and to estimate their moves and flows. Figure 3 shows data for a line feeding flow analysis. It includes Mag Count ratings made by the manufacturing engineer.

Part No.	Part Description	Model	Station/Area Where Used	Length (inches)	Width (inches)	Height (inches)	Design Weight (lbs)	Density	Shape	Risk	Condition	Usage rate % of units	Pcs per Unit	Peak Use / Hour	Weight / Hour (lbs)	Base Mag	Final Mag	Mags / Hour
	Light duty Electric rear axle & motor	G-E	9	9	48	13	92	3	4	2	0	73%	1	25	2,283	19.8	64.4	1,597
	Heavy duty Electric rear axle & motor	T,S-E	9	9	48	13	92	3	4	2	0	2%	1	1	63	19.8	64.4	44
	Light duty Gas rear axle & motor	G-G	9	33	48	16	105	3	4	2	0	21%	1	7	750	33.5	108.8	777
	Heavy duty Gas rear axle & motor	Gas G,T,S	9	33	48	16	105	3	4	2	0	4%	1	1	143	33.5	108.8	148
	Shocks	All	9	13	3	3	4	1	1	-1	0	100%	2	68	272	3.7	4.7	318
	Light duty leaf spring	All	9	36	2	1	10	1	1	-1	0	92%	2	63	626	2.9	3.7	231
	Heavy duty leaf spring	All	9	36	2	1	12	1	1	-1	0	8%	2	5	65	2.9	3.7	20
	Front brake cable	All	9	43	0.5	0.5	3	-1	1	1	0	100%	1	34	102	1.1	1.3	45
	Rear sport brake cable	G+ 800T	9	31	0.5	0.5	3	-1	1	1	0	95%	2	65	194	0.9	1.1	71
	Rear truck brake cable	T	9	34	0.5	0.5	3	-1	1	1	0	4%	2	3	8	0.9	1.2	3
	Rear stretch brake cable	S	9	37	0.5	0.5	3	-1	1	1	0	1%	2	1	2	1.0	1.2	1
	Compensator spring assy	All	9	12	1.5	1.5	4	0	1	0	0	100%	1	34	136	1.8	2.2	75
	Pedal box package	All	9	8	8	18	16	1	1	1	0	100%	1	34	544	10.6	18.5	628
	Cherry sensor - electric	Elec	9	1	3	3	1	-1	0	2	0	74%	1	25	25	1.0	1.2	30
	Cherry sensor - gas	Gas	9	1	3	3	1	-1	0	2	0	26%	1	9	9	1.0	1.2	11
																		3,999

Figure 3. Flow data for one station of a new assembly line. This layout was for a new design and part numbers had not been assigned. Parts used at each station were listed from process sheets and engineers' knowledge. Dimensions and weights were taken from engineering design data. Mag Count ratings were applied by the manufacturing engineer using the reference tables in Appendix I. Containers had not yet been selected. If they had, or if this analysis was for an existing operation, containers per hour could be used instead of Mags. Flow data for the 13-station assembly line and 120 parts were established in less than a day.

Batch processing

In plants processing batches of bulk materials, or converting operations, the flow data is typically found in the formulas and standard yields on recipe and batch order sheets. These show quantities and proportions of ingredients and materials, outputs, and by-products. Routings may be available in electronic files. But if not, they can be obtained from flow charts of the manufacturing process. Movement of packaging materials to and from production and finished product to storage may have to be inferred.

Storage area, storage facility flow analysis

The average flow to and from storage areas can be determined from the usage rates of the stored items since an item cannot leave without having entered. In reality, the arrivals of individual items will be lumpy, but in aggregate and over time, the flow to and from such areas is more or less in balance.

Commonly missing data and oversights

A number of potentially important flows are difficult to establish from readily available information systems. Missing data and potential oversights are common with:

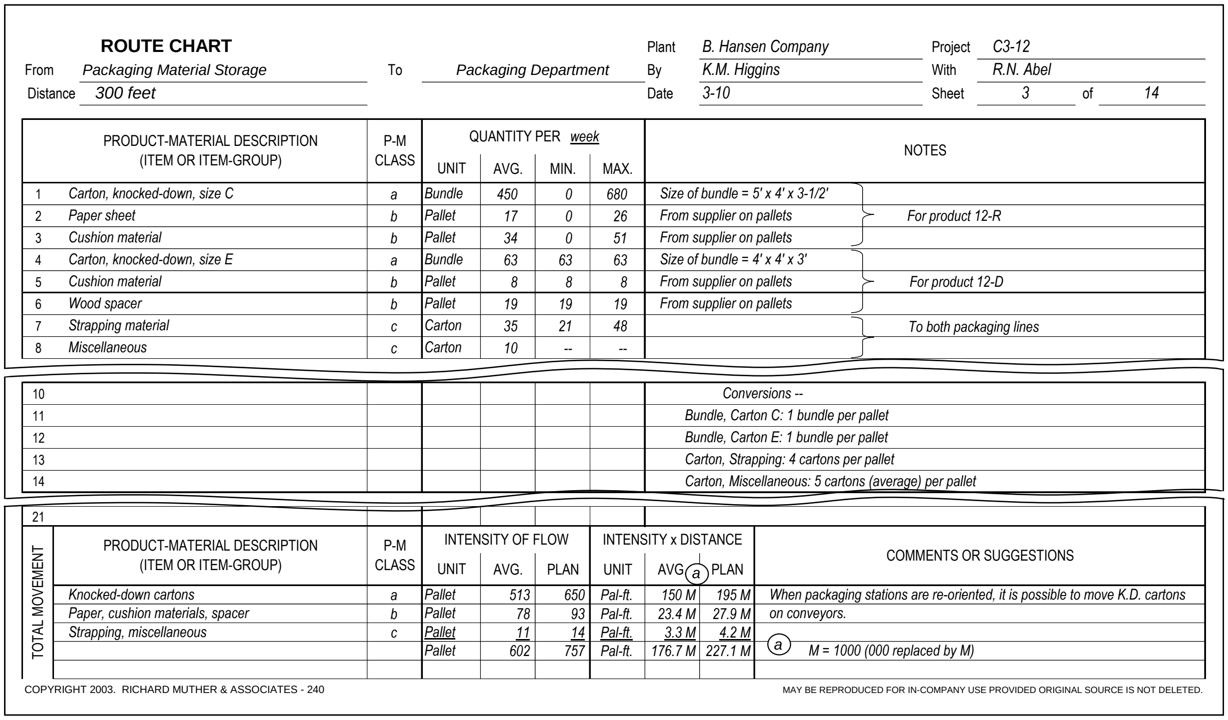
Scrap, rejects and re-work
Moves made at will by production workers
Packaging waste and trash
Empty containers and pallets, returnables
Tools and fixtures
Returns to stockroom (overages, end-of-run)

Kitted parts for assembly
Moves to and from paint and other treating operations when not listed as operations on routings
Parts moving to and returning from outside processes such as heat treat or plating

Information on these flows can often be pieced together from records and estimates of people in purchasing, material handling, and from production workers themselves.

Direct Observation of Movement

When presented to others in large dense spreadsheets, electronic data always looks impressive, authoritative and presumably correct. But the wise planner will always spot check and validate the flow estimates before using or distributing them to others. Always check the largest flows and the routes with highest intensity. Also check flows to and from key activity-areas and be sure that you can explain their degree of balance or imbalance. Walk through your estimates with knowledgeable observers in production or materials departments and make sure they concur with your assumptions and any calculations used. Make some direct observations on the plant floor, assuming this is practical and available. Two proven tools for data gathering on the plant floor are the route chart and the flow-in/flow-out chart. These are shown in Figures 4 and 5.



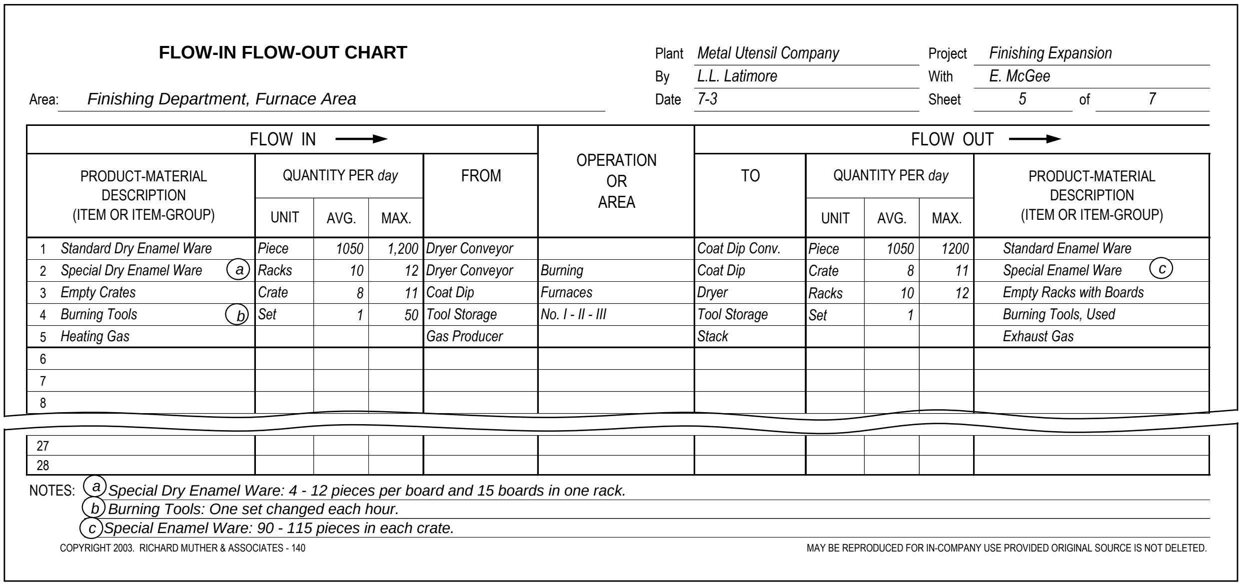
ROUTE CHART

From *Packaging Material Storage* To *Packaging Department*
Distance *300 feet*
Plant *B. Hansen Company*
By *K.M. Higgins*
Date *3-10*
Project *C3-12*
With *R.N. Abel*
Sheet *3* of *14*

	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)	P-M CLASS	QUANTITY PER *week*				NOTES	
			UNIT	AVG.	MIN.	MAX.		
1	*Carton, knocked-down, size C*	*a*	*Bundle*	*450*	*0*	*680*	*Size of bundle = 5' x 4' x 3-1/2'*	
2	*Paper sheet*	*b*	*Pallet*	*17*	*0*	*26*	*From supplier on pallets*	*For product 12-R*
3	*Cushion material*	*b*	*Pallet*	*34*	*0*	*51*	*From supplier on pallets*	
4	*Carton, knocked-down, size E*	*a*	*Bundle*	*63*	*63*	*63*	*Size of bundle = 4' x 4' x 3'*	
5	*Cushion material*	*b*	*Pallet*	*8*	*8*	*8*	*From supplier on pallets*	*For product 12-D*
6	*Wood spacer*	*b*	*Pallet*	*19*	*19*	*19*	*From supplier on pallets*	
7	*Strapping material*	*c*	*Carton*	*35*	*21*	*48*		*To both packaging lines*
8	*Miscellaneous*	*c*	*Carton*	*10*	*--*	*--*		
10							*Conversions --*	
11							*Bundle, Carton C: 1 bundle per pallet*	
12							*Bundle, Carton E: 1 bundle per pallet*	
13							*Carton, Strapping: 4 cartons per pallet*	
14							*Carton, Miscellaneous: 5 cartons (average) per pallet*	
21								

TOTAL MOVEMENT	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)	P-M CLASS	INTENSITY OF FLOW			INTENSITY x DISTANCE			COMMENTS OR SUGGESTIONS
			UNIT	AVG.	PLAN	UNIT	AVG ⓐ	PLAN	
	Knocked-down cartons	*a*	*Pallet*	*513*	*650*	*Pal-ft.*	*150 M*	*195 M*	*When packaging stations are re-oriented, it is possible to move K.D. cartons*
	Paper, cushion materials, spacer	*b*	*Pallet*	*78*	*93*	*Pal-ft.*	*23.4 M*	*27.9 M*	*on conveyors.*
	Strapping, miscellaneous	*c*	*Pallet*	*11*	*14*	*Pal-ft.*	*3.3 M*	*4.2 M*	
			Pallet	*602*	*757*	*Pal-ft.*	*176.7 M*	*227.1 M*	ⓐ *M = 1000 (000 replaced by M)*

Figure 4. The Route Chart is used to analyze the flow of materials between two areas. The different products, materials, or item-groups are listed; their product-or-material class is noted; and the necessary information is entered. In this example, the items are divided into three product-material classes each consisting of items which are similar. In the lower part of the chart the total movements for each product-material class is summarized. The intensity of flow is measured in pallets and the intensity times distance in pallet-feet. Even though the knocked-down cartons are the main item in the example, the other items (cushion materials, wooden spacers, etc.) cannot be overlooked; all movements have to be considered to find a practical solution.



FLOW-IN FLOW-OUT CHART

Plant *Metal Utensil Company* Project *Finishing Expansion*
By *L.L. Latimore* With *E. McGee*
Date *7-3* Sheet *5* of *7*

Area: *Finishing Department, Furnace Area*

	FLOW IN →					OPERATION OR AREA	FLOW OUT →				
	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)	QUANTITY PER *day*			FROM		TO	QUANTITY PER *day*			PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)
		UNIT	AVG.	MAX.				UNIT	AVG.	MAX.	
1	*Standard Dry Enamel Ware*	*Piece*	*1050*	*1,200*	*Dryer Conveyor*		*Coat Dip Conv.*	*Piece*	*1050*	*1200*	*Standard Enamel Ware*
2	*Special Dry Enamel Ware* ⓐ	*Racks*	*10*	*12*	*Dryer Conveyor*	*Burning*	*Coat Dip*	*Crate*	*8*	*11*	*Special Enamel Ware* ⓒ
3	*Empty Crates*	*Crate*	*8*	*11*	*Coat Dip*	*Furnaces*	*Dryer*	*Racks*	*10*	*12*	*Empty Racks with Boards*
4	*Burning Tools* ⓑ	*Set*	*1*	*50*	*Tool Storage*	*No. I - II - III*	*Tool Storage*	*Set*	*1*		*Burning Tools, Used*
5	*Heating Gas*				*Gas Producer*		*Stack*				*Exhaust Gas*
6											
7											
8											
27											
28											

NOTES: ⓐ *Special Dry Enamel Ware: 4 - 12 pieces per board and 15 boards in one rack.*
ⓑ *Burning Tools: One set changed each hour.*
ⓒ *Special Enamel Ware: 90 - 115 pieces in each crate.*

Figure 5. The Flow-in Flow-out Chart shows the movements in and out of one area. On the left side are listed all items which go into the area. On the right side, all items leaving the area. The chart shows the quantity and condition of material moving in and out also. Further, it indicates the change that takes place in the condition of each item (notice how dry enamel ware changes to enamel ware). Filling out such a chart helps avoid overlooking the insignificant movements such as burning tools. If not provided for, these seemingly unimportant materials can cause a poor layout.

Appendix III – Using Microsoft Excel ® for Production Flow Analysis

Production Flow Analysis (PFA) refers to the analysis of piece-part routings in manufacturing plants. The basic inputs to PFA are part routings or operational sequences and processing times, and a volume forecast. The analyst looks for parts with common routings – using the same machines, work centers or operations. The premise is that such parts could be made more quickly with less travel in manufacturing cells. PFA also identifies which machines to put into each cell and which will need to be duplicated for multiple cells. Typical information sources are: the routing file from the engineering or production information system, a forecast, and a master list of work centers or machines.

The layout planner can use the techniques of Production Flow Analysis and its source data to quantify the material flow and thus the closeness desired between pairs of activity areas. This Appendix shows an example using Microsoft Excel. The general approach is to use electronic routing data to determine the number of jobs and pieces moving between pairs of work centers, machines or operations. Any relevant moves not contained in the routings must be added. In our example these are the moves from storage to first operation and from last operation to finished goods. Such additions also need to be made when parts are sent outside for processing and then return, or when inspections are not included in the routings. Multiple operations at the same work center must be removed since these are internal. Once the quantities moving between pairs of work centers have been established, these are mapped to layout planning activity-areas and then aggregated to represent total flow between pairs of activity-areas. When total flows are ranked in descending order, the planner has identified the relative closeness desired based on flow of materials.

The data available in management information systems is never in the form needed for layout planning and production flow analysis. Tables need to be combined, quantities summed, unique lists created for parts and work centers… These and similar tasks lend themselves to database tools such as Microsoft Access, especially when the data sets are large – say 5,000 to10,000 parts made on more than 100 machines, with an average of 5 routing steps each. However, we have chosen to show the use of Excel since it is more familiar to most layout planners and more widely available. To use Excel, the planner will need to learn the functions described in Figure 1.

Function	Uses in the Example
VLOOKUP (function)	Combines data from two tables into one. Used for combining routing and forecast data; associating activity areas with work centers. NOTE: this can also be used for comparing two tables to identify unmatched rows (e.g., missing part numbers) when validating data.
CONCATENATE (function)	Combines data in two columns into one column. Used to create one field that has both the from and to work centers.
Advanced Filter (pull down on toolbar under “Data”, then “Filter”, then “Advanced Filter”)	Creates a unique list of the concatenated work center pairs.
SUMIF (function)	Sums data based on a label which appears multiple times in a table. Used to sum the number of work orders and units for each work center pair.

Figure 1. Because electronic routing data takes different forms, every material flow analysis is unique. However, these Excel functions are consistently useful. For those not familiar with them, we recommend staring with Excel’s Help functions or a basic primer on Excel.

Case Example – Machined Parts

In our example, the plant makes 2875 unique parts using 134 routing work centers – mostly machine tools. Three tables of data were requested from the Information Systems Department and provided as input:

1. Routing Table – part number, description, and the sequence of work centers used, in columns left to right, (WCTR 1, WCTR 2, WCTR 3…) as needed to make the part. If storages before and after production do not appear as work centers, a storage “work center” should be added to the table, along with any other physical operations not called out by number. These will be needed during the flow analysis.
2. Forecast Table – part number, description, number of orders, accumulated quantity. The orders are production work orders, or “number of times run”; the accumulated quantity is the total number of pieces across all the orders or runs. (The basis in our example is the next 6 months.)
3. Work Center (WCTR) Master – work center number and description, to which the layout planner has added a third column to indicate the activity-area in which each work center resides. (This is an important discipline even without flow analysis since it provides and explicit definition of what is in the activity-area)

The manipulation of these tables is illustrated in Figure 2 and explained step-by-step in the sections below. This procedure and example are representative of the work needed to make electronic routing and forecast data useful for material flow analysis. Since we are interested in flow rather than capacity, the processing times at each operation are omitted from the example. These could of course be kept or added to compute the number of machines required.

Step 1. Combine Routings and Forecast

First we will use the VLOOKUP function to add each part’s orders and quantities to its routing. While doing this, the planner should also validate that significant numbers of part numbers aren’t missing orders, quantities or routings. We will call the resulting combined data the Quantified Routings Table.

a) Always create a copy of the data as backup before proceeding.
b) In the Routing Table, insert a column before the first work center column and label it to match the column of interest in the Forecast Table. In our example, two columns are needed in the Routing Table for NBR OF ORDERS and ACCUM QTY.
c) In the first cell of the newly inserted column(s), use the VLOOKUP function to find the values of interest in the Forecast Table and copy them into the Routing Table. In our example, we copy two columns of forecast data for all 2875 parts (cells $A$2:$D$2876, starting in the 3rd column).
d) Review and validate the data.
e) Select and copy the cells just filled with VLOOKUP. Then use “Paste Special-Values” to paste the copied values on top of the formulas in the cells just filled. (The VLOOKUP formulas are no longer needed and the workbook will slow down if you leave them in.)

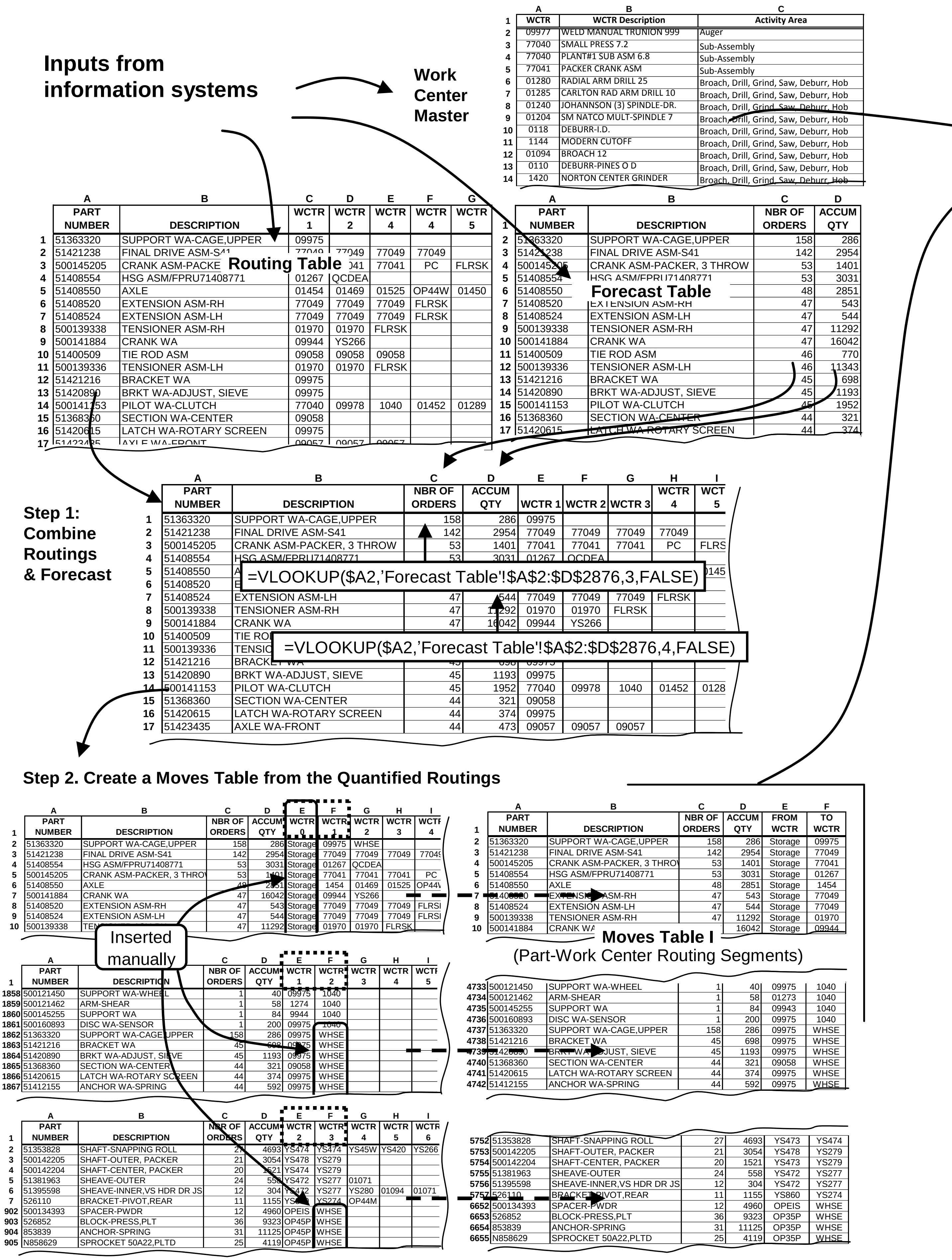
The Routings Table has now become the Quantified Routings Table.

Step 2. Create a Moves Table from the Quantified Routings

Now we must extract each individual work center-to-work center move from the Quantified Routings Table. To do this we first create a Moves Table with 6 columns: part number, description, NBR ORDERS, ACCUM QTY, FROM WCTR, and TO WCTR. Each part will appear as many times as it is moved between pairs of work centers. Thus, a part that is made in three operations – 1, 2 and 3 – will appear twice as it moves from 1 to 2, and from 2 to 3. Additionally, we need to create work centers for Storage before and warehouse (WHSE) after production. Otherwise we will not capture these moves in our flow analysis or relationships.

We will add the initial move from Storage to first operation for all the parts. Then working from left to right (WCTR column by WCTR column) across the Quantified Routings Table, we will use an iterative procedure to sort, add the last move to WHSE, copy and then paste into the Moves Table. The number of iterations is determined by the part(s) with the most operations since each has a column.

a) Always create a copy of the data as backup before proceeding.
b) In the Quantified Routings Table, insert a column for WCTR 0 before the existing column for WCTR 1. Populate the cells in this new column with the activity-area name (or number) that represents the storage or issuing point for raw materials or parts. In our example this area is called “Storage.” This creates the inbound move that is not found in the routings.
c) Create a new worksheet called Moves Table.
d) Copy the columns that contain the part number, description, the quantified movement, the newly inserted raw material/part storage activity area, and work center 1, and then paste them into the Moves Table. This action has created a first move for every part.
e) In the Quantified Routings Table, delete the column that was added for WCTR 0 (activity area for raw materials or parts). It is no longer needed since all moves from it have been captured in the Moves Table.
f) Now, sort Quantified Routings Table by the second work center column, descending. This drops parts in which the cell is blank in this column to the bottom of the list. These are parts whose routing is complete after the first operation.
g) Populate the blank cells with the activity area name that takes finished goods. In our example this is called WHSE. This creates a move to finished goods that is not found in the routings.
h) Copy the columns that contain the part number, description, the quantified movement, work center 1, and work center 2. Then paste them into the Moves Table below the first paste.
i) In the Quantified Routings Table, delete the rows where the finished goods activity area was added. These rows are no longer needed since all of these parts’ moves have been captured in the Moves Table.
j) In the Quantified Routings Table, also delete the column for work center 1. It is no longer needed since all moves to and from each part’s first operation have been captured.
k) Now sort the Quantified Routings Table by the third work center column, descending – again dropping blank cells in this column to the bottom of the list.
l) Populate the blank cells in this column with the activity area name that takes finished goods (again this is WHSE in our example).
m) Copy the columns that contain the part number, description, the quantified movement, work center 2, and work center 3. Then paste them into the Moves Table at the bottom.



	A	B	C
1	WCTR	WCTR Description	Activity Area
2	09977	WELD MANUAL TRUNION 999	Auger
3	77040	SMALL PRESS 7.2	Sub-Assembly
4	77040	PLANT#1 SUB ASM 6.8	Sub-Assembly
5	77041	PACKER CRANK ASM	Sub-Assembly
6	01280	RADIAL ARM DRILL 25	Broach, Drill, Grind, Saw, Deburr, Hob
7	01285	CARLTON RAD ARM DRILL 10	Broach, Drill, Grind, Saw, Deburr, Hob
8	01240	JOHANNSON (3) SPINDLE-DR.	Broach, Drill, Grind, Saw, Deburr, Hob
9	01204	SM NATCO MULT-SPINDLE 7	Broach, Drill, Grind, Saw, Deburr, Hob
10	0118	DEBURR-I.D.	Broach, Drill, Grind, Saw, Deburr, Hob
11	1144	MODERN CUTOFF	Broach, Drill, Grind, Saw, Deburr, Hob
12	01094	BROACH 12	Broach, Drill, Grind, Saw, Deburr, Hob
13	0110	DEBURR-PINES O D	Broach, Drill, Grind, Saw, Deburr, Hob
14	1420	NORTON CENTER GRINDER	Broach, Drill, Grind, Saw, Deburr, Hob

	A	B	C	D	E	F	G
	PART NUMBER	DESCRIPTION	WCTR 1	WCTR 2	WCTR 4	WCTR 4	WCTR 5
1	51363320	SUPPORT WA-CAGE,UPPER	09975				
2	51421238	FINAL DRIVE ASM-S41	77049	77049	77049	77049	
3	500145205	CRANK ASM-PACKE	[illegible]	041	77041	PC	FLRSK
4	51408554	HSG ASM/FPRU71408771	01267	QCDEA			
5	51408550	AXLE	01454	01469	01525	OP44W	01450
6	51408520	EXTENSION ASM-RH	77049	77049	77049	FLRSK	
7	51408524	EXTENSION ASM-LH	77049	77049	77049	FLRSK	
8	500139338	TENSIONER ASM-RH	01970	01970	FLRSK		
9	500141884	CRANK WA	09944	YS266			
10	51400509	TIE ROD ASM	09058	09058	09058		
11	500139336	TENSIONER ASM-LH	01970	01970	FLRSK		
12	51421216	BRACKET WA	09975				
13	51420890	BRKT WA-ADJUST, SIEVE	09975				
14	500141153	PILOT WA-CLUTCH	77040	09978	1040	01452	01289
15	51368360	SECTION WA-CENTER	09058				
16	51420615	LATCH WA-ROTARY SCREEN	09975				
17	51423435	AXLE WA-FRONT	09057	09057	09057		

	A	B	C	D
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY
2	51363320	SUPPORT WA-CAGE,UPPER	158	286
3	51421238	FINAL DRIVE ASM-S41	142	2954
4	500145205	CRANK ASM-PACKER, 3 THROW	53	1401
5	51408554	HSG ASM/FPRU71408771	53	3031
6	51408550	[illegible]	48	2851
7	51408520	EXTENSION ASM-RH	47	543
8	51408524	EXTENSION ASM-LH	47	544
9	500139338	TENSIONER ASM-RH	47	11292
10	500141884	CRANK WA	47	16042
11	51400509	TIE ROD ASM	46	770
12	500139336	TENSIONER ASM-LH	46	11343
13	51421216	BRACKET WA	45	698
14	51420890	BRKT WA-ADJUST, SIEVE	45	1193
15	500141153	PILOT WA-CLUTCH	45	1952
16	51368360	SECTION WA-CENTER	44	321
17	51420615	LATCH WA-ROTARY SCREEN	44	374

	A	B	C	D	E	F	G	H	I
	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	WCTR 1	WCTR 2	WCTR 3	WCTR 4	WCT 5
1	51363320	SUPPORT WA-CAGE,UPPER	158	286	09975				
2	51421238	FINAL DRIVE ASM-S41	142	2954	77049	77049	77049	77049	
3	500145205	CRANK ASM-PACKER, 3 THROW	53	1401	77041	77041	77041	PC	FLRS
4	51408554	HSG ASM/FPRU71408771	53	3031	01267	QCDEA			
5	51408550	A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0145
6	51408520	E	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	51408524	EXTENSION ASM-LH	47	544	77049	77049	77049	FLRSK	
8	500139338	TENSIONER ASM-RH	47	11292	01970	01970	FLRSK		
9	500141884	CRANK WA	47	16042	09944	YS266			
10	51400509	TIE ROI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	500139336	TENSIC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12	51421216	BRACKET WA	45	698	09975				
13	51420890	BRKT WA-ADJUST, SIEVE	45	1193	09975				
14	500141153	PILOT WA-CLUTCH	45	1952	77040	09978	1040	01452	0128
15	51368360	SECTION WA-CENTER	44	321	09058				
16	51420615	LATCH WA-ROTARY SCREEN	44	374	09975				
17	51423435	AXLE WA-FRONT	44	473	09057	09057	09057		

	A	B	C	D	E	F	G	H	I
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	WCTR 0	WCTR 1	WCTR 2	WCTR 3	WCTF 4
2	51363320	SUPPORT WA-CAGE,UPPER	158	286	Storage	09975	WHSE		
3	51421238	FINAL DRIVE ASM-S41	142	2954	Storage	77049	77049	77049	7704
4	51408554	HSG ASM/FPRU71408771	53	3031	Storage	01267	QCDEA		
5	500145205	CRANK ASM-PACKER, 3 THRO	53	1401	Storage	77041	77041	77041	PC
6	51408550	AXLE	48	2851	Storage	1454	01469	01525	OP44
7	500141884	CRANK WA	47	16042	Storage	09944	YS266		
8	51408520	EXTENSION ASM-RH	47	543	Storage	77049	77049	77049	FLRS
9	51408524	EXTENSION ASM-LH	47	544	Storage	77049	77049	77049	FLRS
10	500139338	TEN	47	11292	Storage	01970	01970	FLRSK	

	A	B	C	D	E	F	G	H	I
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	WCTR 1	WCTR 2	WCTR 3	WCTR 4	WCTF 5
1858	500121450	SUPPORT WA-WHEEL	1	40	09975	1040			
1859	500121462	ARM-SHEAR	1	58	1274	1040			
1860	500145255	SUPPORT WA	1	84	9944	1040			
1861	500160893	DISC WA-SENSOR	1	200	09975	1040			
1862	51363320	SUPPORT WA-CAGE,UPPER	158	286	09975	WHSE			
1863	51421216	BRACKET WA	45	698	09975	WHSE			
1864	51420890	BRKT WA-ADJUST, SIEVE	45	1193	09975	WHSE			
1865	51368360	SECTION WA-CENTER	44	321	09058	WHSE			
1866	51420615	LATCH WA-ROTARY SCREEN	44	374	09975	WHSE			
1867	51412155	ANCHOR WA-SPRING	44	592	09975	WHSE			

	A	B	C	D	E	F	G	H	I
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	WCTR 2	WCTR 3	WCTR 4	WCTR 5	WCTR 6
2	51353828	SHAFT-SNAPPING ROLL	27	4693	YS474	YS474	YS45W	YS420	YS266
3	500142205	SHAFT-OUTER, PACKER	21	3054	YS478	YS279			
4	500142204	SHAFT-CENTER, PACKER	20	1521	YS474	YS279			
5	51381963	SHEAVE-OUTER	24	558	YS472	YS277	01071		
6	51395598	SHEAVE-INNER,VS HDR DR JS	12	304	YS472	YS277	YS280	01094	01071
7	526110	BRACKET-PIVOT,REAR	11	1155	[illegible]	YS274	OP44M		
902	500134393	SPACER-PWDR	12	4960	OPEIS	WHSE			
903	526852	BLOCK-PRESS,PLT	36	9323	OP45P	WHSE			
904	853839	ANCHOR-SPRING	31	11125	OP45P	WHSE			
905	N858629	SPROCKET 50A22,PLTD	25	4119	OP45P	WHSE			

	A	B	C	D	E	F
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	FROM WCTR	TO WCTR
2	51363320	SUPPORT WA-CAGE,UPPER	158	286	Storage	09975
3	51421238	FINAL DRIVE ASM-S41	142	2954	Storage	77049
4	500145205	CRANK ASM-PACKER, 3 THRO	53	1401	Storage	77041
5	51408554	HSG ASM/FPRU71408771	53	3031	Storage	01267
6	51408550	AXLE	48	2851	Storage	1454
7	51408520	EXTENSION ASM-RH	47	543	Storage	77049
8	51408524	EXTENSION ASM-LH	47	544	Storage	77049
9	500139338	TENSIONER ASM-RH	47	11292	Storage	01970
10	500141884	CRANK WA	[illegible]	16042	Storage	09944
4733	500121450	SUPPORT WA-WHEEL	1	40	09975	1040
4734	500121462	ARM-SHEAR	1	58	01273	1040
4735	500145255	SUPPORT WA	1	84	09943	1040
4736	500160893	DISC WA-SENSOR	1	200	09975	1040
4737	51363320	SUPPORT WA-CAGE,UPPER	158	286	09975	WHSE
4738	51421216	BRACKET WA	45	698	09975	WHSE
4739	51420890	BRKT WA-ADJUST, SIEVE	45	1193	09975	WHSE
4740	51368360	SECTION WA-CENTER	44	321	09058	WHSE
4741	51420615	LATCH WA-ROTARY SCREEN	44	374	09975	WHSE
4742	51412155	ANCHOR WA-SPRING	44	592	09975	WHSE
5752	51353828	SHAFT-SNAPPING ROLL	27	4693	YS473	YS474
5753	500142205	SHAFT-OUTER, PACKER	21	3054	YS478	YS279
5754	500142204	SHAFT-CENTER, PACKER	20	1521	YS473	YS279
5755	51381963	SHEAVE-OUTER	24	558	YS472	YS277
5756	51395598	SHEAVE-INNER,VS HDR DR JS	12	304	YS472	YS277
5757	526110	BRACKET-PIVOT,REAR	11	1155	YS860	YS274
6652	500134393	SPACER-PWDR	12	4960	OPEIS	WHSE
6653	526852	BLOCK-PRESS,PLT	36	9323	OP35P	WHSE
6654	853839	ANCHOR-SPRING	31	11125	OP35P	WHSE
6655	N858629	SPROCKET 50A22,PLTD	25	4119	OP35P	WHSE

Figure 2. Example of material flow analysis using electronic routing data

Step 3. Add Activity-Areas Names to Move Table Work Centers

Moves Table II (Part-Activity Area Routing Segments)

	A	B	C	D	E	F	G	H
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	FROM ACT AREA	FROM WCTR	TO ACT AREA	TO WCTR
2	51363320	SUPPORT WA-CAGE,UPPER	158	286	Storage	Storage	Weld Stations	09975
3	51421238	FINAL DRIVE ASM-S41	142	2954	Storage	Storage	Axle	77049
4	500145205	CRANK ASM-PACKER, 3 THROW	53	1401	Storage	Storage	Sub-Assembly	77041
5	51408554	HSG ASM/FPRU71408771	53	3031	Storage	Storage	Disc	01267
6	51408550	AXLE	48	2851	Storage	Storage	lathes	1454
7	51408520	EXTENSION ASM-RH	47	543	Storage	Storage	Axle	77049
8	51408524	EXTENSI						77049
9	500139338	TENSIONER ASM-RH	47	11292	Storage	Storage	Wrapper Cell	01970
10	500141884	CRANK WA	47	16042	Storage	Storage	Robot Weld	09944

=VLOOKUP(F2,'Work Center Master'!$A$2:$C$135,3,FALSE)

Moves Table III (Part-Activity Area Routing Segments, Internal Moves Deleted)

	A	B	C	D	E	F	G	H	I
1	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	FROM ACT AREA	FROM WCTR	TO ACT AREA	TO WCTR	
1380	500144630	WRAPPER ASM-W/AUTO LUBE	28	708	Wrapper Ce	01970	Wrapper Cell	01990	delete
1381	500144632	WRAPPER ASM-W/AUTO LUBE	17	380	Wrapper Ce	01970	Wrapper Cell	01990	delete
1382	500124191	WRAPPER ASM-CABLE	29	1438	Wrapper Ce	01970	Wrapper Cell	01970	delete
1383	525831	SHAFT-ROLL DRIVE, LWR	5	363	Broach, Drill	01320	Broach, Drill, G	1420	delete
1384	525828	SHAFT	5	319	Broach, Drill	01320	Broach, Drill, G	1420	delete
1385	51363320	SUPPORT WA-CAGE,UPPER	158	286	Storage	Storage	Weld Stations	09975	
1386	51421238	FINAL DRIVE ASM-S41	142	2954	Storage	Storage	Axle	77049	
1387	500145205	CRANK ASM-PACKER, 3 THROW	53	1401	Storage	Storage	Sub-Assembly	77041	
1388	51408554	HSG ASM/FPRU51408551	53	3031	Storage	Storage	Disc	01267	
1389	51408550	AXLE	48	2851	Storage	Storage			

=IF(E2=G2,"delete","")

Step 4. Identify Unique Activity Pairs

Moves Table IV (Concatenated Activity Pair-Routing Segments)

	A	B	C	D	E	F	G	H	I	J	K
1	Concatenated Act Area Pairs	1st Act Area	2nd Act Area	PART NUMBER	DESCRIPTION	NBR OF ORDERS	ACCUM QTY	FROM ACT AREA	FROM WCTR	TO ACT AREA	TO WCTR
2	Baler - gearbox	Baler	gearbox	500144556	SIDE WA-PLNGR, LH	28	802	Baler	09977	gearbox	09274
3	Baler - gearbox	Baler	gearbox	500144555	SIDE WA-PLNGR, RH	28	803	Baler	09977	gearbox	09274
4	Baler - gearbox	Baler	gearbox	500144552	SIDE WA-RH, PLNGR B9K	27	708	Baler	09977	gearbox	09274
5	Baler - gearbox			500144551	SIDE WA-LH, PLNGR B9K	26	708	Baler	09977	gearbox	09274
6	Baler - gearbox			500144802	SIDE WA-RH,PLNGR	16	360	Baler	09977	gearbox	09274
7	Baler - gearbox	Baler	gearbox	500144801	SIDE WA-LH,PLNGR	16	360	Baler	09977	gearbox	09274
8	Baler - gearbox	Baler	gearbox	500144823	SIDE WA-LH,PLNGR B9P1	4	96	Baler	09977	gearbox	09274
9	Baler - gearbox	Baler	gearbox		RH,PLNGR B9P1	4	96	Baler	09977	gearbox	09274
10	Baler - shaft/roller cell	Baler	shaft/roller		A-LT	20	770	Baler	09977	shaft/roller cell	9041
11	Baler - shaft/roller cell	Baler	shaft/roller		A-RIGHT	19	762	Baler	09977	shaft/roller cell	9041
12	Baler - shaft/roller cell	Baler	shaft/roller cell	500116625	AUGER WA-LEFT	15	412	Baler	09977	shaft/roller cell	9041

=IF(H2<J2,H2,J2)

=IF(H2<J2,J2,H2)

=CONCATENATE(B2," - ",C2)

Step 5: Flow Analysis Table

	Q	R	S
1	Concatenated Act Area Pairs	Total Nbr of Orders	Total Accum Qty
2	Broach, Drill, Grind, Saw, Deburr, Hob - Storage	2515	560709
3	Broach, Drill, Grind, Saw, Deburr, Hob - Warehouse	3709	480443
4	Outside Processing - Warehouse	3074	476444
5	lathes - Storage	3698	431804
6	Storage - Weld Stations	6914	355356
7	lathes - Warehouse		3256
8	V Machining - Warehouse		5123
9	Warehouse - Weld Stations	3264	234514
10	Broach, Drill, Grind, Saw, Deburr, Hob - Outside Processing	1453	212305
11	Robot Weld - Storage	1250	165712
12	Broach, Drill, Grind, Saw, Deburr, Hob - lathes	2221	146386
13	lathes - Outside Processing		
14	Outside Processing - Storage		
15	Rotary Weld - Storage	1383	107787
160	Flywheel Cell - Warehouse	1	45
161	Flywheel Cell - Weld Stations	1	45
162	Sub-Assembly - H Machining	2	29
163	Dispatch - Warehouse	2	20
164	Dispatch - Storage	2	20

=SUMIF($A$2:$A$7169,Q2,$F$2:$F$7169)

=SUMIF($A$2:$A$7169,Q2,$G$2:$G$7169)

n) In the Quantified Routing Table, delete the rows where the finished goods activity area was added.
o) In the Quantified Routing Table, also delete the column for work center 2. It is no longer needed since all the moves to and from second operations have been captured.
p) Continue steps k) through o), until you have worked through the last work center columns that contains a work center number (the last operation of the part(s) with the most operations).

We now have a table with many rows, one for each "move" of each part. Recognize that each part has as many rows as it has "moves". Note however, that some of these moves will be from and to the same work center. This occurs when two or more operations are performed in the same work center. We will remove these "internal moves" in the next step.

Step 3. Add Activity-Areas Names to Move Table Work Centers

Here we will need the Work Center Master to which we have added (mapped) activity-area names and/or numbers. Then, from the Moves Table, we will use VLOOKUP to copy the activity-area name of each work center and paste it next to our work center numbers. Along the way, we will delete instances of parts moving from-to the same work center since these will be internal to the layout and of no interest to our current flow analysis.

a) In the Moves Table, insert a column next to the "from work center" and a column next to the "to work center".
b) Use the VLOOKUP function to search the Work Center Master for each work center's activity area name.
c) Once you have validated the data, copy and use "Paste Special-Values" to paste the values on top of the formulas. (Here again, this eliminates unnecessary formulas that will slow down the workbook.) In our example, you have reached Moves Table II.
d) In the first empty column at the right of Moves Table II set up a "Delete" column. In this column, enter an "If" statement that compares the "from activity area" and the "to activity area". If they are the same, print "delete", otherwise print nothing. This will make it easier to find rows where the "from" and "to" activity areas are the same. In our example, you have reached Moves Table III.
e) Once you have validated the data, copy and use "Paste Special-Values" to paste the values on top of the formulas.
f) Sort the Moves Table by the newly populated delete column and delete the rows where "Delete" is printed, since the From and To activity areas are the same.

Our move origins and destinations are now expressed as activity areas in our layout flow analysis. Our flows are all directional – from to – so the same pair of activity-areas may appear as "from A to B" *and* "from B to A." From a layout perspective, we will need to know the total flow in both directions *between* A and B. Our next step identifies unique pairs so that flow may be summed in both directions.

Step 4. Identify Unique Activity Pairs

A useful way to identify unique pairs (routes or relationships) is with the CONCATENATE function. In practice it can be used to join activity-area names or numbers. Our example uses names.

a) Insert three columns to the left hand side of the latest Moves Table (III) – in front of the part number column.
b) In the second inserted column, use an IF statement to identify and populate the activity area name (from or to) which is first alphabetically.
c) In the third column, use an IF function to identify and populate the activity area name (from or to) which is second alphabetically. The implicit rule is that all activity pairs will be named (concatenated) in alphabetical order.
d) Copy the formulas down through the rest of the rows.
e) Once you have validated the data, copy and use “Paste Special-Values” to paste the values on top of the formulas.
f) In the first column, use the CONCATENATE function to join the activity areas in the second and third columns.
g) Once you have validated the data, copy and use “Paste Special-Values” to paste the values on top of the formulas.

We now have a final Moves Table (IV) in which each row is identified by a concatenated activity-pair. Each row’s ORDERS and QTY still represent directional movement between the pair. And each activity pair still appears multiple times. In our final step, we must sum for each pair (each concatenated identifier) to get total flow in both directions – the flow *between* the areas, and our basis for flow relationships.

Step 5. Create Flow Analysis Table

Our final step uses the Advanced Filter function to create a Flow Analysis Table on the same worksheet with Moves Table IV. In this final table we will total the movements of orders and quantities (pieces) between each activity pair.

a) In the worksheet holding Moves Table IV, highlight the column holding the concatenated activity area pairs. Select Advanced Filter and then select “Copy to another location.” Put the cursor in the “Copy to” field and select a column to the right of the Moves Table where your new table will appear.
b) Now select “Unique Records only” and then OK. The list of unique data will now populate in the designated area. In our example, this is a list of the concatenated activity pairs.
c) If desired, you may copy and paste the unique list to a new worksheet called Flow Analysis Table, or simply label it as such in place.
d) In a column next to the unique list of concatenated activity area pairs, use the SUMIF function to sum the moves for each pair from the Moves Table IV.
e) Once you have validated the data, copy and use “Paste Special-Values” to paste the values on top of the formulas.
f) Sort the Flow Analysis Table by the newly populated summed move quantity, descending so that the pairs with the highest volume are at the top.

We now have a basis for flow of materials relationships between activity areas. These can be used to develop a flow-based layout, or they can be posted to a relationship chart and combined with other-than-flow relationships in a more comprehensive approach.

Appendix IV – Combining Flow and Other-Than-Flow Relationships

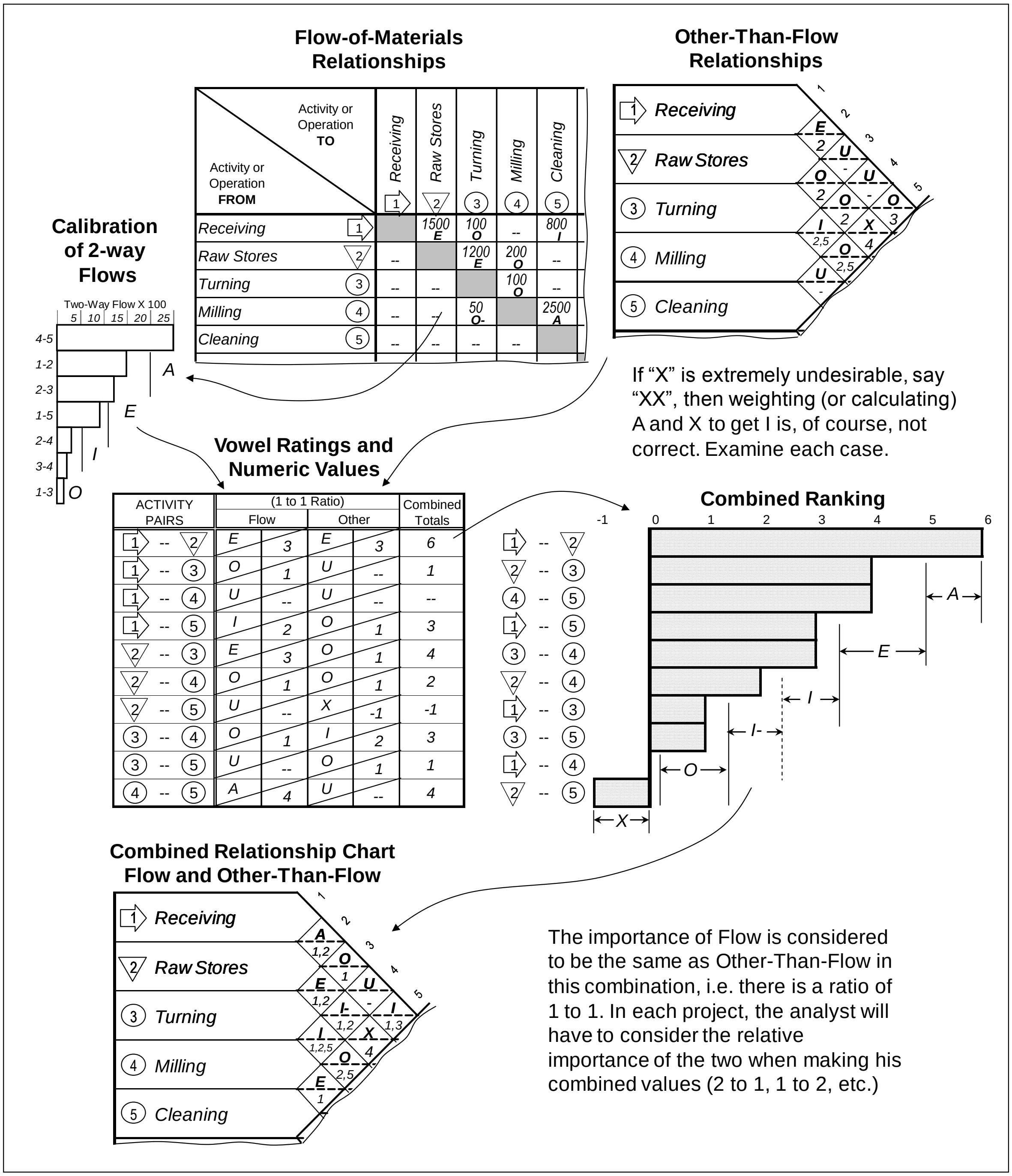
Flow of materials is usually not the only reason for closeness ratings. In most industrial plants, relationships among activity-areas involve both flow of materials and service (or other-than-flow) requirements. These two types of relationships must be combined in a meaningful way to determine the resultant combined relationships.

Combining flow and other-than-flow relationships occurs in Section 2 of the SLP Pattern of Procedures, prior to drawing the Activity Relationship Diagram. Such combining is necessary in probably 60 to 70 percent of all layout-planning projects. That is, in perhaps 15 to 20 percent of the projects, flow of materials so dominates the conditions that the planner can go directly from flow analysis to relationship diagram; and in another 15 to 20 percent of all projects, there is no significant flow of materials involved so the planner can proceed from the chart of other-than-flow relationships directly to the diagram.

When combining the two, use the following general procedure:

1. Determine the flow of materials in each direction between each pair of activity areas.
2. Add flows in both directions between each pair, sort and plot in descending order.
3. Calibrate into vowel-letter ratings: A, E, I, O, U by visual identification of break points.
4. Convert flow ratings into their corresponding point values: 4, 3, 2, 1, 0.
5. Determine the other-than-flow relationships between the same activity pairs; most frequently they are documented on a relationship chart.
6. Determine the *relative importance* of flow and other-than-flow relationships. Usually the layout planner discusses this with others immediately involved in the operations. (In high-volume manufacturing or distribution facilities, flow may be weighted at a ratio of 1.5 or 2 to other-than-flow).
7. Add points for flow and other, after multiplying by any extra weighting ratio. Sort and plot in descending order.
8. Calibrate the plot of combined point values into vowel ratings: A, E, I, O, U, X.
9. Check and adjust the final ratings as needed. Increase those that combined too low and decrease those that combined too high. Recognize that almost every layout has some other-than-flow relationships that are at least as important and perhaps more important than flow. These will usually need adjusting if flow values were multiplied by a factor of 1.5 or 2. "X's" must be considered case by case since they may be absolute and override flow of materials.
10. Post the resultant combined relationships and their reasons on a relationship chart. Use this as a basis for making the activity relationship diagram (combined flow and other-than-flow relationship diagram) – output of Section 2 in the Pattern of Procedures.

Figure 1 shows a simple example in which flow and other ratings receive equal weight (ratio of 1 to 1). Vowel-letter ratings for two-way flow and other are converted to their numerical values and then added. The combined values are then recalibrated back into vowel-letter ratings by ranking, plotting, and dividing the combined values.



Flow-of-Materials Relationships

Activity or Operation FROM \ Activity or Operation TO	Receiving 1	Raw Stores 2	Turning 3	Milling 4	Cleaning 5
Receiving 1	▨	1500 E	100 O	--	800 I
Raw Stores 2	--	▨	1200 E	200 O	--
Turning 3	--	--	▨	100 O	--
Milling 4	--	--	50 O-	▨	2500 A
Cleaning 5	--	--	--	--	▨

Other-Than-Flow Relationships

Calibration of 2-way Flows

Vowel Ratings and Numeric Values

ACTIVITY PAIRS	(1 to 1 Ratio)				Combined Totals
	Flow		Other		
1 -- 2	E	3	E	3	6
1 -- 3	O	1	U	--	1
1 -- 4	U	--	U	--	--
1 -- 5	I	2	O	1	3
2 -- 3	E	3	O	1	4
2 -- 4	O	1	O	1	2
2 -- 5	U	--	X	-1	-1
3 -- 4	O	1	I	2	3
3 -- 5	U	--	O	1	1
4 -- 5	A	4	U	--	4

Combined Ranking

Combined Relationship Chart Flow and Other-Than-Flow

If "X" is extremely undesirable, say "XX", then weighting (or calculating) A and X to get I is, of course, not correct. Examine each case.

The importance of Flow is considered to be the same as Other-Than-Flow in this combination, i.e. there is a ratio of 1 to 1. In each project, the analyst will have to consider the relative importance of the two when making his combined values (2 to 1, 1 to 2, etc.)

Figure 1. Combining by using the SLP convention of numerical values. Vowel ratings for two-way flow and other relationships are converted to their numerical values, then added, ranked and calibrated into final combined ratings. Note that the individual vowel letters written directly on the From-To Chart (upper left) cannot be combined directly if there is back flow as between #3 Turning and #4 Milling. Here, the "O" for 100 and "O-" for 50 must first be rated as total two-way flow of 150 before combining with other-than-flow ratings. This additional step, resulting in an "O" rating for flow between #3 and #4, is accomplished by ranking and plotting the two-way flows between activity pairs. The plot is then calibrated into vowel-letter ratings by visual identification of break points or intervals in the plot.

COMBINING FLOW & SERVICE RELATIONSHIPS

Plant (Company)	*Hevi-Duti Truck*
Project	*Layout Plan*
Flow Source / Reference	*From-To Summary 10/12*
Date	*10/16*
Other-Than-Flow Source	*Relationship Chart 10/15*
By	*LH, RJL*
Sheet	*1* of *2*

Ratio of Flow to Other-Than-Flow: **1** to **1**

			FLOW-OF-MATERIAL INTENSITY						OTHER-THAN-FLOW RELATIONSHIPS				RESULTANT COMBINED RELATIONSHIPS			
Line #	**Activity-Pair**		**From-To**	**To-From**	**2-Way**	**Vowel Rating**	**Value**	**Wt.**	**Vowel Rating**	**Reasons**	**Value**	**Wt.**	**Combined Value**	**Combined Rating**	**Final Assigned Rating**	**Comments**
1	1	3	31.5	0.0	31.5	A	4	1	A	2,7	4	1	8	A	A	
2	1	2	2.0	0.0	2.0	O	1	1	I	2,7	2	1	3	E	E	
3	3	8	21.6	0.0	21.6	E	3	1	U	0	0	1	3	E	E	
4	4	7	18.0	0.0	18.0	E	3	1	U	0	0	1	3	E	E	
5	7	9	21.6	0.0	21.6	E	3	1	U	0	0	1	3	E	E	
6	7	11	0.0	0.0	0.0	--	0	1	E	3,4,6	3	1	3	E	E	
7	7	16	0.0	0.0	0.0	--	0	1	E	4,5	3	1	3	E	I	Could work inside
8	11	16	0.0	0.0	0.0	--	0	1	E	4,5	3	1	3	E	I	Could work inside
9	2	4	12.0	0.0	12.0	I	2	1	U	0	0	1	2	I	I	
10	2	5	8.0	0.0	8.0	I	2	1	U	0	0	1	2	I	I	
11	2	6	10.0	0.0	10.0	I	2	1	U	0	0	1	2	I	I	
12	4	5	0.0	0.0	0.0	--	0	1	I	3,6	2	1	2	I	I	
13	4	14	0.0	0.0	0.0	--	0	1	I	5	2	1	2	I	I	
14	5	7	12.0	0.0	12.0	I	2	1	U	0	0	1	2	I	I	
15	6	7	2.5	3.5	6.0	I	2	1	U	0	0	1	2	I	I	
16	7	10	14.4	0.0	14.4	I	2	1	U	0	0	1	2	I	I	
17	8	9	2.2	0.0	2.2	O	1	1	O	2,3,6	1	1	2	I	I	
18	8	10	1.4	0.0	1.4	O	1	1	O	2,3,6	1	1	2	I	I	
19	9	10	0.0	0.0	0.0	--	0	1	I	3,6	2	1	2	I	I	
20	9	13	0.0	0.0	0.0	--	0	1	I	7	2	1	2	I	I	
21	10	13	0.0	0.0	0.0	--	0	1	I	7	2	1	2	I	I	
22	1	15	0.0	0.0	0.0			1	O	7	1	1	1	O	O	
23	2	7	2.0	0.0	2.0	O	1	1	U	0	0	1	1	O	O	
24	3	6	3.0	0.0	3.0	O	1	1	U	0	0	1	1	O	O	
25	3	7	0.0	2.1	2.1	O	1	1	U	0	0	1	1	O	O	
26	3	9	4.5	0.0	4.5	O	1	1	U	0	0	1	1	O	O	
27	3	10	4.5	0.0	4.5	O	1	1	U	0	0	1	1	O	O	
28	3	15	0.0	0.0	0.0			1	O	7	1	1	1	O	O	
29	4	6	0.0	0.0	0.0			1	O	3,4	1	1	1	O	O	
30	4	15	0.0	0.0	0.0	--	0	1	O	7	1	1	1	O	O	
31	5	6	0.0	0.0	0.0			1	O	3,4	1	1	1	O	O	
32	5	14	0.0	0.0	0.0	--	0	1	O	5	1	1	1	O	O	
33	5	15	0.0	0.0	0.0	--	0	1	O	7	1	1	1	O	O	
34	6	9	2.1	0.0	2.1	O	1	1	U	0	0	1	1	O	O	
35	6	10	1.4	0.0	1.4	O	1	1	U	0	0	1	1	O	O	
36	6	14	0.0	0.0	0.0	--	0	1	O	5	1	1	1	O	O	
37	6	15	0.0	0.0	0.0	--	0	1	O	7	1	1	1	O	O	
38	7	8	0.9	0.0	0.9	O	1	1	U	0	0	1	1	O	O	
39	7	14	0.0	0.0	0.0	--	0	1	O	5	1	1	1	O	O	
40	9	11	1.0	0.0	1.0	O	1	1	U	0	0	1	1	O	O	
41	9	15	0.0	0.0	0.0	--	0	1	O	7	1	1	1	O	O	
42	10	11	0.7	0.0	0.7	O	1	1	U	0	0	1	1	O	O	
43	10	15	0.0	0.0	0.0	--	0	1	O	7	1	1	1	O	O	
44	11	12	2.5	0.0	2.5	O	1	1	U	0	0	1	1	O	O	
45	11	14	0.0	0.0	0.0	--	0	1	O	5	1	1	1	O	O	
46	13	15	0.0	0.0	0.0			1	O	7	1	1	1	O	O	
47	14	15	0.0	0.0	0.0			1	O	7	1	1	1	O	O	
48	4	11	0.0	0.0	0.0	--	0	1	X	8	-1	1	-1	X	X	
49	5	11	0.0	0.0	0.0	--	0	1	X	8	-1	1	-1	X	X	
50	6	11	0.0	0.0	0.0	--	0	1	X	8	-1	1	-1	X	X	

Activity pair

Flows posted from a From-To Chart

Summed flows to capture activity-pairs with 2-way flow

Rated flows and point values

Ratio for Flow (See above)

Other-than-Flow ratings and reason codes posted from a Relationship Chart

Point values

Ratio for Other than flow

Combined point values and ratings

Final rating after any adjustments

Explanation for adjustments

Figure 2 shows a work sheet for major projects. Here, the planner posts flows in the left-hand columns, converts them to vowel ratings and then to numerical values at a desired importance ratio – in this example 1:1. Other-than-flow ratings and their values are posted in the central columns. In the right-hand columns, the values are added and calibrated into combined ratings. At the far right, the planner may make final adjustments if needed – promoting or demoting – to reflect the proper relationships. In practice, the left-hand columns are posted from a summary From-To Chart. The central columns are posted from a Relationship Chart. The final adjusted ratings are typically posted to a final “combined” Relationship Chart of flow and other-than-flow relationships. When colored, this chart becomes a ready basis for drawing the activity relationship diagram.

It is possible to prepare the relationship diagram directly from the worksheet in Figure 2. However, it is awkward and less reliable to do so (even when coloring the vowel-letter entries in the right-hand column). This is because a tabular list of activity-pairs does not assure that all pairs are accounted for. The relationship chart’s intersecting boxes make obvious any missed relationships. And the worksheet’s tabular form typically requires two or more pages to list all activity pairs. This results in much shuffling and potential oversight when compared to the compact, always single-page relationship chart. It is usually best, therefore, to repost the resultant combined ratings on a combined relationship chart, before making the relationship diagram.

Both Figures 1 and 2 combine flow and other relationships by calibrating the summed numerical values of their respective vowel code ratings. There is at least one other method of arriving at a resultant combined relationship. It involves taking the more demanding of the flow and other-than-flow closeness ratings for each pair of activities. This procedure assumes that honoring the dominating relationship more than satisfies the requirements of the lesser one. The specific steps in this method are

1. Calibrate flow intensities between activity pairs into vowel-letter ratings.
2. Post to a Relationship Chart, listing the Reason #1 (flow of materials) for each rating.
3. Using these flow ratings as a starting point (A, E, I, O, U), consider each activity-pair’s other-than-flow relationships.
4. Decide each pair’s other-than-flow relationship relative to the flow rating already posted (Higher than? Lower than? About the same? Or possibly X?)
5. Select the dominant rating between flow and other-than-flow, and make this the final combined relationship. Add reason codes behind the Reason #1 already posted.

Figure 2. Worksheet for combining flow and other-than-flow. The ratio of flow to other may be varied to suit the situation. In high-volume mass production or distribution centers, 2:1 may be appropriate; in laboratories the ratio may be 1:2. In every case, the planner should inspect the results of “blanket ratios” and calibration to assure that all final ratings are sensible and reflect the true relationships. (This example combines other-than-flow ratings with the flow ratings established in Figure 4-20, Step 9.)

Appendix V – Use of Color in Layout Planning

One of the most helpful conventions used in layout planning is color coding. Colors can identify various departments or activities or different types of area or space. Color can also be used to indicate degree of closeness desired or magnitude of flow intensities.

Essentially, color coding is used to aid interpretation and understanding – that is, as an aid to clear visualization. Color adds a decorative and artistic quality, too, and can therefore add appeal to, and aid more ready acceptance of, one's layout plans. It can be used to appeal to the "reader's" heart as well as his eye and his mind.

For layout planning, using color reaps the greatest benefits when each color has a significant meaning. Map-makers long ago discovered that water-blue, grassland or forest-green, desert-tan, and iceland-white are readily recognized. In 1969, the Materials Handling & Management Society – then called the International Materials Management Society – approved a set of Standard Color Codes for Use in Layout Planning and Materials Handling Analysis. The SLP color conventions are almost identical with the IMMS Standard.

The SLP color conventions are basically *two:*

1. Colors for the types of space (activities, areas, or equipment)[1]

    Red – Assembly, including Subassembly and Disassembly Areas.
    Orange/yellow – Transport-related Areas; Storage, Set-down, or Hold Areas
    Green – Forming or Treating Areas
    Blue – Inspect, Test, or Check Areas; Service or Support Areas
    Brown or Gray[2] – Office-Type Areas

2. Colors for rating the relative closeness between activities follow the order of colors of the spectrum:

Red	(A)	Absolutely necessary
Orange/yellow	(E)	Especially important
Green	(I)	Important
Blue	(O)	Ordinary closeness
Uncolored	(U)	Unimportant
Brown or Gray[2]	(X)	Not desirable

Note that only five colors have been included in the conventions. This limits the number of colors to a practical number so that colored paper and pencils can be used in workshops and hand-drawn sketches. Degrees of measure in between these color ratings can be indicated by dots or cross-hatching to represent a half degree.

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[1] 1. Black-and-white shadings may be substituted when color reproduction is unavailable. The old heraldic tincture code for black-and-white shading has been adapted by both the IMMS (MHMS) Standard and SLP as a conventional interchange with type-of-space colors. This black-and-white shading code is indicated on the SLP Capsule Summary (back cover).

[2] 2. Gray, while not an IMMS Standard, is sometimes used in place of brown when easier to reproduce.

Other comments on the use of color in layout planning include:

1. Modifications of the standard type-of-space color convention can be made – typically for the operating areas. For example:
   - red for hot operations and green for cold work
   - red for primary and green for secondary operations
   - lighter red for sub-assembly and darker red for final assembly
   - green for forming and red for finishing.
2. When coloring a large area, the entire area may be covered, or a band of approximately a quarter or a half inch (0.5 to 1.0 cm.) outlining the area along and just inside its boundary line can be used.
3. On site surveys, major contour lines can each be colored differently to indicate the topography of the site.
4. Different colors can be used to indicate degrees of intensity of materials flow.
5. Different colors can be used in diagramming to identify various paths of flow for different products, or product groups, or materials.
6. Color can be used to indicate the degree of attention that should be given to planning the layout of each area, or to indicate areas to be moved, to stay, to be renovated.
7. Color can be used to indicate the degree of "fixity" of equipment, or building features or activity-areas: red for can never be moved; yellow for should not be moved, green for will be (already planned to be) moved…
8. In detail layout planning, color can identify individual templates according to type of function the equipment performs; whether the equipment is new or old; or whether it is to be moved or left behind.
9. Colored lines for various utilities or service lines aid clear planning.

Certain problems in using color should be recognized:

1. Color confuses when inconsistently applied. Always use it in a standard way and always include a color key on all prints and plots.
2. When printing or plotting in black-and-white or grayscale, color is lost and light colors tend to drop out. Therefore, templates of individual machines should be outlined in black, red, or orange; which are all opaque colors. Since other colors fade in varying degrees, a template which prints the equipment outline and equipment information data in a color other than black, red, orange or dark brown is generally not satisfactory.
3. When shading or filling a machine template with color, light tints are ideal. These aid visualization and do not obliterate the machine or equipment outline and other information.

Appendix VI – SLP in Multi-Story Buildings

Systematic Layout Planning (SLP) is an excellent technique for correctly assigning – activities (work groups) to the various floors of multi-story buildings or to the various buildings in a multi-building complex.

Procedure for Application

1. Follow the SLP Pattern through Section 2. That is, make an Activity Relationship Diagram to visually show the desired closeness of all activities to each other. Mandatory locations of any activities are indicated by coding beneath the activity number or symbol. See Figure 1.

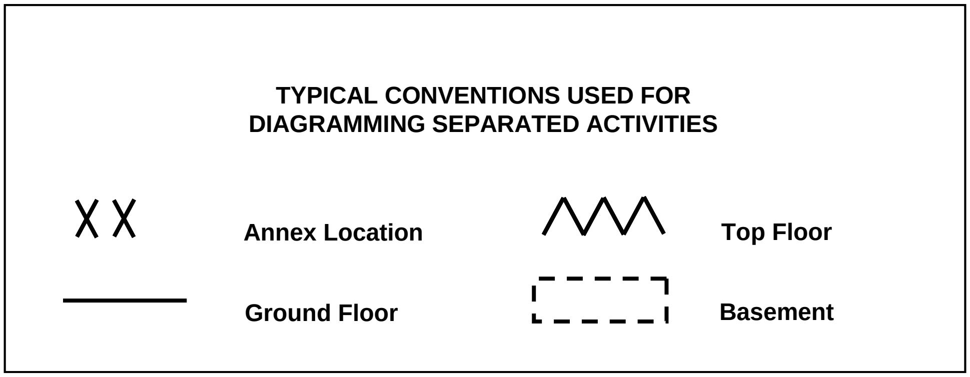


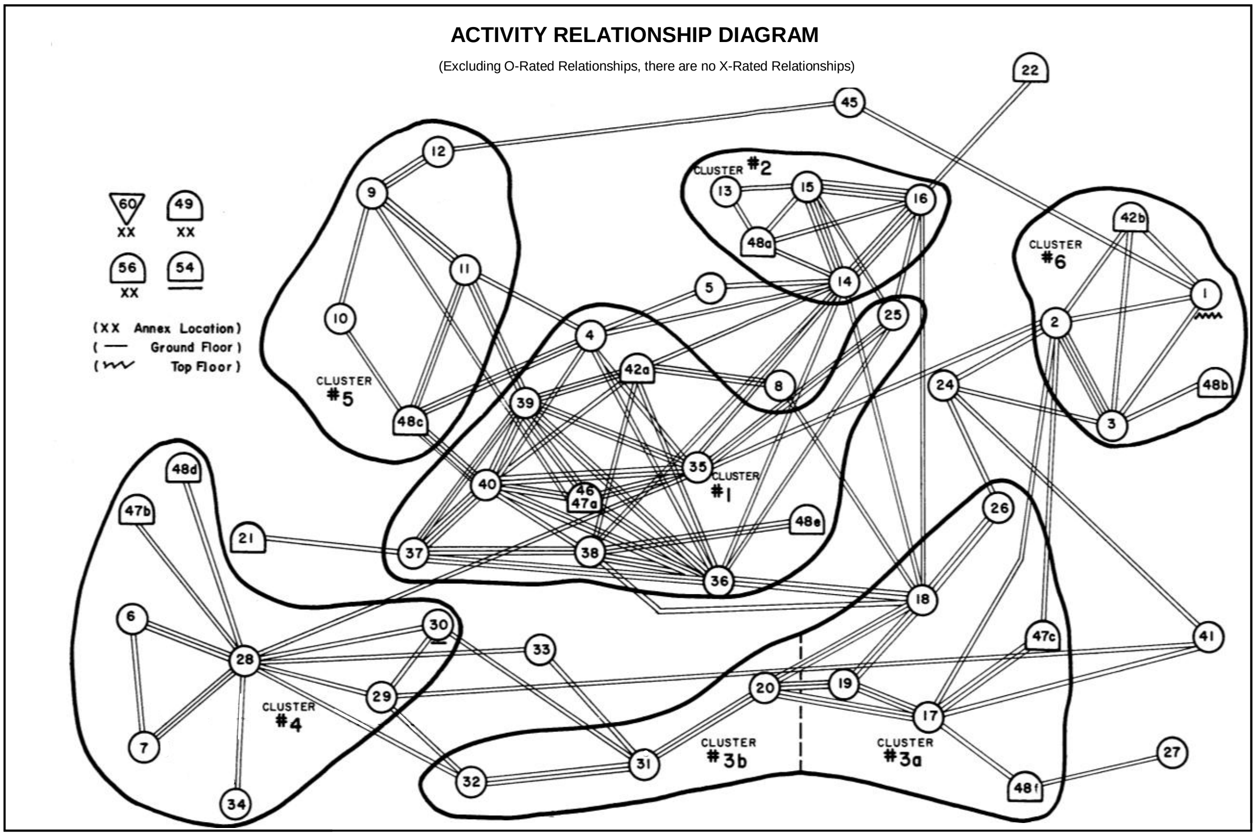
Figure 1.

2. Develop groups of activities or clusters. Each cluster generally contains those activities that cannot be separated or which should be located together – those related with 4-line and 3-line closeness ratings. For example, see Figure 2.

3. Add floor space requirements to make a Space Relationship Diagram. This visually displays the amount of space required by each activity and generally for each cluster as well. See Figure 3.

4. Make a Cluster Relationship Diagram to indicate the desired closeness among all clusters and the non-clustered individual activities. On simple projects, this step is often omitted or is used as an alternate for making a space relationship diagram. See Figure 4.

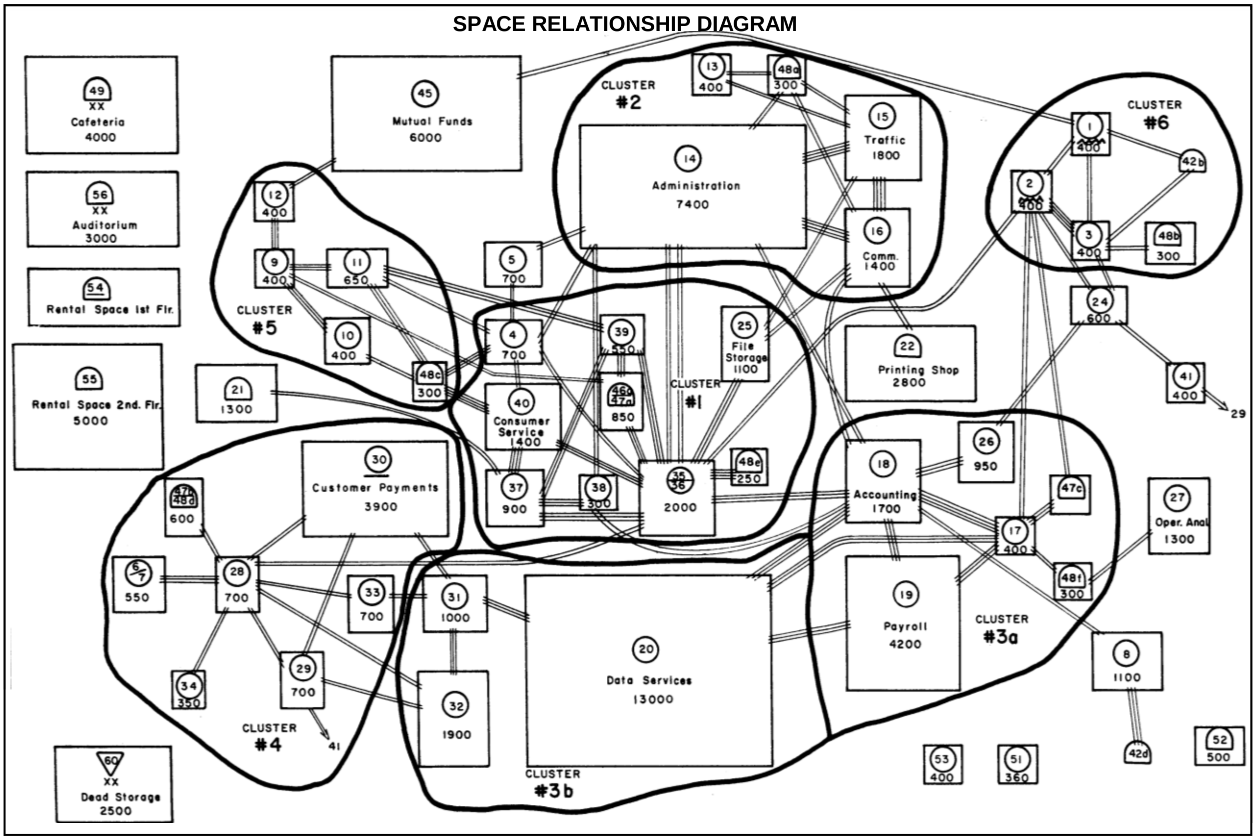
5. Assign activities to specific floors based on the above relationships. See Figure 5. The kind of space or type of activity can become a more dominant consideration than the closeness relationships when balancing activities against the available space per floor. This assignment of activities generally results in two or more alternative arrangements.



ACTIVITY RELATIONSHIP DIAGRAM

(Excluding O-Rated Relationships, there are no X-Rated Relationships)

Figure 2.



SPACE RELATIONSHIP DIAGRAM

Figure 3.

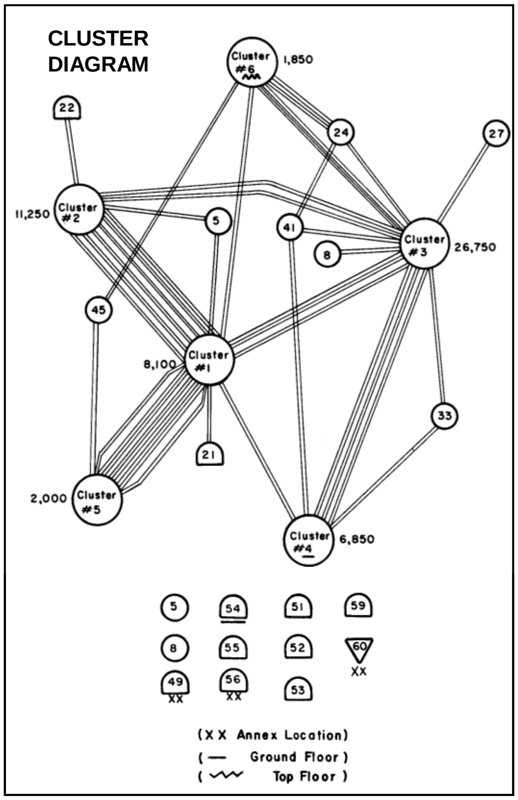


Figure 4.

ACTIVITY ASSIGNMENT BY FLOOR

Total of 7 Floors
14,000 sq. ft. per floor (net)

Cluster No.	Act. No.	Name	Sq. Ft. (x1000)	Sub-Total Sq. Ft. (x1000)	Square Feet x 1000 (Floor Location)							
					Annex	1	2	3	4	5	6	7
#1	4	Market Research	0.7							0.7		
	35	VP Marketing	0.4							0.4		
	36	Mkt. Admin.	1.6							1.6		
	37	Mkt. Services	0.9							0.9		
	38	Advertising	0.3							0.3		
	39	Public Relations	0.6							0.6		
	40	Consumer Service	1.4							1.4		
	46	Large Conference Room	0.5							0.5		
	47	Medium Conference Room	0.4							0.4		
	48e	Small Conference Room	0.3							0.3		
	25	File Room	1.1	8.2						1.1		
#2	13	VP Services	0.4								0.4	
	14	Administration	7.4								7.4	
	15	Traffic	1.8								1.8	
	16	Communications	1.4								1.4	
	48a	Small Conference Room	0.3	11.3							0.3	
#3-a	17	VP Finance	0.4						0.4			
	18	Accounting	1.7						1.7			
	19	Payroll	4.2						4.2			
	26	Insurance & Taxes	1.0	7.3					1.0			
	47	Medium Conference Room	0.4						0.4			
Not in Any Cluster	5	Statistics	0.6							0.6		
	8	H and A Collections	1.1						1.1			
	41	VP and General Counsel	0.4									0.4
	45	Mutual Funds	6.0									6.0
	49	Cafeteria	4.0		4.0							
	51	Credit Union	0.4									0.4
	52	First Aid	0.5						0.5			
	53	Employee Store	0.4									0.4
	54	Rental Space -- 1st Floor	2.5			2.5						
	55	Rental Space -- 2nd Floor	5.0				5.0					
	56	Auditorium	3.0		3.0							
	59	Vault	0.3						0.3			
	60	Dead Storage	2.5		2.5							
		Total	87.4		9.5	9.7	12.6	6.1	12.7	13.5	12.6	11.0
		Utilization			68%	69%	90%	44%	91%	96%	90%	79%

Figure 5.

6. Make sure that each alternative activity assignment can in fact be realistically laid out on each floor – probably by making a sub-application of S L P to each floor level.

7. Evaluate the alternatives to obtain the selected activity assignment for each floor.

Appendix VII – Identifying Machinery, Equipment, and Property

Standard Procedure for Identifying Equipment

Purpose

1. To properly identify capital equipment, machinery, and property for asset accounting and depreciation schedules.
2. To identify equipment and machinery for layout planning and installation (or rearrangement), and for maintenance and/or repair records.

Identification System

Numbers will be assigned in numerical order to all existing and new machinery and equipment as follows:

1. Prefix letter
2. Four-digit number (starting with 0001 regardless of prefix letter)

Prefix Letters

Selected prefix letters indicate the general type of machinery and equipment as follows:

M – Machine tools (lathes, drills, shapers, and the like)
P – Production machinery or equipment other than machine tools (welders, presses, anneal ovens, platers, and the like used in production)
E – Equipment for supporting services (compressors, fans, lockers, tool cabinets, transformers, heaters, and the like)
T – Tools (bench, maintenance, powered and non-powered types, but not including hand tools such as screwdrivers, hammers, or wrenches, nor hand gauges, paint or plating hangers, and the like)
H – Handling and transport equipment (fork trucks, vehicles, major containers, hoists, conveyors and the like, but excluding skids, pallets, and general containers)
O – Office furniture and equipment, including communications and filing equipment
S – Safety, fire prevention, and first aid equipment

Number (Tag or Machinery Inventory Number)

1. All machinery, equipment, and property of the company must be identified by a number.
    a. If there is any question about whether a piece of equipment or a tool should be numbered, consult the Treasurer, whose office is responsible for administering the machinery and equipment inventory.
2. Numbers will be assigned in numerical order starting with 0001, regardless of the letter prefix.
    a. Once assigned, this number should never be changed.
    b. Numbers will be issued by the office responsible for the machinery and equipment inventory (Treasurer).

Tags

1. Brass tags with the Company Name, Letter Prefix, and the Numerical Inventory Number should be attached to each piece of machinery and equipment that is company owned.
2. If the company has a computer-based maintenance or asset management system, it may be desirable to include a bar code or an additional bar-code label to be scanned when maintenance is performed or inventory taken.
   a. Example:

P = Production Equipment (other than machine tools)
1096 = Chronological company number

3. The Maintenance Department should affix this tag – in a conspicuous place for all shop machinery and equipment; not too prominent a place for office equipment.

Other Property

4. Portable jigs, fixtures, and dies are not included in this inventory. They will carry the stamped or painted part or assembly number(s) on which these tools are used.
5. Buildings or installed building features like plumbing fixtures, partitions, and ventilating ducts are also excluded.

Appendix VIII – Calculating Equipment Requirements

Establishing the number of machines required must include several considerations other than the operating capacity of the machine itself. The planner must know the following information:

1. Available Work Time, e.g. hours or minutes per day or per week
2. Demand Rate for the part(s) to be made, e.g. units per hour or day or week
3. Processing Rate when running, e.g. units per hour or day. To allow for occasional short stoppages or slow speed operation, the Processing Rate should be the expected run rate and may be less than the theoretical, ideal or manufacturer's stated run rate for the machine.
4. Efficiency Percentage – the percent of available work time that the machine may be expected to be running. Always less than 100%, this figure makes allowance for:
    Idle time waiting on operators or materials or other potential interferences
    Planned and unplanned downtime for maintenance and repairs
    Set-up and changeover time, and frequencies thereof
5. Yield percentage – the percent of output that is usable. Typically less than 100%, this figure makes allowances for quality losses.

Other factors affecting the number of machines required include peak demand rates, inventory-balancing policies, overtime practices, and in some cases, the number of machines operated by one person.

To help better explain these calculations let us follow an example.

$$\text{Number of machines required} = \frac{\text{pieces per hour to meet production requirements}}{\text{pieces per hour per machine}} \quad \text{or} \quad \frac{\text{time per piece per machine}}{\text{time per piece to meet production requirements}}$$

Suppose that a drug company's requirements call for making five varieties of tablets each week on a Model EG3 tabletting machine. The plant operates one shift of 40 hours. The quantity of granulated powder for each tablet variety and the machine capacity for each variety is as follows:

Tablet Variety	Lbs. per Week Required	Machine Capacity Lbs. per Hour
A	4,560	30
B	3,040	40
C	760	50
D	570	37½
E	190	50

Previous studies show that on an average the Model EG3 tabletting machines actually produce at 80 percent of capacity (idle-time interferences, set-up allowance, and downtime losses) and that acceptable tablets are obtained 95 percent of the time (yield or quality loss). How many Model EG3 tabletting machines are required to produce the five tablet varieties?

Required Production, Yields, Processing Rates and Efficiencies

Tablet A	4,560 lbs. per week ÷ 0.95 yield = 4800 lbs. per week requiring tabletting. 30 lbs. per hour machine capacity × 0.80 machine efficiency = 24 lbs. per hour average production.
Tablet B	3,040 lbs. per week ÷ 0.95 yield = 3,200 lbs. per week requiring tabletting. 40 lbs. per hour machine capacity × 0.80 machine efficiency = 32 lbs. per hour average production.
Tablet C	760 lbs. per week ÷ 0.95 yield = 800 lbs. per week requiring tabletting. 50 lbs. per hour machine capacity × 0.80 machine efficiency = 40 lbs. per hour average production.
Tablet D	570 lbs. per week ÷ 0.95 yield = 600 lbs. per week requiring tabletting. 37½ lbs. per hour machine capacity × 0.80 machine efficiency = 30 lbs. per hour average production.
Tablet E	190 lbs. per week ÷ 0.95 yield = 200 lbs. per week requiring tabletting. 50 lbs. per hour machine capacity × 0.80 machine efficiency = 40 lbs. per hour average production.

Number of Machines Required based on Average Production Rate and Hours Available

Tablet A 4800 lbs. per week ÷ 40 hours per week available = 120 lbs. per hr. required.
1 ÷ 120 lbs. per hour = 0.00833 hrs. per lb. required.
1 ÷ 24 lbs. per hour = 0.04166 hrs. per machine per pound produced.

$$\text{Number of machines required} = \frac{\text{120 lbs. per hr. required}}{\text{24 lbs. per hr. per machine}} = \text{5 machines}$$

$$\text{or} = \frac{\text{0.04166 hrs. per lb. per machine}}{\text{0.00833 hrs. per lb. required}} = \text{5 machines}$$

Tablet B:

$$\text{Number of machines required} = \frac{3{,}200 \div 40}{32} = \text{2.5 machines}$$

Tablet C:

$$\text{Number of machines required} = \frac{800 \div 40}{40} = \text{0.5 machines}$$

Tablet D:

$$\text{Number of machines required} = \frac{600 \div 40}{30} = \text{0.5 machines}$$

Tablet E:

$$\text{Number of machines required} = \frac{200 \div 40}{40} = \text{0.125 machines}$$

Total number of machines required to produce week's requirements = 5 + 2.5 + 0.5 + 0.5 + 0.125 = 8.625 or 8 5/8 machines.

Obviously, we cannot have or use less than a whole machine. Therefore, nine Model EG3 machines will be required. However, the possibility of obtaining the production of five-eighths of a machine by working overtime or additional shifts should be considered, along with increasing the 80% efficiency through actions to reduce the idle time.

Note that it is easier to make eight machines do the work of 8-5/8 machines (by overtime, extra shifts, or reduced idleness) than to make one machine do the work of 1-1/4 machines. In the first case the additional work is only just over seven per cent for each machine, whereas in the second case the overload is 25 per cent.

When we established 80 per cent of capacity as our anticipated production, this might have been based on one person operating two machines. If we decide that one person can actually operate four machines, we may save labor cost. However, if one operator running four machines results in more idleness or perhaps lower quality yield, we would have to recalculate the number of machines using say 70 percent efficiency and/or 93 percent yield of acceptable tablets.

In this example we have assumed average requirements. If our peak-period requirements were 25 per cent greater for each tablet, we would have to add additional machines. We could add enough to take care of peak conditions directly, or we could build an inventory of finished tablets during the slow period and use up the inventory faster than we produced during the peak period. Theoretically, on this latter basis we could balance our machines by adjusting inventories, thus requiring no more equipment than for level-production, average conditions. This does not always work out in practice, however. But the chief point is that our policy on inventory-building will make a significant difference on machinery investment and therefore on space.

Still one other consideration is how much insurance against failures to meet customer requirements can be tolerated. Extra or stand-by machinery may be added over and above that required for the normal expected losses in order to protect the company and its customers' needs. The amount of such protection will vary depending on the importance of this consideration, the availability of outside equipment that can be used or leased for short periods, the critical nature of the machine, the likelihood of prolonged downtime, and whether or not the work can be done on other types of equipment in the company, even if less productively.

Note on Use of Takt Time

Some planners find it useful to establish the number of machines using allowable processing time – sometimes called Takt or required cycle time. (Takt is a German word that refers to a timed sequence.) The allowable processing time is equal to the Available Work Time divided by the Demand during that work time; for example, 40 available hours divided by demand of 4560 lbs. = 0.00877 hrs. per lb. This is the interval or frequency at which good units must be produced to keep pace with average (leveled) demand. The planned processing time must always be less (faster) to allow for speed loss, idle time, downtime, changeovers, and yield loss. In our example, 0.00877 must be reduced to 0.0066 to allow for 95% yield at 80% efficiency. If a machine can produce 30 lbs. per hour, then it produces one pound every 1/30 or 0.0333 hours. Dividing this rate by our planned processing time of 0.0066 hours per pound would indicate a need for 5 machines.

Appendix IX – Layout Planning as a Kaizen Event

Where traditional industrial and manufacturing engineering departments have been replaced by continuous improvement or quality improvement programs, layout planning is often conducted during periodic improvement planning projects or *Kaizen* events to use the popular Japanese term. The typical event is a team-based "workshop" lasting one week or less, with a status presentation at the end of each day for management or other teams working in parallel.

The predefined steps and standard working forms of Systematic Layout Planning (SLP) make it ideal for running team based workshops of one week or less. The three fundamentals of *relationships, space* and *adjustment*, and the five sections of the SLP pattern of procedures form a logical day-by-day agenda with ready-made assignments. Completing the working forms and diagrams makes the process self-documenting. Daily status presentations "prepare themselves." And at the end of the event, the entire process has already been documented. Numerous examples have been provided in this text.

Layout planning events can result in three types of outputs:

1. Templates on paper or rough sketches – overall layout for a site or plant, or detail layout for an activity-area. (May be supported with models or renderings)
2. Actual mock-up or prototype layout – typically for standard bench workstation, assembly-line station, or small manufacturing cell, when mock-up space permits.
3. Installed layout – where machines and equipment can be moved within the timeframe of the workshop

One week is rarely enough time to include precision drafting of layout plans. So the workshop typically ends with the alternatives and the selected plan as pasted paper templates on a base drawing, or an electronic "sketch" of templates. Creating the final refined version(s) and dimensioned installation drawings will still need to be done later.

When a mock-up is the goal, SLP typically proceeds as far as the space relationship diagram or rough arrangement of scaled templates. Then, each template is modeled at actual size using corrugated paperboard and/or steel tubing. The adjustment into layouts is performed by moving the mock-up equipment around. Because there is no paper record of the alternatives being explored it is wise to photograph good alternatives as the team evolves to a final best arrangement.

When the goal is an actual layout, the "mock-up approach" can also be used if the equipment is limited to benches, shelves and parts racks. But for heavy machines or conveyors with bolts in the floor and utility hook-ups, it is impractical and wasteful to move them around in search of the best plan. Here, SLP should proceed all the way through evaluation of two or more alternatives on paper. These will be approximate arrangements of pasted templates on a scaled base drawing. For more precision, the drawing should include a scaled grid. Once the best arrangement has been identified, the team or installers move the actual equipment into final position.

Standard agendas for each type of output appear in Figure 1. Essential elements of successful one-week workshops are pictured in Figure 2.

	Goal / Output		
Day	**Plan on Paper**	**Mock-up or Prototype**	**Actual Installation**
One	Quick overview of Systematic Layout Planning (SLP). Confirm process and operating practices. Review input data. Make detailed operation process chart. Finalize activity-area or equipment list. (SLP Pattern Section 1)		
Two	Flow analysis (sub-team); Other-than-flow relationships (sub-team); Space estimates (sub team); Sub teams work in parallel. (SLP Sections 2 & 3)	Flow analysis (if needed). Relationship chart and diagram. Scaled templates and instruction sheets for mock-up builders. (SLP Sections 2 & 3)	Flow analysis (if needed). Relationship chart and diagram. Scaled templates and template relationship diagrams. (SLP Sections 2 & 3)
Three	Finish flow analysis. Combine flow & other. (leader/facilitator) Finish space estimates. Diagram relationships and space. Make scaled templates (evening) (SLP Sections 2 & 3)	Build mock-up elements. Complete any left-over work from Day 2 while mock-ups are built. Template-relationship diagram. (SLP Section 3)	Evaluate template arrangements and select the best. (SLP Sections 4 & 5). Begin machine and equipment moves if practical. (Evening)
Four	Finish scaled templates. Develop alternative template arrangements on base drawing. Evaluate alternatives. (SLP Sections 4 & 5)	Adjust mock-up into preferred arrangement. (SLP Sections 4 & 5)	Move machinery and equipment. Work as late as needed.
Five	Review and confirm Day Four evaluation. Capture good ideas from rejected plans. List next steps and open issues. Present results to management.	Final adjustment. Walk-through with operators and/or management. List next steps and open issues. Workshop presentation to management.	Walk-through with operators, final adjustments and hook-up. Safety review. Sign-offs. List of open issues and tasks still to do. Walk through with management.
Post-Workshop	Refine and prepare drawings of selected layout plan from selected template arrangement. Refine cost estimates. Confirm selection.	Prepare layout drawings from final mock-up.	Update layout drawings to match installation. Painting, floor striping, signage, markings, new containers, new equipment, etc. if not done during the workshop.

Figure 1. Daily agenda for 5-day layout planning workshop. Sections of the SLP Pattern provide milestones for each day of planning. By working at a small scale and keeping the activity list to fewer than 35 areas, plans on paper can easily cover 50,000 square meters (500,000 square feet) or more. Mock-up and actual installation workshops are typically for planning small areas. These are effective for manufacturing cells or departments of four to 10 easily-moved pieces of machinery and equipment; or for assembly line stations consisting of easily-moved fixtures, benches and parts-presentation racks.

Team Size, Staffing and Work Assignments

The ideal team size is between 5 and 8 people. Fewer and the team will likely lack knowledge of some areas, their relationships and space. More and it becomes hard to keep everyone actively involved. But very large teams of 10 or even 20 people can be accommodated by creating sub teams and working their assignments in parallel.

When planning for site and plant layouts with many activity areas, the facilitator should consider three sub-teams to work on: Flow, Other-Than-Flow, and Space. When it comes time to develop alternatives, two or three sub-teams should work in parallel on different alternative plans. This speeds up the planning and assures that more alternatives are considered.

When planning for mock-ups, sub-divide the construction of mock-up elements to keep everyone busy and avoid any delays waiting on construction.

Facilitator – trained, experienced and ideally certified in SLP. Available evenings. Working Forms downloaded; ready to use.

Knowledgeable cross-functional team, prepared and available without interruption. Operator involvement.

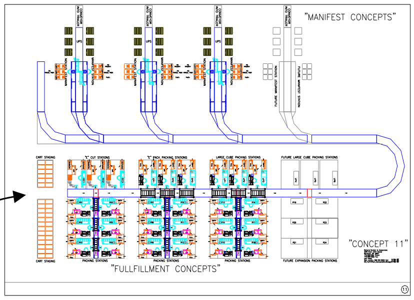
Large wall to display key documents. Display of hand-drawn and pasted up layouts OK if plotting not available.

Large work room and break out rooms for sub-teams. Also for management presentation of recommended plan.

Large work surface and area when planning in the shop itself, especially for detail layout at large scale.

Skilled support person to produce documentation and templates as the work progresses. Available evenings. Support equipment. Transparency projector; digital projector; printers, plotters; flip charts; white boards…

Supplies and equipment for making mock-ups. Here steel tube is being used. Large open area for full scale layout.



Computer-aided drafting support if drawings are desired. Available evenings.

Figure 2. Photos from various SLP workshops in North America, Asia and Europe. The captions describe capabilities essential for success in a one-week event.

Advanced Preparation

Finishing in one week requires thorough preparation before the workshop. The leader/facilitator must do the following:

1. Review the planned location, confirm space available and become familiar with any fixed monuments, activity-locations or other layout issues.
2. Understand the major layout alternatives that should be explored.
3. Formulate a list of objectives and assign weights, for guidance and as input to eventual layout evaluation.
4. Get P-Q data and any process charts or value-stream maps.
5. Prepare brief overview and instruction material in SLP.

6. Set up the working area. If in a conference or training room, provide a digital projector and small color ink jet plotter. If work will be done in the shop itself, then provide an extra-large table and display board.
7. Arrange for a drafting person, including evenings, if drawings are planned.
8. If the goal is an actual installation, two additional steps are:
    a. Survey all equipment and get detailed data on the hook-up of each.
    b. Assure that maintenance and plant engineering resources are available for making the moves, including evenings.

Workshop space and support

The workshop team will need a large space and perhaps multiple spaces for sub-teams. The main work area needs to be available at all times. Break out rooms – if needed – are only necessary on Days 2, 3 and 4. Laptop computers with spreadsheet software and the ability to print without walking long distances are essential. A small color ink-jet printer will be valuable for plotting color analyses and for making templates. Bring in meals and refreshments to avoid losing the team. Expect to work late at least two evenings and provide for supper and refreshments. Don't forget to include any shop personnel who may be helping with mock-ups or actual rearrangements.

Role of the Workshop Leader/Facilitator

The most important duties of the workshop leader/facilitator are:

1. Pick a team with the requisite knowledge of the operation, good analytical skills, and teamwork skills. Avoid "know-it-alls" and "lone rangers."
2. Understand the working forms of SLP and have some practice using them. (The ideal facilitator will be a certified practitioner in SLP[1]).
3. Conduct brief team training in SLP to explain the procedure, and to illustrate the steps and working forms[2]. (The best training will come from showing and explaining your own prior applications of SLP).
4. Perform the more tedious SLP tasks of combining flow and other relationships (if necessary) and drawing the relationship diagram. (Give the team an extended break while you do these; or do them on the evenings of Day 2 or 3).
5. Follow-up with team members and sub-teams to make sure they are making progress during break-outs. Reschedule and adapt if some fall behind.
6. Manage the level of detail during analysis – too little leads to superficial results and potential rework later; too much and the workshop doesn't produce.
7. Plan to work about 4 hours each evening after the team quits –to take care of documentation, catch-up any lagging tasks, and prepare for the next day.

Once you have one SLP workshop under your belt, you may find that you can get a lot of detail planning done in one week by facilitating two or three workshops in parallel.

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1. Certification in SLP is offered through Richard Muther & Associates. It consists of passing a written test and submitting a project using the method.

2. A training package in Plant Floor Layout is available from the Society of Manufacturing Engineers. It explains SLP in DVD format and may be helpful in training others.

Appendix X – Systematic Handling Analysis (SHA)

Materials handling is *moving*, transporting, or physically relocating *materials*, products, items, substances, or things, by *methods* that include equipment, containers, and a working system of routes, people, and procedures.

The fundamentals of materials handling – and therefore, the basis on which any handling analysis must rest – are *MATERIALS, MOVES,* and *METHODS.*

SHA – What is it?

Systematic Handling Analysis is an organized, universally applicable approach to any materials handling project. SHA consists of:

1. Framework of Phases
2. Pattern of Procedures
3. Set of Conventions

The Four Phases of SHA

As each handling project runs its course – from the initial statement of objectives to installed physical reality – it passes through four phases:

Phase I	External Integration
Phase II	Overall Handling Plan
Phase III	Detailed Handling Plans
Phase IV	Installation

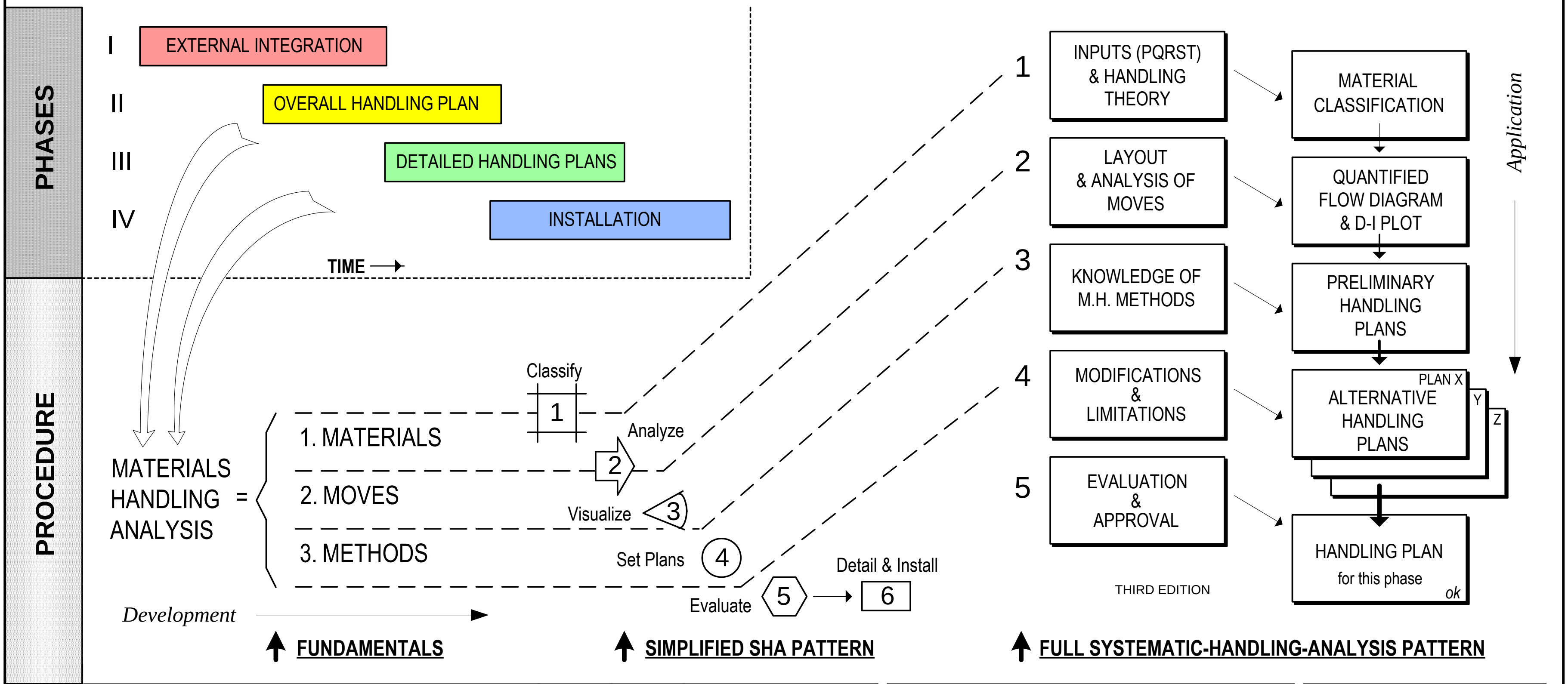
Refer to the upper left-hand portion of the SHA Capsule Summary, Figure 1.

Phase I is *External Integration.* Here we appraise the movements to and from the total area, or areas, being studied. We first consider the movement of material outside or external to our problem area. In this way, we correlate the specific handling problem with outside situations or external conditions, over which the planner may or may not have control. For example, this means identifying and possibly changing the way that incoming materials are packaged or contained, or changing truck access to our property or buildings.

Phase II involves the *Overall Handling Plan.* Here we establish the method(s) of moving the materials *between* the major areas. Overall decisions must be made on the basic system of moves, the general type(s) of equipment, and the transport units or containers to be used.

Phase III is the developing of *Detailed Handling Plans.* It concerns the movements of materials between various points *within* each major area. In this phase, we must decide on the detailed handling methods such as the specific system of moves, equipment, and containers to be used between individual workplaces. While Phase II related to moves between departments or buildings on a site, Phase III always relates to moves from one specific work place or piece of equipment to another.

SYSTEMATIC HANDLING ANALYSIS (SHA) -- Capsule Summary



CONVENTIONS

Process Chart Symbols & Action*	Symbols Extended to Identify Equipment & Space	Color Ident.	Black & White**	Formulas and Explanations
* ○ Operation	○ Forming or Treating Equipment & Space	Green**	▧	Intensity (I) = nP/t Designated by width of flow line
	○ Assembly, Sub-Assembly, Dis-Assembly	Red**	▥	
* ⇨ Transportation	⇨ Transport-related Equipment & Space	Orange Yellow**	░	Distance (D) Designated by length of flow line
⬠ Handling	⬠ Handling Areas – Pick-up & Set-down	Orange Yellow**	░	Transport Work (TW) TW = I x D = nP/t x D Designated by area of flow line
* ▽ Storage	▽ Storage Equipment and Space	Orange Yellow**	░	
* D Delay	D Set-down or Hold Areas	Orange Yellow**	░	
* □ Inspection	□ Inspect, Test, Check Equipment & Space	Blue**	▤	Example:
* A.N.S.I. Standard ** MHMS (IMMS) Standard (Adopted as basic to SHA procedure)	∩ Service & Support Equipment & Space	Blue**	▤	
	⇧ Office or Planning Areas, or Building Features	Brown** (Gray)	▓	M-H Systems: D-Direct C-Central K-Channel (Kanal)

Vowel Letter	No. Value	No. of Lines	Intensity Rating of Material Moves	Color Code
A	4	////	Abnormally High Intensity of Moves	Red**
E	3	///	Especially High Intensity of Moves	Orange Yellow**
I	2	//	Important Intensity	Green**
O	1	/	Ordinary Intensity	Blue**
U	0		Unimportant Moves of Negligible Intensity	Uncol-ored**

* Dash (dotted) line indicates half a line, or half-way between two ratings -- recorded by minus sign behind vowel letter.

** MHMS (IMMS) Standard (Adopted as basic to S.H.A. procedure)

Evaluating Description	Letter / Value
Almost Perfect Results (Excellent)	A / 4
Especially Good Results (Very Good)	E / 3
Important Results (Good)	I / 2
Ordinary Results (Fair)	O / 1
Unimportant Results (Poor)	U / 0
Not Acceptable Results (Not Satisfactory)	X / ?

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Figure 2.

Phase IV is *Installation.* Here, we plan the necessary make-ready, procure the equipment, complete the training of personnel, schedule and accomplish the installation of physical handling facilities. After this, we complete the try-out of planned handling methods, release to operating people, and monitor the completed installation to be sure it is operating properly.

The four phases follow each other in chronological sequence. And, for best results, they should overlap, with approval at the completion of each phase.

Phase I and Phase IV are frequently not part of the materials-handling engineer's specific problem. For this reason, we shall concentrate on the strictly planning phases: II, the Overall Handling Plan, and III, the Detailed Handling Plans.

Key Input Data

The key input elements or preliminary information needed to analyze a materials handling problem include:

P	Products or materials (parts, items, commodities)
Q	Quantities (sales-or-contract volume)
R	Routing (operating sequence and process requirements)
S	Supporting Services (like scheduling, order writing, maintenance)
T	Time (timing and operating times)

These are virtually identical with the input data required for SLP – or for almost any facilities planning project for that matter. Gathering this information is the first step in SHA.

The SHA Pattern of Procedures

Materials-handling analysis, involves analyzing the *materials* to be moved, analyzing the *moves* that must be made, and establishing practical economic *methods* to accomplish the movement of the materials. These three fundamentals are listed on the left-center of Figure 1. Dashed lines across the center show how the SHA Pattern of Procedures rests squarely on upon them.

The Pattern of Systematic Handling Analysis is a step-by-step series of procedures to follow. The more complicated the problem, the more useful and timesaving this pattern becomes.

The analytical part of making a handling plan begins with the study of the materials (products or items). This involves a *Material Classification* (Section 1 of the Pattern). Classes of materials are based on common or similar physical characteristics and on their quantities, timing, or special control requirements.

Before we can fully analyze or visualize the moves, we need a *layout* plan (Section 2) within which the handling methods must work. As a result, the layout plan – real or on paper, existing or projected – provides the context for our analysis and visualization of moves.

Next comes the *Analysis of Moves.* Basically, this involves determining the intensity and character of moves required to be made for each material on each route (origin to destination).

The next step is to translate our analysis into a visual “picture.” This is commonly done by a quantified flow diagram or a distance-intensity plot.

Before we can develop a solution, we need some *Knowledge of Materials Handling Methods* (Section 3). We apply this knowledge to our analysis of moves and set *Preliminary Handling Plans.* That is, we make a make a systematic tie-in of the system of moves, the handling equipment, and the transport unit (or container). Actually, we develop a number of logical preliminary possibilities.

In Section 4, we adjust our preliminary plans by considering all relevant Modifications and Limitations. Here, we modify and adjust each plan, converting what is possible to what is practical.

The purpose of adjusting or modifying the preliminary plans is to eliminate all ideas which are not workable. But before we can make any real selection of the best methods, we need to calculate the number of pieces of equipment or transport units, the costs involved, and the operating times involved.

We are now ready for the last steps in the pattern (Section 5). Here we make an *Evaluation* of alternative plans – usually of costs and intangibles. As a result of this evaluation, an approval is made of one of the alternatives – although often a combination of two or more plans may result from the evaluation process itself. By this evaluation, one of the alternative plans is now chosen. This becomes our *Handling Plan* for Phase II.

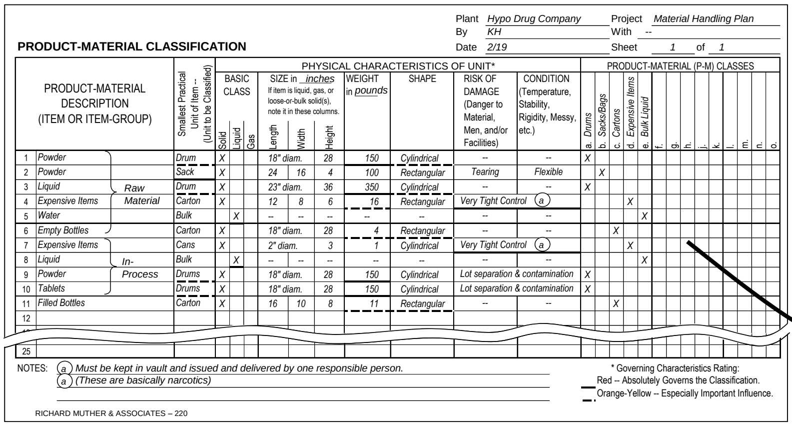
Illustrated Example

To help understand the SHA Pattern, an actual example is shown in Figure 2. For this project, the SHA Pattern was used in planning the overall handling methods. All details are not shown. The case example is intentionally oversimplified for ease of understanding.

SHA Pattern Applies to Both Phases II and III

The SHA Pattern applies to both Phase II – Overall Handling Plan – and to Phase III – Detailed Handling Plans. That is, the same pattern of steps prevails, although the degree of application will be more detailed and finite in Phase III. And of course, the handling methods for the detailed areas themselves will have to integrate with the more important overall handling methods selected in Phase II.

1. Key Input Data: P, Q, R, S, T



Plant *Hypo Drug Company* Project *Material Handling Plan*
By *KH* With --
Date *2/19* Sheet *1* of *1*

PRODUCT-MATERIAL CLASSIFICATION

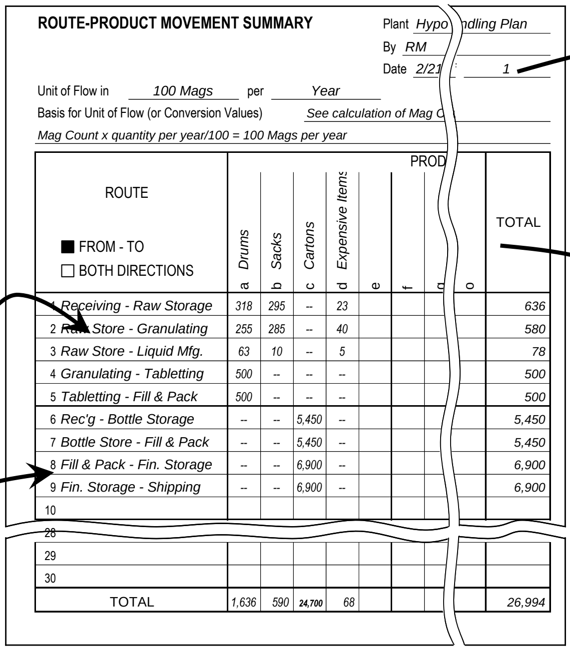
	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)		Smallest Practical Unit of Item -- (Unit to be Classified)	PHYSICAL CHARACTERISTICS OF UNIT* BASIC CLASS Solid	Liquid	Gas	SIZE in *inches* If item is liquid, gas, or loose-or-bulk solid(s), note it in these columns. Length	Width	Height	WEIGHT in *pounds*	SHAPE	RISK OF DAMAGE (Danger to Material, Men, and/or Facilities)	CONDITION (Temperature, Stability, Rigidity, Messy, etc.)	PRODUCT-MATERIAL (P-M) CLASSES a. Drums	b. Sacks/Bags	c. Cartons	d. Expensive Items	e. Bulk Liquid	f.	g.	h.	j.	k.	l.	m.	n.	o.
1	*Powder*	*Raw Material*	*Drum*	*X*			*18" diam.*		*28*	*150*	*Cylindrical*	--	--	*X*													
2	*Powder*		*Sack*	*X*			*24*	*16*	*4*	*100*	*Rectangular*	*Tearing*	*Flexible*		*X*												
3	*Liquid*		*Drum*	*X*			*23" diam.*		*36*	*350*	*Cylindrical*	--	--	*X*													
4	*Expensive Items*		*Carton*	*X*			*12*	*8*	*6*	*16*	*Rectangular*	*Very Tight Control* ⓐ					*X*										
5	*Water*		*Bulk*		*X*		--	--	--	--	--	--	--					*X*									
6	*Empty Bottles*		*Carton*	*X*			*18" diam.*		*28*	*4*	*Rectangular*	--	--			*X*											
7	*Expensive Items*	*In-Process*	*Cans*	*X*			*2" diam.*		*3*	*1*	*Cylindrical*	*Very Tight Control* ⓐ					*X*										
8	*Liquid*		*Bulk*		*X*		--	--	--	--	--	--	--					*X*									
9	*Powder*		*Drums*	*X*			*18" diam.*		*28*	*150*	*Cylindrical*	*Lot separation & contamination*		*X*													
10	*Tablets*		*Drums*	*X*			*18" diam.*		*28*	*150*	*Cylindrical*	*Lot separation & contamination*		*X*													
11	*Filled Bottles*		*Carton*	*X*			*16*	*10*	*8*	*11*	*Rectangular*	--	--			*X*											
12																											
25																											

NOTES: ⓐ *Must be kept in vault and issued and delivered by one responsible person.*
ⓐ *(These are basically narcotics)*

* Governing Characteristics Rating:
Red -- Absolutely Governs the Classification.
Orange-Yellow -- Especially Important Influence.

RICHARD MUTHER & ASSOCIATES – 220

1. Material Classification



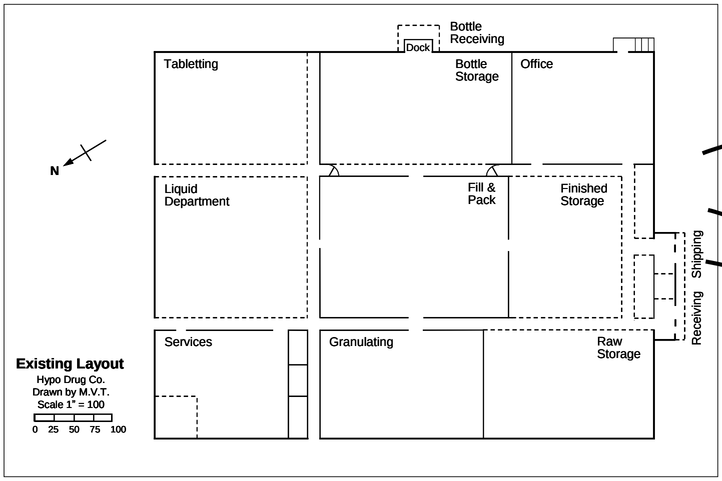
ROUTE-PRODUCT MOVEMENT SUMMARY

Plant *Hypo ndling Plan*
By *RM*
Date *2/21* *1*

Unit of Flow in *100 Mags* per *Year*
Basis for Unit of Flow (or Conversion Values) *See calculation of Mag C*
Mag Count x quantity per year/100 = 100 Mags per year

ROUTE ■ FROM - TO ☐ BOTH DIRECTIONS	PROD a *Drums*	b *Sacks*	c *Cartons*	d *Expensive Items*	e	f	g	o	TOTAL
1 *Receiving - Raw Storage*	*318*	*295*	--	*23*					*636*
2 *Raw Store - Granulating*	*255*	*285*	--	*40*					*580*
3 *Raw Store - Liquid Mfg.*	*63*	*10*	--	*5*					*78*
4 *Granulating - Tabletting*	*500*	--	--	--					*500*
5 *Tabletting - Fill & Pack*	*500*	--	--	--					*500*
6 *Rec'g - Bottle Storage*	--	--	*5,450*	--					*5,450*
7 *Bottle Store - Fill & Pack*	--	--	*5,450*	--					*5,450*
8 *Fill & Pack - Fin. Storage*	--	--	*6,900*	--					*6,900*
9 *Fin. Storage - Shipping*	--	--	*6,900*	--					*6,900*
10									
28									
29									
30									
TOTAL	*1,636*	*590*	*24,700*	*68*					*26,994*

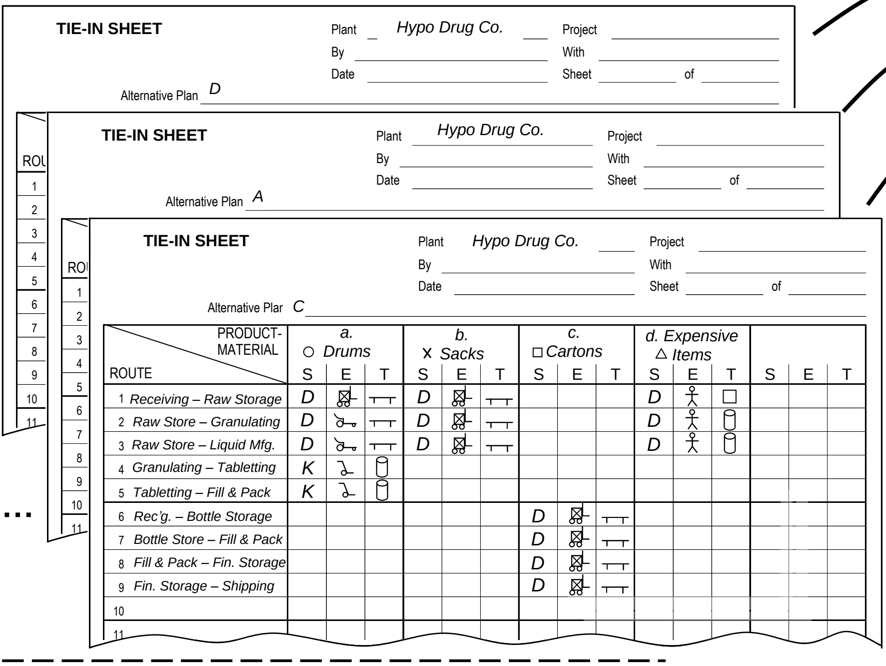
2. Analysis of Moves



Existing Layout
Hypo Drug Co.
Drawn by M.V.T.
Scale 1" = 100

2. Layout

4. Alternative Handling Plans
based on modification and limitations to preliminary plans



TIE-IN SHEET
Plant *Hypo Drug Co.* Project
By With
Date Sheet of
Alternative Plan *D*

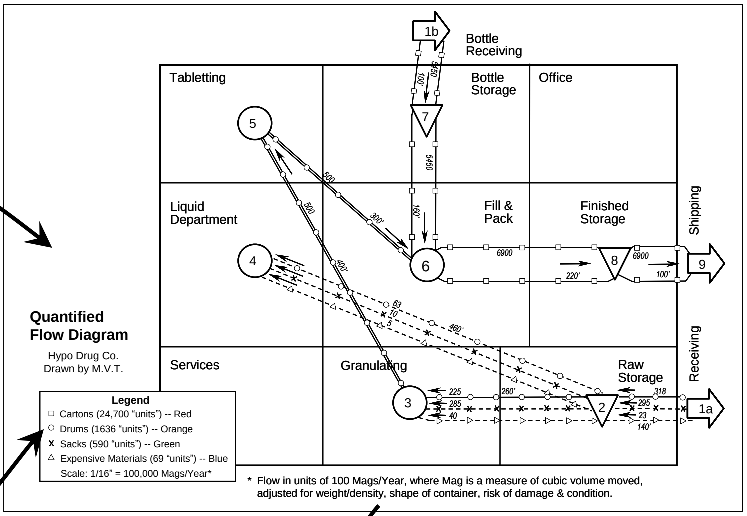
TIE-IN SHEET
Plant *Hypo Drug Co.* Project
By With
Date Sheet of
Alternative Plan *A*

TIE-IN SHEET
Plant *Hypo Drug Co.* Project
By With
Date Sheet of
Alternative Plar *C*

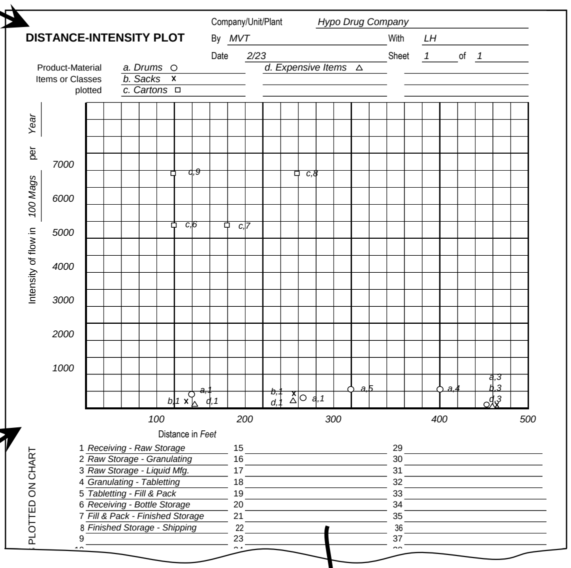
PRODUCT-MATERIAL / ROUTE	*a.* ○ *Drums* S	E	T	*b.* X *Sacks* S	E	T	*c.* □ *Cartons* S	E	T	*d. Expensive* △ *Items* S	E	T	S	E	T
1 *Receiving – Raw Storage*	*D*			*D*						*D*		□			
2 *Raw Store – Granulating*	*D*			*D*						*D*					
3 *Raw Store – Liquid Mfg.*	*D*			*D*						*D*					
4 *Granulating – Tabletting*	*K*														
5 *Tabletting – Fill & Pack*	*K*														
6 *Rec'g. – Bottle Storage*							*D*								
7 *Bottle Store – Fill & Pack*							*D*								
8 *Fill & Pack – Fin. Storage*							*D*								
9 *Fin. Storage – Shipping*							*D*								
10															
11															

3. Experience, knowledge, and understanding of materials handling methods… leading to Preliminary Handling Plans

S.H.A. in Action



2. Quantified Flow Diagram



DISTANCE-INTENSITY PLOT

Company/Unit/Plant *Hypo Drug Company*

By *MVT* With *LH*

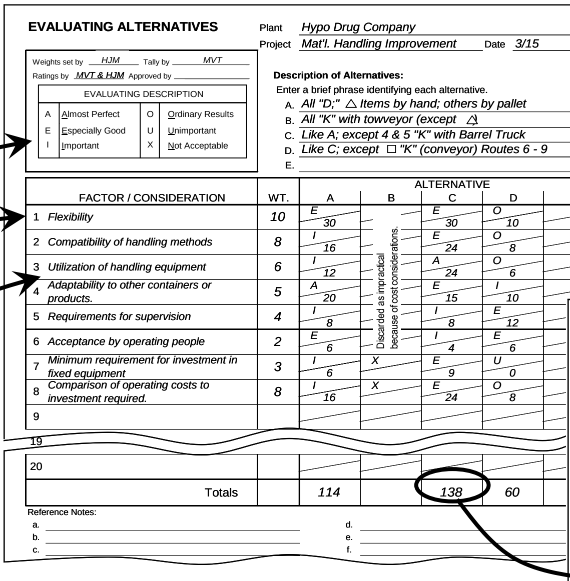
Date *2/23* Sheet *1* of *1*

Product-Material Items or Classes plotted: *a. Drums* ○ *b. Sacks* x *c. Cartons* □ *d. Expensive Items* △

PLOTTED ON CHART

1 *Receiving - Raw Storage*	15	29
2 *Raw Storage - Granulating*	16	30
3 *Raw Storage - Liquid Mfg.*	17	31
4 *Granulating - Tabletting*	18	32
5 *Tabletting - Fill & Pack*	19	33
6 *Receiving - Bottle Storage*	20	34
7 *Fill & Pack - Finished Storage*	21	35
8 *Finished Storage - Shipping*	22	36
9	23	37

2. Distance-Intensity Plot



EVALUATING ALTERNATIVES

Plant *Hypo Drug Company*

Project *Mat'l. Handling Improvement* Date *3/15*

Weights set by *HJM* Tally by *MVT*

Ratings by *MVT & HJM* Approved by

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important	X	Not Acceptable

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. *All "D;" △ Items by hand; others by pallet*

B. *All "K" with towveyor (except △)*

C. *Like A; except 4 & 5 "K" with Barrel Truck*

D. *Like C; except □ "K" (conveyor) Routes 6 - 9*

E.

FACTOR / CONSIDERATION	WT.	ALTERNATIVE A	B	C	D	E
1 *Flexibility*	*10*	*E* *30*	Discarded as impractical because of cost considerations.	*E* *30*	*O* *10*	
2 *Compatibility of handling methods*	*8*	*I* *16*		*E* *24*	*O* *8*	
3 *Utilization of handling equipment*	*6*	*I* *12*		*A* *24*	*O* *6*	
4 *Adaptability to other containers or products.*	*5*	*A* *20*		*E* *15*	*I* *10*	
5 *Requirements for supervision*	*4*	*I* *8*		*I* *8*	*E* *12*	
6 *Acceptance by operating people*	*2*	*E* *6*		*I* *4*	*E* *6*	
7 *Minimum requirement for investment in fixed equipment*	*3*	*I* *6*	*X*	*E* *9*	*U* *0*	
8 *Comparison of operating costs to investment required.*	*8*	*I* *16*	*X*	*E* *24*	*O* *8*	
9						
19						
20						
Totals		*114*		*138*	*60*	

Reference Notes:

a.

b.

c.

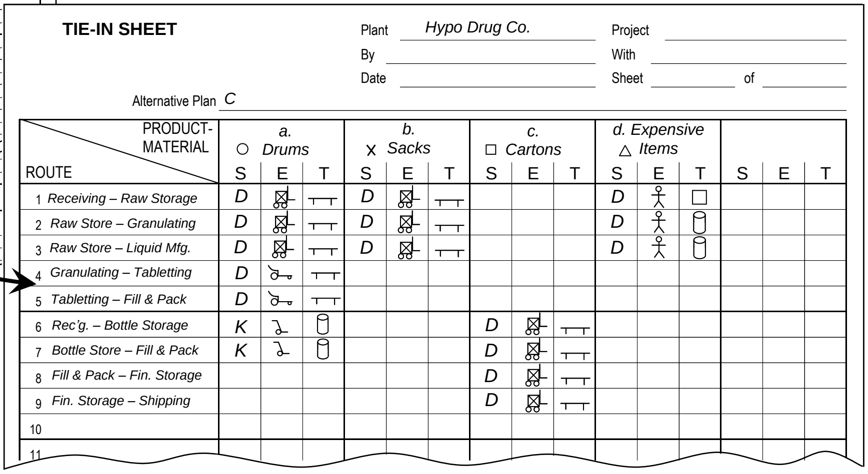
d.

e.

f.

5. Evaluation

5. Selected Handling Plan
Phase II – Overall Handling Plan



TIE-IN SHEET

Plant *Hypo Drug Co.* Project

By With

Date Sheet of

Alternative Plan *C*

PRODUCT-MATERIAL / ROUTE	*a.* ○ *Drums* S	E	T	*b.* x *Sacks* S	E	T	*c.* □ *Cartons* S	E	T	*d. Expensive* △ *Items* S	E	T	S	E	T
1 *Receiving – Raw Storage*	*D*	⊠	┬─┬	*D*	⊠	┬─┬				*D*	🚶	□			
2 *Raw Store – Granulating*	*D*	⊠	┬─┬	*D*	⊠	┬─┬				*D*	🚶	⌷			
3 *Raw Store – Liquid Mfg.*	*D*	⊠	┬─┬	*D*	⊠	┬─┬				*D*	🚶	⌷			
4 *Granulating – Tabletting*	*D*	🛒	┬─┬												
5 *Tabletting – Fill & Pack*	*D*	🛒	┬─┬												
6 *Rec'g. – Bottle Storage*	*K*	⅃	⌷				*D*	⊠	┬─┬						
7 *Bottle Store – Fill & Pack*	*K*	⅃	⌷				*D*	⊠	┬─┬						
8 *Fill & Pack – Fin. Storage*							*D*	⊠	┬─┬						
9 *Fin. Storage – Shipping*							*D*	⊠	┬─┬						
10															
11															

Figure 2. Steps and key documents of Systematic Handling Analysis (SHA). The example is for a pharmaceutical manufacturing plant. Alternative handling plans are summarized in Section 4 using equipment symbols presented in the following Appendix XI.

SHA includes a six-step simplified or short-form procedure for small projects.[1] The six steps are symbolized in the center of Figure 1. Simplified SHA is suitable for planning the handling methods in smaller facilities or individual areas and work cells within a larger facility. In such projects, Steps 1 through 5 develop and evaluate alternative plans. Step 6 works out the details for the selected plan.

SHA Conventions

When performing the steps in the SHA pattern, we use certain conventions to identify route origins and destinations, to visualize moves, to rate alternatives, to sort into orders of magnitude, and the like. These conventions include the various symbols, colors, black-and-white shadings, vowel letters, lines, and numbers shown in the lower portion of the Capsule Summary, Figure 1. The SHA conventions are consistent with those of SLP, including the American Society of Mechanical Engineers' former Standard on Operation and Flow Process Charts and the Material Handling Management Society in its Standard Color Codes for Plant Layout and Materials Handling Analysis.

SHA – An Organized Approach

In this synopsis, we have examined the basic methodology of Systematic Handling Analysis: an approach to solving problems, a series of steps to follow, and a set of recording, rating, and visualizing conventions. Basically, SHA includes a *framework of four phases* of analysis, each of which overlaps the preceding and following phases. It includes a *pattern of step-by-step procedures* to follow in Phase II and Phase III, the steps being enlarged from the fundamentals: Materials, Moves, Methods.

The pattern draws directly on the five key elements needed to analyze a handling problem. And it ties in with external conditions and recognizes and processes the key input data and integrates layout plans as part of the handling-plan analyses.

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1. A detailed explanation of Simplified SHA is available in the booklet: *Simplified* Systematic Handling Analysis by Richard Muther et al. available from the Material Handling Industry of America or from Management and Industrial Research Publications at www.MIRPBooks.com. An updated edition of the full text, Systematic Handling Analysis (SHA) by Richard Muther and Knut Haganäs is planned for publication in 2015.

Appendix XI – Material Handling Equipment and Containers

It is beyond the scope of this book on layout planning to discuss the features and functions of the many kinds of material handling equipment used in industry.[1, 2] Instead, we have simply discussed (in Chapters 9, 11 and 12) the need to decide and know what handling methods will be used in the layout being planned. Figure 9-7 presents an evaluation form useful for selecting handling equipment. In Chapter 16, we also briefly recognized the value of an integrated approach to industrial facilities planning, in which layout and handling are two interrelated components.

In Appendix X we provide a synopsis of Systematic Handling Analysis (SHA), a companion method to SLP for planning sound material handling methods. In SHA, choices of equipment are illustrated with the symbols sets are presented here in Figures 1, 2 and 3. They are organized in a meaningful way and thus provide the reader with at a general overview or survey of equipment types available for use in any industrial layout.

Figure 1 shows equipment symbols for moving materials through a layout. The symbols are organized in columns by technical nature or classification: vehicles (flexible path); conveyors (fixed path); cranes/hoists (some flexible; some fixed) and other.

The vehicle and conveyor symbols are arranged roughly from “simple” for low-intensity short-distance moves to “complex” for high-intensity and long-distance. “Complex” typically means mechanized and even automatic. Equipment costs rise from simple (top) to complex (bottom).

Figure 2 shows equipment symbols for picking-up and setting-down and for containing materials. Some of the pick-up and set-down devices and all of the containers will be used in conjunction with the handling symbols in Figure 1. Pick-up and set-down devices may affect space required at the ends of a move and are therefore of interest in detail layout of the areas and workplaces where they will be used.

Figure 3 shows equipment symbols for storage and order picking. The choice of this equipment has a direct bearing on floor space requirements wherever material comes to rest for staging or storage. As illustrated in Figure 9-8, storage equipment must be chosen with handling equipment in mind.

All three symbols sets are available in Microsoft Excel ® format from the Richard Muther & Associates website: www.RichardMuther.com They are intended to annotate layouts and to populate tables and charts. Actual photographs can be used instead, but ironically the reality and detail in a photo often makes it harder to read than a symbol.

Examples of how these symbols are used appear in Figure 2 of Appendix X, on the Tie-In Sheets illustrating Sections 4 & 5. They may also be used directly on a layout plan as shown Figure 9-6.

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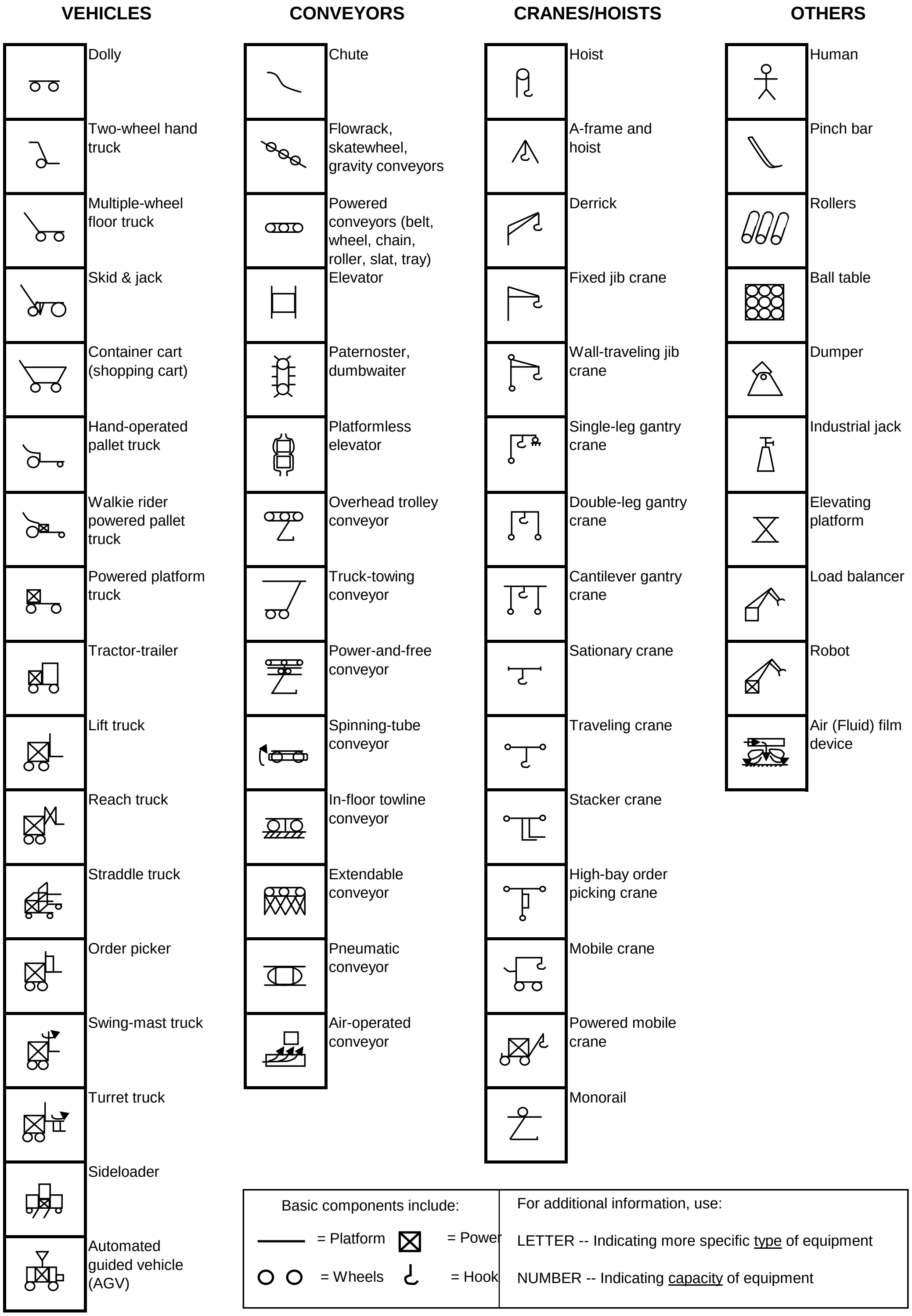
1. A the time of this publication, the most recent industry handbook on handling equipment is already 30 years old: Materials Handling Handbook, 2nd ed., Raymond Kulwiec, John Wiley & Sons, Inc. 1985. Somewhat more ore recent and narrow is the Tool and Manufacturing Engineers Handbook: Volume 9 Material and Part Handling in Manufacturing, Ed. Philip Mitchell, Society of Manufacturing Engineers, 1998.

2. Much information on particular types of handling and storing equipment can be found by searching the Material Handling Industry of America website: www.mhia.org and its various links.

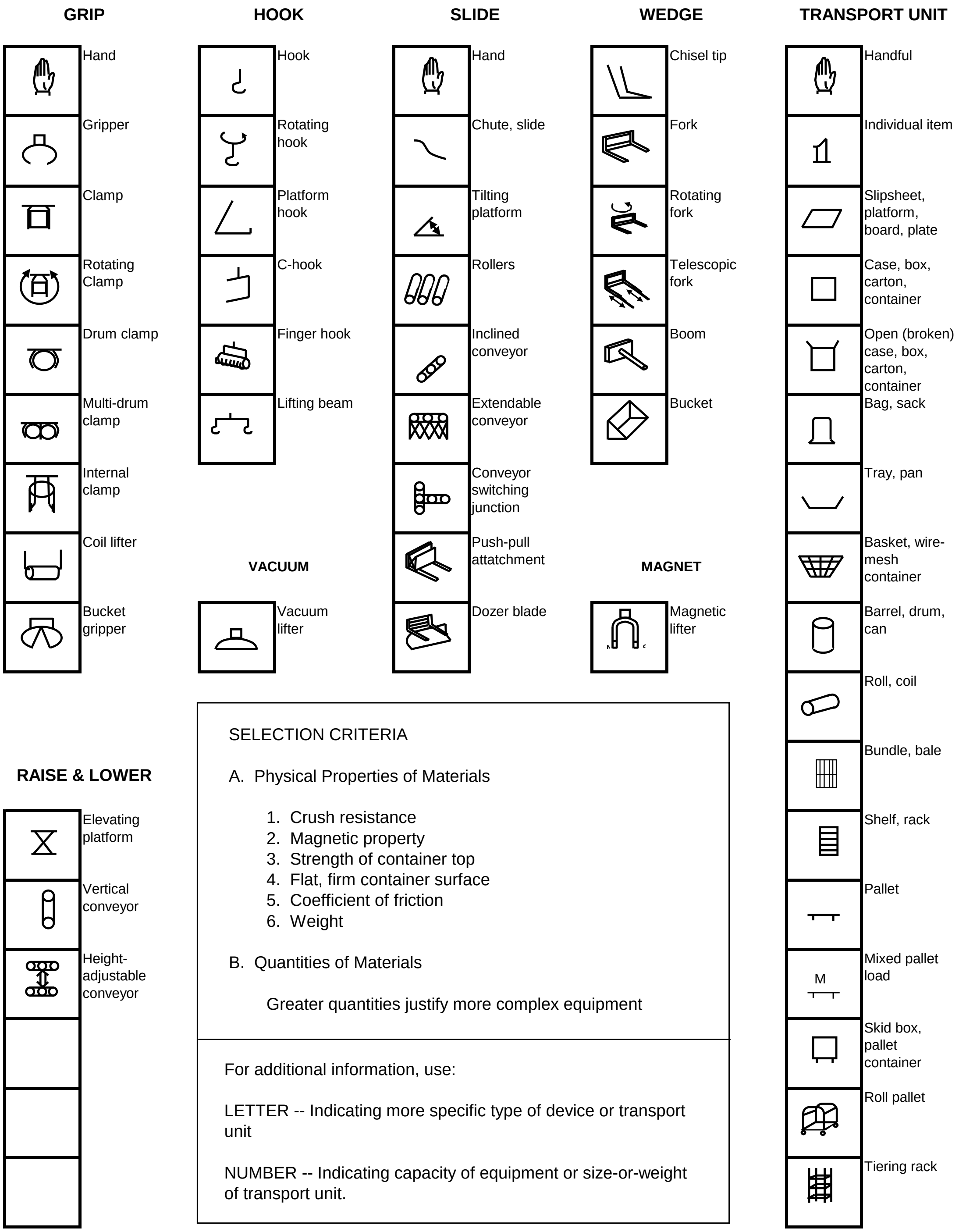
MATERIALS HANDLING EQUIPMENT SYMBOLS



RICHARD MUTHER & ASSOCIATES - 1245

Figure 1. Materials handling equipment symbols. Available in electronic form at www.RichardMuther.com

PICK-UP & SET-DOWN DEVICES AND TRANSPORT UNITS SYMBOLS



SELECTION CRITERIA

A. Physical Properties of Materials

1. Crush resistance
2. Magnetic property
3. Strength of container top
4. Flat, firm container surface
5. Coefficient of friction
6. Weight

B. Quantities of Materials

Greater quantities justify more complex equipment

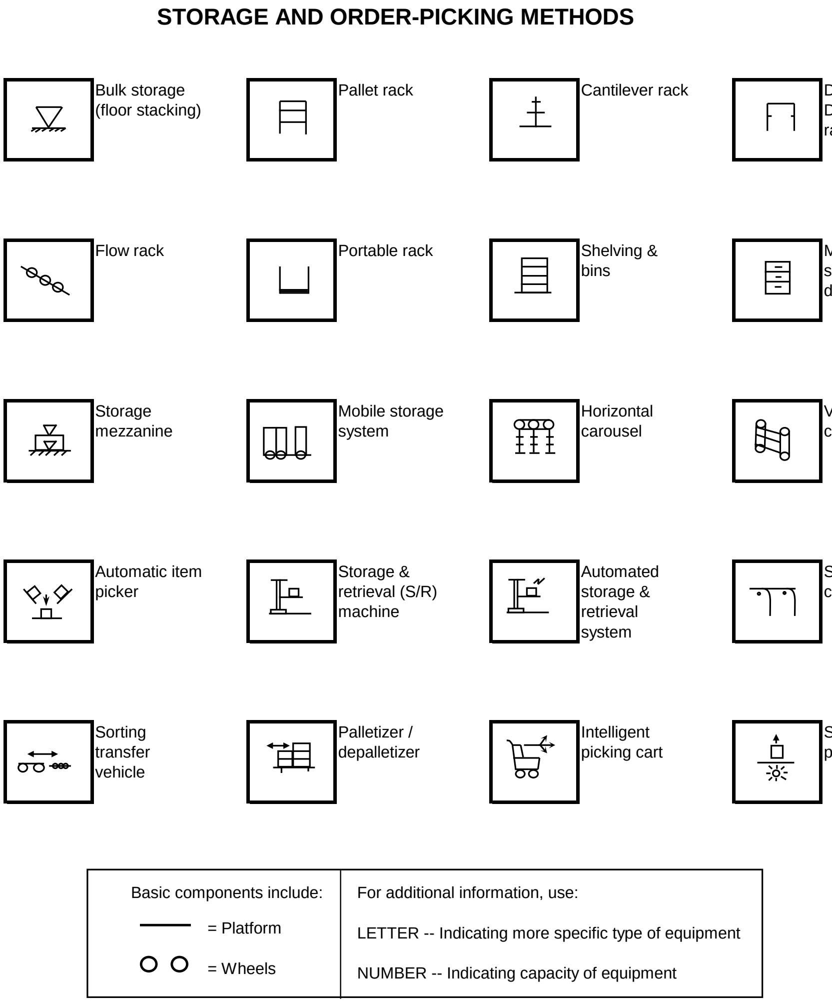
For additional information, use:

LETTER -- Indicating more specific type of device or transport unit

NUMBER -- Indicating capacity of equipment or size-or-weight of transport unit.

RICHARD MUTHER & ASSOCIATES - 1247

Figure 2. Pick-up and set-down devices and transport units symbols. Available in electronic form at www.RichardMuther.com



RICHARD MUTHER & ASSOCIATES - 1248

Figure 3. Storage and order-picking methods symbols. Available in electronic form at www.RichardMuther.com

Appendix XII – Factors or Considerations in Selecting the Layout

When evaluating alternative layouts, there are many factors which can affect the selection of the most suitable plan. The factors most frequently identified are listed below. A definition of each is also given. Then key points to consider in making an evaluation are set forth. These factors, definitions, and key points – in a consolidated form or together with others that may be added as appropriate for a particular company or project – can be extremely helpful in keeping a clear understanding and meaning for each factor during the process of evaluation.

1. EASE OF FUTURE EXPANSION *(The simplicity of increasing the space. employed.)*

a. Tie-in with long-range potential use of the space,
    - with the future plans for building or property development,
    - with the basic overall allocation of space, and
    - with the overall flow pattern(s).

b. Ability to spread out to adjacent areas – beside, above, below,
    - to encroach on readily moved storage or service areas, or
    - to add vertical storage equipment, balconies, mezzanines.

c. Freedom from fixed or permanent building features,
    - from divided or honeycombed areas, and
    - from space blocked-in by physically long equipment, property lines, natural obstructions or limitations, and the like.

d. Regularity of allocated space amounts in terms of
    - readily exchangeable amounts and types of areas,
    - modular units of layout space, multiple unit areas.

e. The amount of disruption or rearrangement of areas other than the one(s) specifically being expanded.

f. Shrinkability – ease of contracting the layout economically, to cut down the size if necessary.

2. ADAPTABILITY AND VERSATILITY *(The ease of accommodating, in the layouts as planned (without rearrangement), changes (normal or emergency) in, and variety (or number) of, items like the following.)*

a. Product, materials, or items
b. Quantity or volume
c. Frequency of delivery
d. Process equipment
e. Operation sequence
f. Working methods and operating time
g. Handling or storing methods
h. Utilities or auxiliaries
i. Other services
j. Type or classification of employees
k. Time-keeping or count system
l. Hours of work
m. Material dispatching procedure
n. Inspection controls
o. Rework procedures
p. Standby equipment
q. Additional space for stock
r. Alternate routes
s. Test runs, pilot lots, experimental engineering

3. FLEXIBILITY OF LAYOUT *(The ease of physically rearranging the layout to accommodate changes.)*

a. Mobility of machinery and equipment
b. Relative size and fixity of equipment
c. Standardization of equipment, containers, work places
d. Freedom from fixed building features or walls, unmatching floor levels, other barriers
e. Overly dense saturation of space
f. Independence or self-sufficiency of facilities (not dependent on central coordination or centralized service tie-in)
g. Ready accessibility of service lines, piping, power distribution, heating and ventilating, service holes, etc.
h. Access to the area laid out at more than one point or side

4. FLOW OR MOVEMENT EFFECTIVENESS *(The effectiveness of sequenced working operations or steps-without unnecessary back-tracking, cross flow, transfers, long hauls-of materials, paper work, or people.)*

a. Greatest flow intensities with minimum distances
b. Basic regularity or consistency of flow pattern(s)
c. Proximity of related areas to each other where movement of material, people, or major paper work is involved, or where frequent, urgent or significant personal contact takes place
d. Access to, away from, and between major areas (like receiving, shipping, key operating areas)
e. Flow of auxiliary or service materials: supplies, tools, scrap or waste, and other service materials
f. Accessibility for delivery and pick-up, visitors, or employed non-company service personnel

5. MATERIALS HANDLING EFFECTIVENESS *(The ease or simplicity of the handling system, equipment, and containers to move materials into, through, and out of the areas laid out.)*

a. Ease of tie-in with external handling methods and equipment: rail line, docks, highway, and other accessways
b. Necessity for re-handling, extra handling, delays, awkward positioning, undue physical effort, undue dependence on frequency or urgency of moves, undue amount of jury-rig or non-integrated equipment
c. Traffic congestion and interferences other than due to flow pattern
d. Balanced variety of handling systems, equipment and containers
e. High utilization of handling equipment and containers
f. Simplicity of handling devices
g. Equipment integrated for multiple use
h. Dependence on M. H. equipment on maintenance, repair, replacement parts
i. Avoidance of synchronizing two or more people at same time or place
j. Ability to move completely around buildings on company property
k. Take advantage of gravity
l. Combined purposes of handling equipment for storing, pacing, sequencing, inspecting, work-holding, weighing and the like, as well as moving

6. STORAGE EFFECTIVENESS *(The effectiveness of holding required stocks of materials, parts, products, service items.)*

a. Inclusion of all storage – raw, in-process, finished goods, supplies, tools, scrap or waste, trash and equipment or materials not in current use
b. Accessibility of items stored
c. Ease of locating or identifying items stored
d. Ease of stock and inventory control
e. Ability to make stored items available according to urgency of demand
f. Protection of material (fire, moisture, dust, dirt, heat, cold, pilferage, deterioration, spoilage.)
g. Adequacy of storage space(s)
h. Suitably close to points of delivery and use

7. SPACE UTILIZATION *(The degree to which floor area and cubic space is put to use.)*

a. Conservation of floor space, property, or land – or most desirable portions thereof
b. Utilization of overhead space in terms of cubic density
c. Ability to share or exchange space among similar activities, and balancing of areas with seasonally complimentary space requirements
d. Effectiveness of aisle space:
    - to serve areas adjacent to them,
    - to lead to areas needing access,
    - to handle traffic without wasting space or without excessive aisleways (too few, too many, too wide, too narrow, too cornered or crooked, too angular.)
e. Waste or idle space, caused by split, divided, cornered, scattered or otherwise honeycombed structures, too-close columns, too-frequent partitions or walls.
f. Less desirable or out-of-way space utilized for slow, dead areas; convenient space for fast, active areas

8. EFFECTIVENESS OF SUPPORTING SERVICE INTEGRATION *(The way supporting areas are arranged so as to serve the operating areas.)*

a. Ability of existing (or planned) systems, procedures, and controls to work effectively with the layout, including: production planning, scheduling and control, time-keeping, material or stock issuing, work count, tool control, personnel records, receiving and shipping system
b. Ability of the layout to integrate with desired or effective pay plans, performance measure, cost reports, lot size, order quantities
c. Physical closeness of service areas according to each area's need for the service (actual versus desired relationships).
d. Ability of the utilities, auxiliary service lines, and central distribution or collection systems to serve the layout. (Compressors, steam generators, transformers, chargers, and the like, and their accompanying pipes, ducts, wiring, etc.)
e. Service convenience of baler, salvage equipment, reclaim, incinerators, filter beds, scrap collection, and similar waste control areas or equipment
f. Ability of engineering groups, and technical advisors to support the layout effectively.

9. SAFETY AND HOUSEKEEPING *(The effect of the layout and its features on accidents or damage to employees and facilities, and on the general cleanliness of the areas involved.)*

a. Basic regularity of the aisles and work areas, and degree of freedom from equipment protruding into aisles or work areas, congestion, blind corners
b. Degree to which all safety codes and regulations are satisfied
c. Risk of danger to people or equipment
d. Availability of adequate exits and clear escape ways
e. First-aid facilities and fire extinguishers nearby
f. Floors free of obstructions, spillage, and mess, and not overly congested
g. Adequate protection or segregation for dangerous or unsightly operations
h. Workers not located under or above unprotected hazards;
    - workers not located too near moving parts, unguarded equipment, and other hazards
i. Workers able to get benefit from special safety devices or guards
j. Effectiveness of ways to clean or clear area of waste, offal, trimmings, trash
k. Ease of keeping areas clean, sanitary, snow-white, under controlled conditions

10. WORKING CONDITIONS AND EMPLOYEE SATISFACTION *(The extent to which the layout contributes to making the area(s) a pleasant place to work and free from inconveniences, awkwardness, or disruptions for employees.)*

a. Effect of layout on attitude, performance, or general morale of employees
b. Working conditions suitable to the type of operation
c. Suitability of the layout's arrangement and allocated space to the personnel
d. Convenience for employees-access, distances, interruptions, delays, and adequacy and convenience of parking, lockers, rest rooms, food facilities, etc.
e. Freedom from features causing workers to feel afraid, hemmed-in, embarrassed, discouraged, discriminated against
f. Noise, distractions, or undue heat, cold, drafts, dirt, glare, or vibrations
g. Utilization of employee know-how and skills
h. Balanced man-power allocations

11. EASE OF SUPERVISION AND CONTROL *(The ease or difficulty for supervisors and managers to direct and control the operations for which they are responsible.*)

a. Ability to see the area fully and easily
b. Ability to get around the area conveniently
c. Ease of controlling quality, quantity counts, schedules, inventories in process
d. Ease of controlling waste time, lost materials, or supplies
e. Ease of moving or reassigning personnel to other work

12. APPEARANCE, PROMOTIONAL VALUE, PUBLIC OR COMMUNITY RELATIONS *(The ability of the layout to afford engaging or attractive facilities, having value in promoting the company name or reputation in the community and territories served by the company.)*

a. Attractiveness of external or viewable features, yards, main structure, out buildings
b. Ability to serve as show-place or reflect reliability, progressiveness or other company qualities
c. Regularity, symmetry, clean lines, and organized appearance
d. Fit with community appearance, tradition, character
e. Effects on neighbors (benefits and irritants)

13. QUALITY OF PRODUCT OR MATERIAL *(The extent to which the layout affects quality of the product, material, or their workmanship.)*

a. Damage or risk to materials caused by nature of the layout or its transport facilities
b. Contamination, corrosion, spoilage, or other detriments to the product's nature or condition as caused by the layout
c. Convenience and inter-relationship of quality control activities: inspection areas, Q.C. office, test facilities, control laboratories, engineering office, sample room, gauge crib, and the like

14. MAINTENANCE PROBLEMS *(The extent to which the layout will benefit or hinder maintenance work, including building and machine repair as well as day-to-day service.)*

a. Adequacy of facilities for maintenance and repair work
b. Sufficiency of space for access to machinery and equipment to be lubricated, checked, cleaned, adjusted, on-spot repaired, or otherwise maintained
c. Appropriate janitor and cleaner facilities

15. FIT WITH COMPANY ORGANIZATION STRUCTURE *(The degree to which the layout matches or disrupts the planned or desired organization structure.)*

a. Eliminate, combine, or streamline supervision, or effectiveness with which the layout helps otherwise improve the alignment of managerial personnel
b. Areas having the same supervisory responsibility are adjacent or convenient to each other
c. Staffing or manning of layout fits with job classifications and salary schedules

16. EQUIPMENT UTILIZATION *(The extent to which machinery and equipment, both operating and service, is used.)*

a. Degree of utilizing all equipment: operating, utility and auxiliary handling, storing, servicing or otherwise supporting
b. Necessity for duplicating equipment caused by layout versus use of common equipment and services
c. Over-capacity equipment necessitated by the layout
d. Man-machine efficiency planned into the layout

17. PLANT SECURITY AND THEFT *(The ease or difficulty of safeguarding company proprietary or security-classified information, and of controlling theft or pilferage.)*

a. Ease of controlling and/or monitoring access to the plant:
    during working hours
    during off-shift hours
b. Ability to provide guard-controlled traffic access for all pedestrian and vehicular
c. Effective control of visitor or casual access to secure areas or information within the plant
d. Provision of adequate vaults for safe, secure storage of valuable or confidential records and documents
e. Ease of patrolling building(s) and/or grounds
f. Ease of controlling access to and dispensing of: drug supplies, tools, and expendables or easily pilfered items

18. UTILIZATION OF NATURAL CONDITIONS, BUILDING OR SURROUNDINGS *(The extent to which the layout takes advantage of or capitalizes on the natural conditions of the site, physical surroundings, building structure, or neighboring areas, and the suitability of the layout to these features.)*

a. Slope, topography, foundation, drainage
b. Direction of sun, prevailing wind
c. Rail line, highway, waterway, bridges, accessways, crossings
d. Building features, structure, shape, height, construction, docks, door locations, elevator(s), windows, walls, columns
e. Zoning of site and restrictions of community or neighborhood
f. Fit of the area(s) laid out onto the natural site or into the existing building or area allocated

19. ABILITY TO MEET CAPACITY OR REQUIREMENTS *(How well the layout actually meets the planned needs or output wanted from the installation.)*

a. The right products or materials, properly meeting specifications
b. The right quantities of each variety or item in the operating time planned, without overtime or premium pay
c. The right yield in terms of projected quantities and qualities of product

20. COMPATIBILITY WITH LONG-RANGE COMPANY PLAN *(The ability of the planned layout to fit with long-range growth projections and with long-range master site plan or total facilities development plan(s).)*

a. Degree of tie-in with long-range projections of products and/or materials, sales or operating quantities, process sequence and equipment, services, working hours and operating times
b. The ease of complete renovation, rehabilitation, modernization, or change in function
c. Ease of integration with other buildings, plants, or sites of the organization
d. Effect of the layout on the re-sale value of the property

Appendix XIII – Simplified Systematic Planning of Manufacturing Cells

Cell layout is usually straight-forward since it closely follows the process chart or flow diagram. But to fully plan an effective cell also requires the setting of handling methods, operating procedures, and personnel policies and practices. Systematic Planning of Manufacturing Cells (SPMC) was developed to address this full scope of cell planning. A six-step, short-form of the SPMC method – *Simplified* SPMC – is presented here.[1] It can be used with or as an alternative to SLP when planning an individual cell's operations and management. The full SPMC method is appropriate when planning several linked cells or a significant plant-wide implementation of cellular manufacturing.[2]

The six steps of Simplified SPMC form a logical sequence that takes the planner from raw data to a workable cell plan. The steps encompass the three fundamentals of any cell-planning project.

1. Parts – that are converted, treated and/or assembled or disassembled.
2. Process – the operations, their sequence and the equipment or machinery used to convert, treat or assemble the parts.
3. Coupling – the joining, combining or tying together of the parts and the process for effective production.

Figure 1 provides an illustrated overview of the working forms and outputs of Simplified SPMC. The six steps are explained in the following sections.

Step 1: Orient the Project

The first step organizes the project, identifying its objective(s) and situation. Here the planner also gains understanding of the planned physical location, its surrounding conditions and considerations. Planning issues – expected problems or opportunities related to the cell's planning or subsequent operations – are listed and rated. A plan and schedule for the cell planning project are prepared. The output of this step is a well-defined, understood and scheduled project.

Step 2: Classify the Parts

Step 2 determines which parts should go into the cell and identifies any sub-groupings within the cell. The planner lists the potential or candidate cell parts and gathers data for each one: basic material, size, weight, shape, risk of damage, production volume, routing and more. The planner uses this data to identify parts that should be included in the cell and places them into classes. Each part class will go through the same sequence of operations and equipment, and can be physically handled the same way. Classification is accomplished using a worksheet to sort parts by their characteristics. Those with similar characteristics and routings are assigned to the same class. The output of Step 2 is a clear identification of the classes of parts (groups of items) included in the cell, their distinguishing characteristics, and what parts are in each class.

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1. A detailed explanation of Simplified SPMC is available in the booklet: *Simplified* Systematic Planning of Manufacturing Cells, by Richard Muther et al. English-language copies are available from Management and Industrial Research Publications at www.MIRPBooks.com

2. The full SPMC method for large projects is explained in the text: Planning Manufacturing Cells, by H. Lee Hales and Bruce Andersen, published by the Society of Manufacturing Engineers.

Step 3: Analyze the Process

Step 3 uses the Group-of-Parts Process Chart to determine the sequence of operations for each class of parts and the type and number of equipment needed for the cell. This is then visualized with the Equipment and Flow Diagram. This diagram illustrates the sequence of operations and relative arrangement of equipment for most effective flow of materials, use of equipment, and balance of working times.

The Group-of-Parts Process Chart is a version of the multi-product process chart illustrated earlier in Figures 4-11 and 12. Each class of parts has a column; each operation a row. The routing for each class is shown by placing and connecting a circle in each operation (row) used by the class. The planner also enters operating times for each operation and multiplies these by the number of parts utilizing the operation. This calculates the total time for each operation. Dividing the total time per operation by hours available for each piece of equipment yields the required number of machines for each operation, adjusted as needed to allow for yields and downtime.

Starting with the highest-volume class, the planner draws the Equipment and Flow Diagram using rectangular boxes to represent the operations and machines required. These are placed in the sequence shown on the Group-of-Parts Process Chart. The routing for each class is depicted by drawing and labeling lines between the symbols. When completed, the diagram portrays in necessary sequence all machines needed for the cell. This diagram interrelates the parts and their processes and leads the planner directly to layouts that provide effective material flow.

Step 4: Couple Into Cell Plans

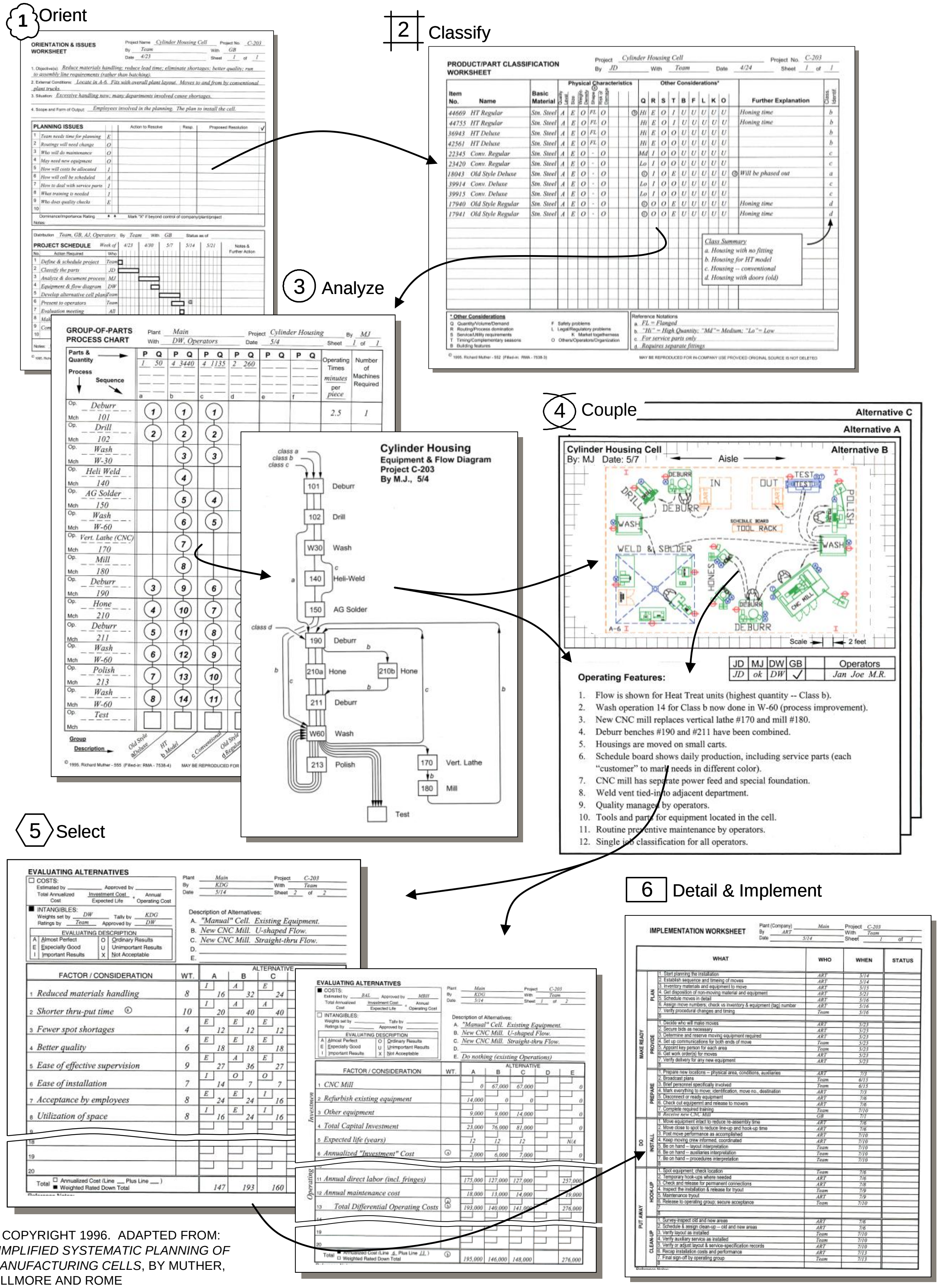
In Step 4, the planner ties together the physical equipment (including tools or attachments) with proposed handling methods, controls and operating practices to develop viable alternative cell plans.

First develop layouts based on the flow of material depicted on the Equipment and Flow Diagram. Then determine material handling methods, production control and reporting procedures, and other practices and procedures appropriate to each layout. Involvement is crucial. Operators and others who have a stake in the cell should assist in developing alternative layouts and operating plans. Check the planning issues identified in Step 1 to make sure all significant problems and opportunities are addressed.

The output of Step 4 is two or three viable alternative cell plans. Each will work, but each has different features, benefits, costs and risks. Each cell plan should include:

- A layout of operating equipment.
- The method of moving or handling parts.
- Written description of how to schedule, operate, service and support the cell.
- Resolution of the planning issues.

Figure 1. Steps, key documents and outputs of Simplified SPMC. Adapted from the booklet: Simplified Systematic Planning of Manufacturing Cells, Richard Muther et al., Management & Industrial Research Publications.



ORIENTATION & ISSUES WORKSHEET

Project Name *Cylinder Housing Cell* Project No. *C-203*
By *Team* With *GB*
Date *4/23* Sheet *1* of *1*

1. Objective(s): *Reduce materials handling; reduce lead time; eliminate shortages; better quality; run to assembly line requirements (rather than batching).*
2. External Conditions: *Locate in A-6. Fits with overall plant layout. Moves to and from by conventional plant trucks.*
3. Situation: *Excessive handling now; many departments involved cause shortages.*
4. Scope and Form of Output: *Employees involved in the planning. The plan to install the cell.*

PLANNING ISSUES			Action to Resolve	Resp.	Proposed Resolution	✓
1	*Team needs time for planning*	*E*				
2	*Routings will need change*	*O*				
3	*Who will do maintenance*	*O*				
4	*May need new equipment*	*O*				
5	*How will costs be allocated*	*I*				
6	*How will cell be scheduled*	*A*				
7	*How to deal with service parts*	*I*				
8	*What training is needed*	*I*				
9	*Who does quality checks*	*E*				
10						

Dominance/Importance Rating Mark "X" if beyond control of company/plant/project
Notes:

Distribution *Team, GB, AJ, Operators* By *Team* With *GB* Status as of

PROJECT SCHEDULE		Week of	4/23	4/30	5/7	5/14	5/21	Notes & Further Action
No.	Action Required	Who						
1	*Define & schedule project*	*Team*						
2	*Classify the parts*	*JD*						
3	*Analyze & document process*	*MJ*						
4	*Equipment & flow diagram*	*DW*						
5	*Develop alternative cell plans*	*Team*						
6	*Present to operators*	*Team*						
7	*Evaluation meeting*	*All*						

PRODUCT/PART CLASSIFICATION WORKSHEET

Project *Cylinder Housing Cell* Project No. *C-203*
By *JD* With *Team* Date *4/24* Sheet *1* of *1*

Item No.	Name	Basic Material	Quality Level	Size	Weight-Density	Shape ⓐ	Risk of Damage				Q	R	S	T	B	F	L	K	O		Further Explanation	Class. Identif.
44669	*HT Regular*	*Stn. Steel*	*A*	*E*	*O*	*FL*	*O*			ⓑ	*Hi*	*E*	*O*	*I*	*U*	*U*	*U*	*U*	*U*		*Honing time*	*b*
44755	*HT Regular*	*Stn. Steel*	*A*	*E*	*O*	*FL*	*O*				*Hi*	*E*	*O*	*I*	*U*	*U*	*U*	*U*	*U*		*Honing time*	*b*
36943	*HT Deluxe*	*Stn. Steel*	*A*	*E*	*O*	*FL*	*O*				*Hi*	*E*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*b*
42561	*HT Deluxe*	*Stn. Steel*	*A*	*E*	*O*	*FL*	*O*				*Hi*	*E*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*b*
22345	*Conv. Regular*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				*Md*	*I*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*c*
23420	*Conv. Regular*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				*Lo*	*I*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*c*
18043	*Old Style Deluxe*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				ⓒ	*I*	*O*	*E*	*U*	*U*	*U*	*U*	*U*	ⓒ	*Will be phased out*	*a*
39914	*Conv. Deluxe*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				*Lo*	*I*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*c*
39915	*Conv. Deluxe*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				*Lo*	*I*	*O*	*O*	*U*	*U*	*U*	*U*	*U*			*c*
17940	*Old Style Regular*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				ⓒ	*O*	*O*	*E*	*U*	*U*	*U*	*U*	*U*		*Honing time*	*d*
17941	*Old Style Regular*	*Stn. Steel*	*A*	*E*	*O*	-	*O*				ⓒ	*O*	*O*	*E*	*U*	*U*	*U*	*U*	*U*		*Honing time*	*d*

Class Summary
a. Housing with no fitting
b. Housing for HT model
c. Housing -- conventional
d. Housing with doors (old)

* Other Considerations
Q Quantity/Volume/Demand
R Routing/Process domination
S Service/Utility requirements
T Timing/Complementary seasons
B Building features
F Safety problems
L Legal/Regulatory problems
K Market togetherness
O Others/Operators/Organization

Reference Notations
a. *FL = Flanged*
b. *"Hi" = High Quantity; "Md" = Medium; "Lo" = Low*
c. *For service parts only*
d. *Requires separate fittings*

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JD	MJ	DW	GB	Operators
JD	*ok*	*DW*	✓	*Jan Joe M.R.*

Operating Features:

1. Flow is shown for Heat Treat units (highest quantity -- Class b).
2. Wash operation 14 for Class b now done in W-60 (process improvement).
3. New CNC mill replaces vertical lathe #170 and mill #180.
4. Deburr benches #190 and #211 have been combined.
5. Housings are moved on small carts.
6. Schedule board shows daily production, including service parts (each "customer" to mark needs in different color).
7. CNC mill has separate power feed and special foundation.
8. Weld vent tied-in to adjacent department.
9. Quality managed by operators.
10. Tools and parts for equipment located in the cell.
11. Routine preventive maintenance by operators.
12. Single job classification for all operators.

EVALUATING ALTERNATIVES

☐ COSTS:
Estimated by ______ Approved by ______
Total Annualized Cost = Investment Cost / Expected Life + Annual Operating Cost
■ INTANGIBLES:
Weights set by *DW* Tally by *KDG*
Ratings by *Team* Approved by *DW*

Plant *Main* Project *C-203*
By *KDG* With *Team*
Date *5/14* Sheet *2* of *2*

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant Results
I	Important Results	X	Not Acceptable

Description of Alternatives:
A. *"Manual" Cell. Existing Equipment.*
B. *New CNC Mill. U-shaped Flow.*
C. *New CNC Mill. Straight-thru Flow.*
D.
E.

FACTOR / CONSIDERATION	WT.	A	B	C
1 *Reduced materials handling*	*8*	*I* 16	*A* 32	*E* 24
2 *Shorter thru-put time* ⓐ	*10*	*I* 20	*A* 40	*A* 40
3 *Fewer spot shortages*	*4*	*E* 12	*E* 12	*E* 12
4 *Better quality*	*6*	*E* 18	*E* 18	*E* 18
5 *Ease of effective supervision*	*9*	*E* 27	*A* 36	*E* 27
6 *Ease of installation*	*7*	*I* 14	*O* 7	*O* 7
7 *Acceptance by employees*	*8*	*E* 24	*E* 24	*I* 16
8 *Utilization of space*	*8*	*I* 16	*E* 24	*I* 16
9				
18				
19				
20				
Total ☐ Annualized Cost (Line ___ Plus Line ___) ■ Weighted Rated Down Total		*147*	*193*	*160*

EVALUATING ALTERNATIVES

■ COSTS:
Estimated by *BAL* Approved by *MBH*
Total Annualized Cost = Investment Cost / Expected Life + Annual Operating Cost
☐ INTANGIBLES:
Weights set by ______ Tally by ______
Ratings by ______ Approved by ______

Plant *Main* Project *C-203*
By *KDG* With *Team*
Date *5/14* Sheet *1* of *2*

Description of Alternatives:
A. *"Manual" Cell. Existing Equipment.*
B. *New CNC Mill. U-shaped Flow.*
C. *New CNC Mill. Straight-thru Flow.*
D.
E. *Do nothing (existing Operations)*

	FACTOR / CONSIDERATION	WT.	A	B	C	D	E
Investment	1 *CNC Mill*		*0*	*67,000*	*67,000*		*0*
	2 *Refurbish existing equipment*		*14,000*	*0*	*0*		*0*
	3 *Other equipment*		*9,000*	*9,000*	*14,000*		*0*
	4 *Total Capital Investment*		*23,000*	*76,000*	*81,000*		*0*
	5 *Expected life (years)*		*12*	*12*	*12*		*N/A*
	6 *Annualized "Investment" Cost*	ⓐ	*2,000*	*6,000*	*7,000*		*0*
Operating	11 *Annual direct labor (incl. fringes)*		*175,000*	*127,000*	*127,000*		*257,000*
	12 *Annual maintenance cost*		*18,000*	*13,000*	*14,000*		*19,000*
	13 *Total Differential Operating Costs*	ⓐⓑ	*193,000*	*140,000*	*141,000*		*276,000*
	19						
	20						
	Total ■ Annualized Cost (Line *6* Plus Line *13*) ☐ Weighted Rated Down Total	ⓑ	*195,000*	*146,000*	*148,000*		*276,000*

Step 5: Select the Best

In Step 5 the cell planning team evaluates the alternative cell plans and selects the best. This typically includes a comparison of the initial investment, ongoing operating costs, and intangible advantages of each plan. A simple way to compare and evaluate costs is to annualize the investment for each alternative based on the expected life of the cell and its equipment. Then add the annualized investment to annual operating cost to get the total annual cost for each alternative. Use the weighted-factor method explained in Chapter 10 to compare and evaluate the intangibles. Compare all costs and intangibles to select the preferred cell plan. Recognize that it is often the intangibles evaluation that makes the winner.

Step 6: Detail and Implement

The final step is to plan the details for both the design and the installation. Reproduce the cell plan in more detail – suitable for installation. Design or provide the tools or attachments for each operation within the cell. Complete and write the procedures for the cell. Verify the supporting equipment, procedures and training. Plan and schedule the implementation. Mobilize the implementers and make it happen.

The Full SPMC Method

Systematic Planning of Manufacturing Cells (SPMC) is an organized way to conduct cell planning for large-scale, multiple-cell installations. Like its companion methods SLP and SHA, SPMC uses a framework of four overlapping phases to plan at successive levels of detail; here, from plant to an area of cellular operations, and then to individual cells, sub-cells and workplaces.

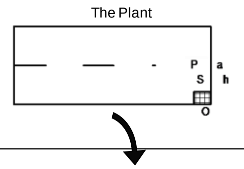
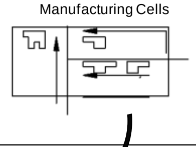
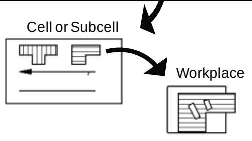
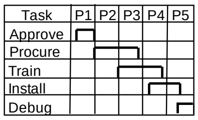
Planning Phases	Scope & Visualization	Outputs
I. ORIENTATION Location, external conditions and planning the planning. The surrounding physical and non-physical conditions/considerations; plus the objective, situation and plan for planning the cell.		• Objectives • Project plan & schedule • Targeted parts or operational area • Planned location • External conditions • Scope; “givens”, or limits of team’s authority
II. OVERALL CELL PLAN The general plan for cellular operations. Definition of the cell or cells: how many; what parts, what processes and equipment. Alternative block layouts of space and equipment. Operating relationships and integration between cells and the rest of the plant.		• Definition of cells: what parts, what operations, what equipment • Block layout of cells and supporting areas • Material handling and coupling between cells • Preliminary cell layouts • General operating policies and practices
III. DETAILED CELL PLANS Detail plans and designs for each cell. The detailed arrangements of equipment and workplace design. Specification of detailed operating procedures and methods within each cell.		• Confirmed definition of cell: parts, operations, equipment • Detailed layout for each cell • Material handling within the cells (between work stations) • Detailed operating policies and procedures
IV. IMPLEMENTATION Do; take action on the plans. Schedule, provide, procure, train, install, cleanup, debug...		• Project approval and funding • Detailed implementation plan • Procured equipment • Working cell

Figure 2. Four phases for planning multiple and linked-cell installations. From the book: Planning Manufacturing Cells, H. Lee Hales & Bruce Andersen, Society of Manufacturing Engineers.

Appendix XIV – Synopsis of Simplified SLP

Simplified Systematic Layout Planning is an abbreviated version of Systematic Layout Planning (SLP). This simplified version of SLP is best suited to office areas up to about 3,000 square feet, to shop or laboratory areas up to about 5,000 square feet, and in storage areas up to about 8,000 or 10,000 square feet. Basically, it comprises a set of six procedures or steps that encompass the three fundamentals of any layout planning project.

1. *Relationships* between various functions, activities, or work stations
2. *Space* in a certain amount, kind, and/or shape for each activity
3. *Adjustment* of the relationships and spaces into a layout planes)

The six steps form a logical sequence which takes the planner from raw data to a workable layout plan. Figure 1 illustrates each of the six steps, and each is described below in more detail. Note that a different symbol is used to help identify each step, though the symbol has no significance itself in the planning.

Step 1. Chart the Relationships

To determine which activities (or departments or work groups) should be located next to others, the relative closeness required must be measured, and recorded in a simple way that shows the relative closeness desired between each pair of activities. In addition, we should have some way of recording *why* that particular closeness rating is assigned.

The Relationship Chart (RMA-130) is a device for recording, in an organized way, the results of these decisions. A vowel-letter closeness-desired rating (A, E, I, O, and U in descending order of value) is used; X is used to show a not desirable relationship. The closeness-rating letter is posted in the upper half of the diamond-shaped block that shows the relationship between a pair of activities. Additionally, the "reason" is coded by numbers, entering the number in the lower half of the block. The reason coded to each number is explained in a separate section of the form. In this way, the individual relationship between every pair of activities is rated, substantiated, and recorded.

Step 2. Establish Space Requirements

In the next step, establishing space requirements, the same activities as in Step 1 are listed. Then establish and record the space required to support each activity. These amounts of space can be established in several ways. One is to determine, for each individual activity, the amount of space now used; then, apply a factor for the effectiveness of utilization of existing space and another factor for any projected change in the level of operations to be supported. Another is to sketch out to scale, or otherwise tally, the space for each piece of equipment (allowing for working area, access aisles, maintenance room and the like); calculate the area required to house each work area; and total the space required for the entire operation. For rest rooms, private offices, and parking areas, standard space requirements may be used.

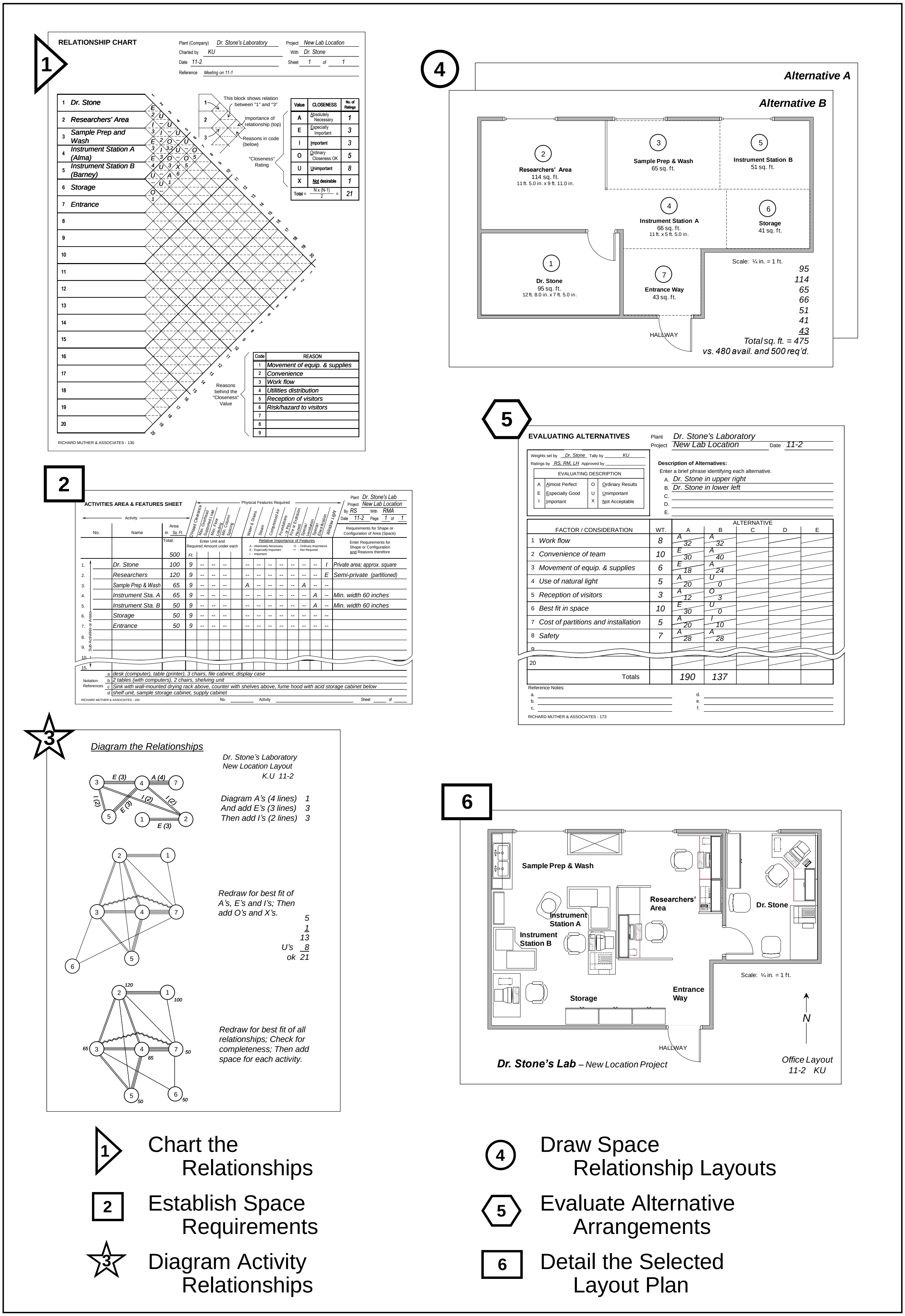


Figure 1. The Six Steps of Simplified SLP

The center portion of the Activities Area and Features Sheet (RMA-150) provides a way of entering pertinent data about physical features that are required. And, on the right-hand side of the form, there is space for noting any specific shape or configuration – and the reasons for it.

Step 3. Diagram Activity Relationships

So far, we have merely tabulated, accumulated data. Now convert those data into a more usable form by preparing an activity relationship diagram. Circles, numbered for identification, are used to represent the activities. Each pair of activities is connected by parallel lines corresponding to the ratings on the relationship chart prepared in Step 1. The highest rated relationships (A) are represented by four connecting lines; the E's and I's with three and two lines, respectively. The diagram is then redrawn for the best fit of relationships, and the O's and X's added. X's are shown as zig-zag or wiggly lines. The diagram may be rearranged a second or third time for best fit of all relationships.

The goal is to place activities with the highest closeness ratings nearest each other, and lower ratings relatively farther away. When the best arrangement is worked out, the required floor space is marked on the diagram beside each activity circle. This completed diagram represents the theoretical ideal arrangement of activities without consideration of the actual space involved for each activity. The relationship diagram is the most important step in the entire procedure. If it is not properly done, the planner cannot be certain of getting a layout with the best overall arrangement.

Step 4. Draw Space Relationship Layouts

The first two fundamental problems, relationships and space, having been solved, the diagram can be adjusted into a layout.

Draw the preliminary layout to scale in electronic form or perhaps on a sheet of graph paper or grid-line tracing paper laid over a floor plan or building print. The space required for each activity is blocked in, the relative position of each activity being maintained according to the relationships diagramed in Step 3. Ordinarily, the layout will need some adjustments to allow for such factors as availability of utilities, personnel convenience, procedures and controls, building features, equipment configurations, access ways, and the like. Such considerations influence the layout, whether the problem is a rearrangement of existing facilities or a completely new area.

Several workable layout plans usually result from this planning, and normally the two, three, or four best alternatives are drawn up.

Step 5. Evaluate Alternative Arrangements

An evaluation procedure is now used to assess objectively the relative value of the alternative layouts. First identify each alternative plan on the form used – RMA-173 is designed specifically for this purpose. Then list all the objectives to be achieved and factors influencing the choice. Assign relative weights to each factor-starting with 10 for the most important. Then rate the effectiveness of each arrangement for each factor, again using A, E, I, O, and U, in descending order of results provided by each plan.

After all ratings are thus made and recorded, convert the letter ratings to corresponding numerical values: A = 4, E = 3, I = 2, O = 1, and U = O. The numerical values are then multiplied, each by its factor's weight value, and the weighted, rated values down totaled for each alternative arrangement. The highest total value should indicate the most suitable layout.

Step 6. Detail the Selected Layout Plan

The final step is to redraw the layout to scale, identify the areas, show major features and equipment, draw in the details of each item of equipment and/or machinery, and show individual utilities as required. Reappraise the fit of these details; adjust as necessary; provide appropriate identification data and dimensions; and reproduce the required number of copies. After final approval, the planner should be able to turn the plans over to those persons who will actually install the equipment.

Simplified SLP should not be used for large or complex problems. Specifically, it is not suited to layouts where a high or dominant flow of materials is involved. In such cases, the full Systematic Layout Planning procedure is preferable. But the simplified method is ideal for small office, laboratory, or service areas. It is often used to train service department managers so they can plan their own Phase III detail layouts, and so save the planner’s time for the more complex areas. Banks, small businesses, and all manner of service and office operations have put Simplified SLP to good practical use. Indeed, just as Work Simplification takes the basic elements of cost reduction right to the supervisors and operators themselves, so Simplified S L P takes the basic elements of layout planning right to the non-technically trained supervisor or business manager.

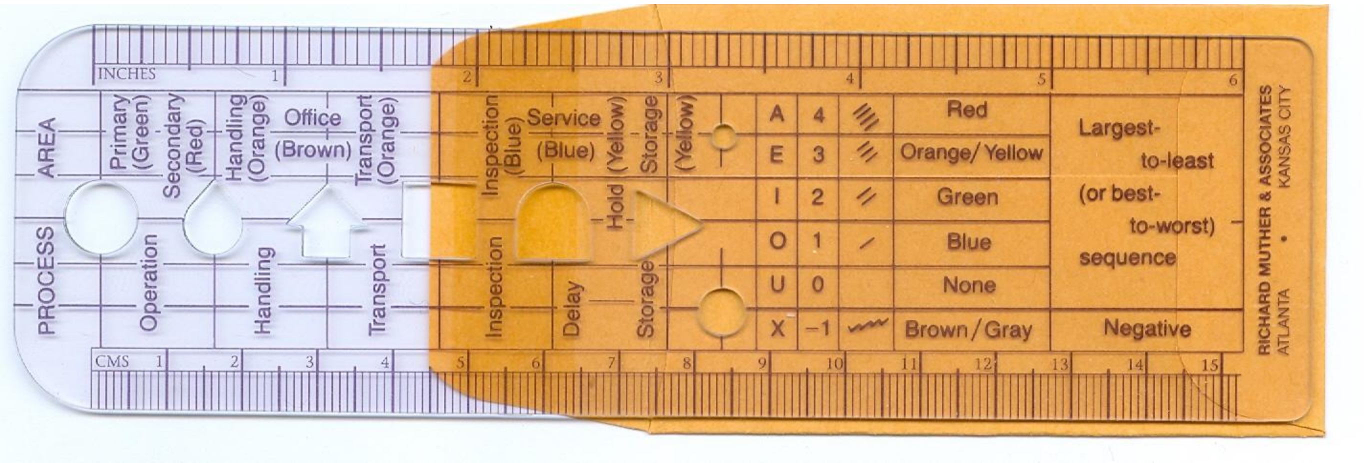
A more complete explanation of Simplified SLP is available in the booklet, *Simplified Systematic Layout Planning*, by Richard Muther and John Wheeler. With over 250,000 copies distributed world-wide, this publication is perhaps the most popular ever on the subject of layout planning. English-language copies can be obtained from Management and Industrial Research Publications at www.MIRPBooks.com

Working Forms

Following this page are fresh copies of most of the forms illustrated throughout the text. They may be removed and put to use when planning your next specific layout project.

You may reproduce copies of these forms for your own use, provided you recognize their original source and hold the use of the forms within the copyright restrictions covering this book. You may also obtain electronic copies of most forms at: www.RichardMuther.com Select Downloads and then register for Working Forms.

In the pocket below is a ruler with die-cut symbols. These should be used when charting and diagramming flow and activity relationships with pencil and paper. Also on the rule, for easy reference, are listed the chief rating and recording conventions used in Systematic Layout Planning (SLP).



See reverse side for list of Working Forms.

List of Working Forms

Each of the forms included in this section is explained in the text in the figure number referenced below and they are listed here in order of their appearance in the text. However, for ease of finding the working forms in this section, they are arranged behind this page in 3-digit form number sequence.

Fig No.	Form No.	Form Title
1-3	120	Product-Quantity Data Sheet
4-16	136	From-To Chart
5-2	130	Relationship Chart (20 activity-areas)
5-7b	129	Office Space Relationship Survey
5-8	131	Relationship Chart (45 activity-areas)
7-2	154	Machinery & Equipment Layout Data
7-3	164	Machinery & Equipment Layout Data Worksheet
7-4	153	Machinery & Equipment Area & Features Sheet
7-5	151	Office Layout Requirements Data
7-7	155	Space Requirements -- Converting
7-11	150	Activities Area & Features Sheet
9-7	202	M.H. Equipment Evaluation
9-15	901	Universal Problem-Solving Procedure
10-8	173	Evaluation of Alternatives
11-4	227	Flow Process Chart
11-5	535	Line Feeding Flow Chart
11-7	554	Group-of-Parts Process Chart
11-13	305	Review and Approval Record
12-5	524	Workplace Equipment Worksheet
12-11	564	Standardized Work
15-2	302	Installation Cost Summary
15-3	310	Installation Coordination Worksheet
15-6	315	Installation Instructions Summary
15-7	320	Installation Record
16-6	706	Project Schedule Sheet
16-7	710	Coordination and Progress Summary
App. II-4	240	Route Chart
App. II-5	140	Flow-In Flow-Out Chart
App. IV-2	142	Combining Flow & Service Relationships

PRODUCT-QUANTITY DATA SHEET

Plant
Data gathered by
Date

Project
With
Sheet of

Fill-in as applicable **PRODUCT INFORMATION**

For ONE PRODUCT - Form and/or Treat only

Product Name & Description
Finished condition (fluid, delicate, hazardous, etc.)
Size-shape
Normal unit of measure Weight/unit
Starting material condition
Size-shape Weight/unit
Normal container: as received as shipped:

For ONE PRODUCT - Assemble and/or Disassemble involved

Product Name & Description
Finished condition
Size-shape Weight/unit

Major Components:	Material Condition	Size-shape	Weight/unit
a.			
b.			
c.			
d.			
e.			

☐ See Parts list(s) or Component Breakdown

PRODUCTION REQUIREMENTS

Quantity produced this year Source
Quantity anticipated next year Approved
Quantity anticipated in 5 yrs. Est. by
Length of time present product or model will be produced
Seasonal variation
Expansion Plans

Trends in product:

- Size Diversification
- Weight Simplification
- Materials
- Rec'g. & Shipping amounts and frequencies
- Refinements
- Other

Operating hours per shift per day
per week

Plan Layout for (no. of units)
per hour, day, week

For SEVERAL PRODUCTS

				Quantity:						
								Per Order or Lot	% of Produc-tion	Plan Layout for
Name of Product or Group	Condition	Size-shape	Weight/unit	This Yr.	Last Yr.	Next Yr.	5 Yrs			
A.										
B.										
C.										
D.										
E.										
F.										
G.										

Trends in Product:
Seasonal Variation
Expansion Plans
NOTES:

OFFICE SPACE RELATIONSHIP SURVEY

Activity Area ____________________
Sub-Area or Individual ____________________

Date: ____________________
By: ____________________
With: ____________________

Period Covered ____________________
Location ____________________
Space Assigned ____________________
Sheet ______ of ______

Note the activity-area, sub-area or individual entered above. Use the vowel-letter ratings below to rate the degree of closeness desired between this activity-area and the others listed on the left below. Ratings should represent closeness desired in an ideal situation. For each rating other than "U" (Unimportant), give one or more reasons using the code numbers below on the right. If the proper reason is not already listed, please write it in next to your rating. Most ratings should be U's and O's. There should be very few E's and perhaps only one or even no A's. Make ratings for the planning period indicated above.

No.	**Activity Area**	Enter Vowel Code for Closeness Desired to: **(Letter)**	For each rating other than "U", please enter one or more Reason Code #s from the list, or write in. **(Number)**

Vowel Code Ratings	**Meaning**
A	Closeness Absolutely Necessary
E	Closeness Especially Important
I	Closeness Important
O	Ordinary Closeness OK
U	Closeness Unimportant
X	Closeness Not Desirable

Reason Code #	**Meaning**
1	
2	
3	
4	
5	
6	
7	
8	
Other	

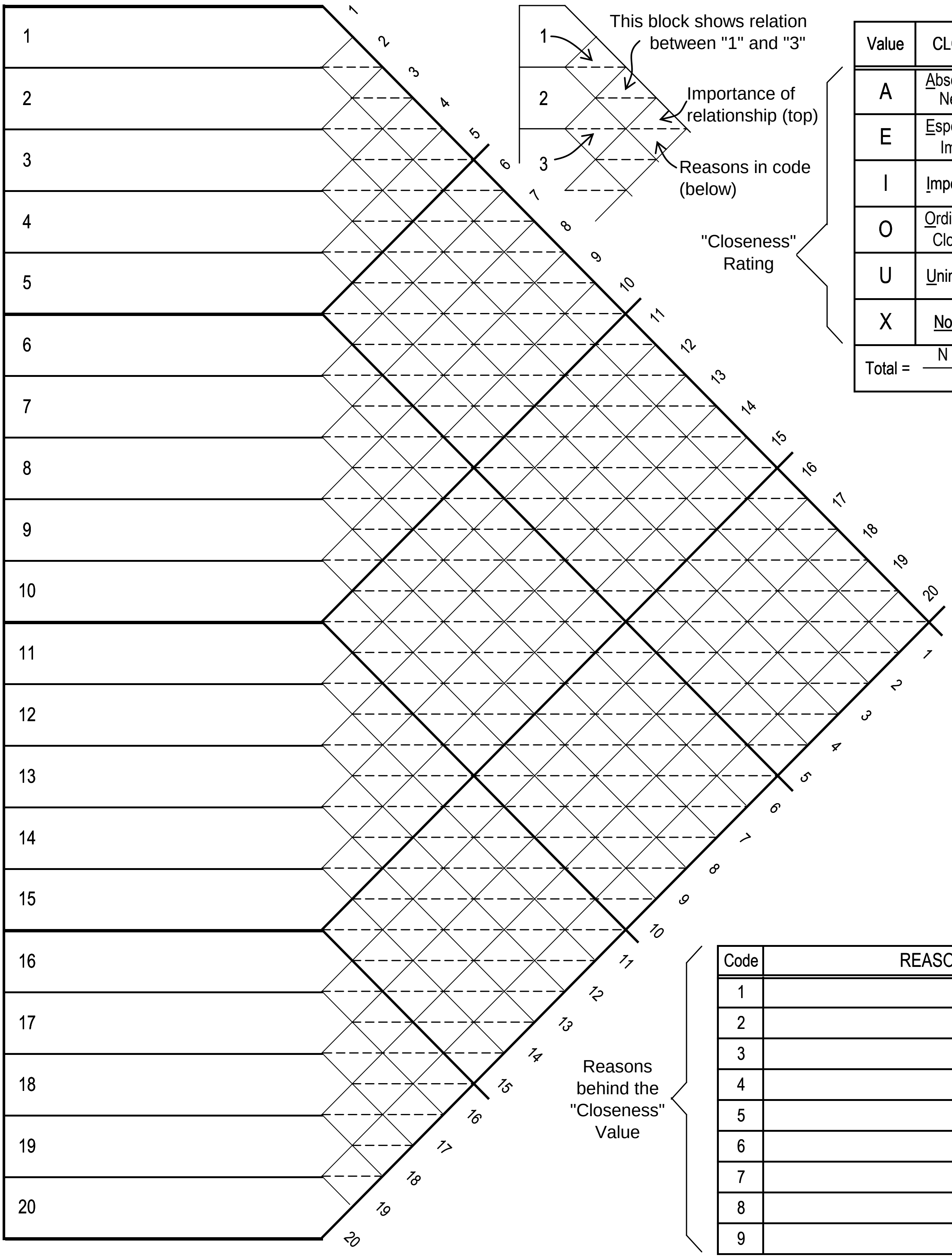
RELATIONSHIP CHART

Plant (Company) ____________ Project ____________

Charted by ____________ With ____________

Date ____________ Sheet ______ of ______

Reference ____________



"Closeness" Rating

Value	CLOSENESS	No. of Ratings
A	Absolutely Necessary	
E	Especially Important	
I	Important	
O	Ordinary Closeness OK	
U	Unimportant	
X	Not desirable	
Total = $\frac{N \times (N-1)}{2}$ =		

Reasons behind the "Closeness" Value

Code	REASON
1	
2	
3	
4	
5	
6	
7	
8	
9	

RELATIONSHIP CHART

Plant (Company) ______________________ Project ______________________

Source - Reference ______________________ Date ____________ Charted by ______________

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
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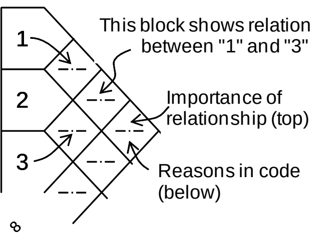
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45



"Closeness" Rating

Value	CLOSENESS	Color	No. of Ratings
A	Absolutely Necessary	△ RED	
E	Especially Important	△ OR-YEL	
I	Important	△ GREEN	
O	Ordinary Closeness OK	△ BLUE	
U	Unimportant	U	
X	Not desirable	△ BROWN	
Total =	$\frac{N \times (N-1)}{2}$	=	

Reasons behind the "Closeness" Value

Code	REASON
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Dept. Date	Sign "OK"	Dept. Date	Sign "OK"

Notation References

a
b
c
d
e
f
g

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FROM-TO-CHART

Plant ______________________ Project ______________________
By ______________________ With ______________________
Date ______________________ Page ______ of ______

Item(s) Charted: ______________________ Basis of Values: ______________________

Activity or Operation **TO** Activity or Operation **FROM**	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	**TOTAL**
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					
11																					
12																					
13																					
14																					
15																					
16																					
17																					
18																					
19																					
20																					
TOTALS																					

NOTES:

FLOW-IN FLOW-OUT CHART

Plant
Project
By
With
Date
Sheet of

Area:

FLOW IN →					OPERATION OR AREA	FLOW OUT →				
PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP) CLASS	QUANTITY PER *day*			FROM		TO	QUANTITY PER *day*			CLASS PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)
	UNIT	AVG.	MAX.				UNIT	AVG.	MAX.	
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										

NOTES:

COMBINING FLOW & SERVICE RELATIONSHIPS

Ratio of Flow to Other-Than-Flow:

	to	

Plant (Company) ____________________ Project ____________________

Flow Source / Reference ____________________ Date ____________________

Other-Than-Flow Source ____________________ By ____________________

Sheet ______ of ______

Line #	Activity-Pair		FLOW-OF-MATERIAL INTENSITY						OTHER-THAN-FLOW RELATIONSHIPS				RESULTANT COMBINED RELATIONSHIPS			Comments
			From-To	To-From	2-Way	Vowel Rating	Value	Wt.	Vowel Rating	Reasons	Value	Wt.	Combined Value	Combined Rating	Final Assigned Rating	

ACTIVITIES AREA & FEATURES SHEET

Plant ____________
Project ____________
By ________ With ________
Date ________ Page ____ of ____

← Activity →

← Physical Features Required →

No.	Name	Area in ______	O'Head Clearance	Max. Overhead Supported Load	Max. Floor Loading	Min. Column Spacing		Water & Drains	Steam	Compressed Air	Foundations - or Pits	Fire or Explosion Hazard	Special Ventilation	Special Electrification		Requirements for Shape or Configuration of Area (Space)
		Total:	Enter Unit and Required Amount under each					Relative Importance of Features A - Absolutely Necessary E - Especially Important I - Important O - Ordinary Importance — - Not Required								Enter Requirements for Shape or Configuration and Reasons therefore
1.																
2.																
3.																
4.																
5.																
6.																
7.																
8.																
9.																
10.																
11.																
12.																
13.																
14.																
15.																

Sub-Activities or Areas

Notation References
a ____________
b ____________
c ____________

No. ________ Activity ____________ Sheet ____ of ____

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OFFICE LAYOUT REQUIREMENTS DATA

Company/Plant ______________ Department ______________ Sheet ______ of ______

Bldg ______________ Floor ______________ Section ______________ Date ______________

☐ Present ☐ Projected

Area now assigned ______________ By ______________ With ______________

Room or Area Number	Identification Data		Space Req'd.				Regular Equipment															Other Equipment					
	Personal Name or Work Group. (List each individual -- arranged by work group -- or list name of work group or function. If individual's name is used, check appropriate columns; if working group, enter numbers.)	Job title or Description	Male	Female	Type of Space #		Std. Work Surface	Clerical Work Surface	Bench or Table	Size	Chair or Stool	Letter File	Legal File		Special Light	Telephone	Data/network port	Monitor	Computer	Desktop Printer		No.	Description	Left to Right	Front to Back	Height	Special Utilities or Requirements (Describe)
Totals																											

\# Type of Space: P-Private E-Semi-Private Enclosure O-Open or Semi-Open S-Service or Special Areas (For special areas furnish sketch and dimensions)
G-General areas not specifically assigned. (Shared areas not considered service or special.)

* Net Area: Excludes stairways, restrooms, central corridors and aisles, etc. (except where specifically listed), but includes working and access area or apportioned share thereof.

** Filled in by layout planner (or office analyst)

Reference Notes: a. ______________

b. ______________

c. ______________

d. ______________

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MACHINERY & EQUIPMENT AREA & FEATURES SHEET

Project ____________________

By ____________________ With ____________________

Company/Plant ____________________ Bldg/Dept/Area ____________________ Date ____________________ Sheet ________ of ________

Identification Data		Space									Physical Features Required															
Machine or Equipment Identification Number	Name and/or Description	Left -- Right *Inches*	Front -- Back *Inches*	Height *Inches*	Area for Machinery or Equip. in ____	Operator(s) Work & Maintenance Area	Material Set-down Area	Total Area each Machine or piece of Equip.	No. of Machines/Equip.	Total Net Area* (in ____)	110 - A.C.	120 - A.C.	Other Power	Ampere Rating		Water	Steam	Drains	Compressed Air	Other Piping Gas	Foundation/Pit	Exhaust/Hood	Dust Collector			Comments - - - - - Shape/Configuration Special Requirements

* Required space for main or delivery aisles and service areas not included.

Total Net Area Required* (in)

Aisles ________

Services ________

Other ________

Total Area Req'd. ________

Reference Notes:

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

MACHINERY & EQUIPMENT LAYOUT DATA

Company/Unit/Plant
Project
Prepared by
With
Date

Water
Steam
Drains
Comp. Air
Gas
Foundation
Pit
Level/Lag
Exhaust
Sp'l. Elect.
Max. Height
Weight (less attatch.)

Electrical	H.P.	Volts	Cycle	Phase	Amps.		
Drive Motor							
Auxiliary Motor							
Auxiliary Motor							

Name/Type
File
Manufacturer
Size/Model
Speed/Capacity
Signif. Ident.

Left-Right
Front-Back
Net Floor Area
Worker/Main.Area
Material Set-down
Area for Aisles
Service/Other
Gross Area (plan for)

Co. Mach./Equip. Identification Numbers Covered by this Sheet		

ELEVATION SKETCH OR PHOTO
SOURCE
DATE

PLAN VIEW
SCALE

Reference Notations/changes

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MACHINERY & EQUIPMENT LAYOUT DATA WORK SHEET

File

Plant
Bldg.
Dept.
Area
Nearest Column Location
as of
Compiled by
With
Date

Company Identification No.
Name/Type
Size/Model/Style
Speed
Capacity
Manufacturer
Signif. Identfn. (Serial No., Code)

Dimensions and Area Reqmts:

Utilities and Service Reqmts:

Height at max. point
Water
Steam
Weight (less attachments)
Drains
Comprsd. Air
Gas
Left-Right (base)
Other Piping
Left-Right (max)
Foundation
Pit
Front-Back (base)
Level
Lag
Front-Back (max)
Exhaust
Net Floor Area Req'd.
Elect. Outlet
Direct Connection
Special Electr.
Worker/Maint. Area
Material Setdown Area

Motors	HP	Volt	Phase	Amp	
Drive					
Auxiliary					
Auxiliary					

Area for Aisles
Support/Other Areas
Gross area allocated
(on current ☐ basis
projected ☐ basis)

Elevation Sketch (Scale ________)

Template Sketch (Scale ________)

File

Reference of Explanatory Notes:

SPACE REQUIREMENTS -- CONVERTING

Plant ____________ Project ____________

By ____________ With ____________

Basis (year, period, quantity) of Columns e, f, g ____________ Columns h, j, k ____________ Date ____________ Sheet ______ of ______

a Activity-- Area or Dept.	b Area Now Occupied	c + or - Adjstmt.	d Should Have Now	e Increase Decrease	f Req'd Area Determined	g Plan-For Area	h Increase Decrease	j Req'd Area Determined	k Plan-For Area
Unit →									
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									
11.									
12.									
13.									
14.									
15.									
16.									
17.									
18.									
19.									
20.									
TOTALS									

NOTES:

EVALUATING ALTERNATIVES

Plant ______________________________

Project ______________________ Date ______________

Weights set by __________ Tally by ________________

Ratings by __________ Approved by ________________

EVALUATING DESCRIPTION			
A	Almost Perfect	O	Ordinary Results
E	Especially Good	U	Unimportant
I	Important Results	X	Not Acceptable

Description of Alternatives:

Enter a brief phrase identifying each alternative.

A. ______________________________

B. ______________________________

C. ______________________________

D. ______________________________

E. ______________________________

FACTOR / CONSIDERATION	WT.	RATINGS AND WEIGHTED RATINGS				
		A	B	C	D	E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
Totals						

Reference Notes:

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

M.H. EQUIPMENT EVALUATION

Plant ____________ Project ____________

Handling Situation ______________________ By ____________ With ____________

______________________ Date ____________ Shee ______ of ______

Alternative A: ______________________

Alternative B: ______________________

Alternative C: ______________________

Alternative D: ______________________

Alternative E: ______________________

OBJECTIVE	WHAT IS WANTED FROM ANY HANDLING EQUIPMENT?	REQMTS. Importance to the Project		ALTERNATIVE									
Does it --	Enter the requirements (what is required of this specific equipment?) -- That is, the importance to the project of each Objective and Sub-Objective, using numerical values. Rate each alternative by rating letter; convert, extend, total.	O	S-O	A		B		C		D		E	
MOVEMENT -- move materials 1	a. freely?												
	b. to the right place?												
	c.												
DIRECTNESS -- move materials 2	a. without transfers?												
	b. directly to point of use?												
	c. without unnecessary delays												
	d.												
CONVENIENCE -- allow minimum 3	a. loading time?												
	b. unloading time?												
	c. rehandling?												
	d.												
SAFETY AND QUALITY 4	a. keep materials safe from breakage or damage?												
	b. keep material free from contamination, deterioration?												
	c. avoid hazard to workers or facilities?												
	d.												
SPACE -- accomplish more 5	a. without consuming much floor-space?												
	b. without obstructing workers, machines, storage services?												
	c.												
COMBINED ACTIVITY -- allow equip.. to be used as 6	a. a worktable or holding device?												
	b. a storage device?												
	c. an inspection or checking device?												
	d. a pace setter?												
	e.												
FLEXIBILITY 7	a. handle several different materials, products, containers?												
	b. have adaptability to change, removal, or relocation?												
	c. have adaptability for increased volume, weight, size?												
	d.												
PRODUCTIVE AID -- keep materials 8	a. in sequence or easily rearrangeable?												
	b. from getting lost?												
	c. timed, scheduled, or synchronized?												
	d. free of workers' watching or attention?												
	e. easy to count, check, oversee?												
	f. readily available to operators?												
	g.												
OPERATING ECONOMY -- operate with optimum 9	a. operating man-hours?												
	b. maintenance and repair cost?												
	c. power or fuel cost?												
	d.												
DEPRECIATION INVESTMENT 10	a. carry optimum rate of depreciation?												
	b. require reasonable outlay of funds?												
	c.												
OTHERS 11													
NOTES/ADDITIONAL SOLUTIONS SUGGESTED		TOTAL											

FLOW PROCESS CHART

Process charted: ______________________

☐ Man or ☐ Material

Starting point ______________________

Ending point ______________________

Conversions for Charted Unit to End Unit

Charted Unit	Size/Weight	Qty/End Unit

Plant ______________________ Project ______________________

By ______________________ With ______________________

Date ______________________ Sheet ________ of ________

Quantity of End Unit (unit of end item) per (time) ______________________

☐ Present ☐ Proposed (Alternative # ______________________)

Description of Alternative: ______________________

CHARTED UNIT (Unit of Poduct or Material Charted)	UNITS PER LOAD	Operation	Handling	Transport	Inpsection	Delay	Storage	DESCRIPTION OF ACTION	Weight or Size of Load in ______	Number of trips per ____	Distance in ______	Time in ______ per ______	Cost in ______ per ______	NOTES Verify: Product-Quantity-Route-Support-Time Analyze: Why-What-Where-When-Who-How Eliminate-Combine-Rearrange
1		○	◇	⇨	☐	D	▽							
2		○	◇	⇨	☐	D	▽							
3		○	◇	⇨	☐	D	▽							
4		○	◇	⇨	☐	D	▽							
5		○	◇	⇨	☐	D	▽							
6		○	◇	⇨	☐	D	▽							
7		○	◇	⇨	☐	D	▽							
8		○	◇	⇨	☐	D	▽							
9		○	◇	⇨	☐	D	▽							
10		○	◇	⇨	☐	D	▽							
11		○	◇	⇨	☐	D	▽							
12		○	◇	⇨	☐	D	▽							
13		○	◇	⇨	☐	D	▽							
14		○	◇	⇨	☐	D	▽							
15		○	◇	⇨	☐	D	▽							
16		○	◇	⇨	☐	D	▽							
17		○	◇	⇨	☐	D	▽							
18		○	◇	⇨	☐	D	▽							
19		○	◇	⇨	☐	D	▽							
20		○	◇	⇨	☐	D	▽							
21		○	◇	⇨	☐	D	▽							
22		○	◇	⇨	☐	D	▽							
23		○	◇	⇨	☐	D	▽							
24		○	◇	⇨	☐	D	▽							
25		○	◇	⇨	☐	D	▽							
26		○	◇	⇨	☐	D	▽							
27		○	◇	⇨	☐	D	▽							
28		○	◇	⇨	☐	D	▽							
29		○	◇	⇨	☐	D	▽							
30		○	◇	⇨	☐	D	▽							
	Totals									Totals				

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ROUTE CHART

From ______________________ To ______________________ Plant ______________________ Project ______________________

Distance ______________________ By ______________________ With ______________________

Date ______________________ Sheet __________ of __________

	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)	P-M CLASS	QUANTITY PER *week*				NOTES
			UNIT	AVG.	MIN.	MAX.	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							

TOTAL MOVEMENT	PRODUCT-MATERIAL DESCRIPTION (ITEM OR ITEM-GROUP)	P-M CLASS	INTENSITY OF FLOW			INTENSITY X DISTANCE			COMMENTS OR SUGGESTIONS
			UNIT	AVG.	PLAN	UNIT	AVG.	PLAN	

INSTALLATION COST SUMMARY

Description ____________________

Plant ____________________ Project ____________________

Estimated by ____________________ With ____________________

Currency __________ Date __________ Sheet ______ of ______

	NATURE OF WORK	Estimated		Rate/ Hour	Labor Cost	Total Cost	Ouside Bid
		Material	Hours				
1	Clear and prepare new area -- including marking aisles, columns, locations.						
2	Building repairs, alterations, or construction.						
3	Paint new areas, before and after move.						
4	Clean-up and repair machines and equipment now in storage.						
5							
6	Disconnect utilities -- electric, water, air, gas, etc.						
7	Disconnect auxiliaries -- vents, drains, ducts, conveyors, other handling equipment, etc.						
8	Move out operating machines and equipment.						
9	Move out all service and miscellaneous equipment.						
10	Move out materials, work-in-process, stores, tools, supplies.						
11	Remove operating machines and equipment not to be relocated.						
12	Remove service and miscellaneous equipment not to be relocated.						
13	Prepare non-movers for storage, sale, or other disposition.						
14	Fill-in pits, close holes, and clean-up old area.						
15							
16	Install pits, foundations, openings, special enclosures.						
17	Install conveyors, hoists, other handling equipment, racks, shelving, storage equipment.						
18	Install electric power equipment, leads, outlets, lighting fixtures, etc.						
19	Install utility lines and outlets -- water, air, gas -- drains and sewers,						
20	Install heating, ventilating, air conditioning, ducts, fans, filters, dust collectors, etc.						
21	Move operating machines -- spot, level, lag, mount						
22	Move in all service and miscellaneous equipment (not already installed).						
23	Move in all materials, work-in-process, stores, tools.						
24	Hook-up or connect, straighten-up, try out prior to operating.						
25							
	Total						

NOTES: ____________________

REVIEW AND APPROVAL RECORD

Plant ______________ Project ______________
By ______________ With ______________
Date ______________ Sheet ______ of ______

Project Identification Name and Description:

According to good practice and established procedure, all persons having responsibility for subsequent performance of any installation should review and approve the plans beforehand.

I, the undersigned, have carefully reviewed the plans for the above mentioned installation. It is complete and workable as far as I can tell and I will fully support having this project installed as planned and function as designed.

Title or Department Name	Approval Signature	Date	Drawing/Print Number and Revision or Model Identification
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

INSTALLATION
COORDINATION WORKSHEET

Plant (Company) ____________________
By ____________________
Date Originated ____________________

Project ____________________
With ____________________
Sheet ________ of ________
Date of this review ____________________

WHAT			WHO	WHEN	STATUS	As of (date)
MAKE READY	PLAN	1. Start planning the installation				
		2. Establish sequence and timing of moves				
		3. Inventory materials and equipment to move				
		4. Get disposition of non-moving material and equipment				
		5. Schedule moves in detail				
		6. Assign move numbers; check vs inventory & equipment (tag) number				
		7. Verify procedural changes and timing				
		8.				
	PROVIDE	1. Decide who will make moves				
		2. Secure bids as necessary				
		3. Determine and reserve moving equipment required				
		4. Set up communications for both ends of move				
		5. Appoint key person for each area				
		6. Get work order(s) for moves				
		7. Verify delivery for any new equipment				
		8.				
	PREPARE	1. Prepare new locations -- physical area, conditions, auxiliaries				
		2. Broadcast plans				
		3. Brief personnel specifically involved				
		4. Mark everything to move; identification, move no., destination				
		5. Disconnect or ready equipment				
		6. Check out equipment and release to movers				
		7. Complete required training				
		8.				
DO	INSTALL	1. Move equipment intact to reduce re-assembly time				
		2. Move close to spot to reduce line-up and hook-up time				
		3. Post move performance as accomplished				
		4. Keep moving crew informed, coordinated				
		5. Be on hand -- layout interpretation				
		6. Be on hand -- auxiliaries interpretation				
		7. Be on hand -- procedures interpretation				
		8				
PUT AWAY	HOOK-UP	1. Spot equipment; check location				
		2. Temporary hook-ups where needed				
		3. Check and release for permanent connections				
		4. Inspect the installation & release for tryout				
		5. Maintenance tryout				
		6. Release to operating group; secure acceptance				
		7.				
		8.				
	CLEAN-UP	1. Survey-inspect old and new areas				
		2. Schedule & assign clean-up -- old and new areas				
		3. Verify layout as installed				
		4. Verify auxiliary service as installed				
		5. Verify or adjust layout & service-specification records				
		6. Recap installation costs and performance				
		7. Final sign-off by operating group				
		8.				

Reference Notes:

a. ____________________ c ____________________
b. ____________________ d. ____________________

INSTALLATION INSTRUCTIONS SUMMARY

Description ______________________________

Plant ______________ Project ______________
By ______________ With ______________
Date ______________ Sheet ________ of ________

ITEM No.	DESCRIPTION	MOVE	UTILITIES						MILLWRIGHTS-MECHANICAL	ELECTRICAL						ELECTRICIANS	OTHER WORK -- (Code who and describe) C - Carpenters M - Methods S - Safety Engr. F - Fire Marshall P - Plant Engrg. * - Outside Contractor	
	MACH./EQPT. No.		Air	Water	Gas	Drain	Vent	*Steam*		Volts	Phase	KVA	Amps	H.P.			WHO	WHAT

To accompany Drwg. Nos. ☐ Work Order ☐

INSTALLATION RECORD

Mach. or Eqpt. No. ☐
Mach. /Eqpt. Type
Mfgr.
Size/Model
Signif. Identification

Plant
Project
Bldg.
Area
Dept.
Nearest Column Location
Sheet issued by*
Date issued
Date returned

MECHANICAL, MAINTENANCE, MILLWRIGHTS

Level Resp. Due
Lag Resp. Due
Mount Resp. Due
Resp. Due

Complete (sign)
Date
Comments

ELECTRICIANS

Power Resp. Due
Control Resp. Due
Lights Resp. Due
Resp. Due

Complete (sign)
Date
Comments

PIPING & SHEET METAL

Water Resp. Due
Steam Resp. Due
Drains Resp. Due
Comp. Air Resp. Due
Gas Resp. Due
Coolant, Lube Resp. Due
Hoods, Ducts, Fans Resp. Due
Resp. Due

Complete (sign)
Date
Comments

PAINT and CLEAN-UP

Paint Resp. Due
Clean-Up Resp. Due
Resp. Due

Complete (sign)
Date
Comments

SAFETY

Guards Resp. Due
Fire Regs. Resp. Due
Fumes, Acids Resp. Due
Resp. Due

Complete (sign)
Date
Comments

OTHER INSTALLATION WORK SIGN-OFF

Resp. Due
Resp. Due
Resp. Due
Resp. Due

Complete (sign)
Date
Comments

FINAL ACCEPTANCE (by installation coordinator or operating supervision)

Name Title Sign Date
Comment
Name Title Sign Date
Comment

(After final acceptance, return this sheet to person originally issuing it. See above.)

NOTES, Special Instructions, Reasons for Delay

* Return this sheet to person originally issuing it, after final acceptance

WORKPLACE EQUIPMENT WORKSHEET

Plant ____________ Project ____________

By ____________ With ____________

Workplace: ____________ Date ____________ Sheet ______ of ______

No.	Name	Description	Physical Characteristics						Elevation
			Front to Back	Left to Right	Bottom to Top	Weight-Density	Shape		
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									

Notes:

a. ____________

b. ____________

c. ____________

d. ____________

e. ____________

Elevation Codes

4 = Overhead
3 = Shoulder Level
2 = Waist Level
1 = Knee Level
0 = Floor Level
U = Under Floor

! = Mandatory
? = Preferred
(none) = Not relevant

LINE-FEEDING FLOW CHART

Plant ____________________ Project ____________________
By ____________________ With ____________________
Line or Product ____________________ Date ____________________ Sheet ________ of ________
Starting at ____________________ Present Method ☐ Proposed Method ☐

Feed-in from ________ side		Feed-in from ________ side

Reference Notes: ____________________

GROUP-OF-PARTS PROCESS CHART

Plant ______________ Project ______________ Date __________
By ______________ With ______________ Sheet _____ of _____

Parts & Quantity **Process** **Sequence**	**P**	**Q**	**P**	**Q**	**P**	**Q**	**P**	**Q**	**P**	**Q**	**P**	**Q**	Operating Times per	Number of Machines Required
	a		b		c		d		e		f			
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														
Op. Mch														

Group Description:

a. ______________
b. ______________
c. ______________
d. ______________
f. ______________
g. ______________
h. ______________

Referenced Notations:

a. ______________
b. ______________
c. ______________
d. ______________
f. ______________
g. ______________
h. ______________

STANDARDIZED WORK

Manual Work ————
Machine Time ··················
Walking /\/\/\/\/\/\/\/\/\/\

Company/Plant
Operation/Process
Production Rate Takt Time

Part/Product
By With Issue Date
Sheet of Rev. Date

Ref. Symbol	Cyclical Work Element	Element Time (Sec.)			5	10	15	20	25	30	35	40	
		Manual	Machine	Walking									
	Sub-Total												
	Total Operator Cycle Time												

No.	Non-Cyclical Work Element	Time	Freq.	Total
	Total Operator Time			

LAYOUT SKETCH & WALK PATH

Notes

Notes

PROJECT SCHEDULE SHEET

Covering __________ Status as of __________

Distribution __________

Originating Department __________

Prepared by __________

Date __________ Sheet _____ of _____

Task/Proj. No. and/or Description	Work to do; Action to take	Resp. of																															Further Schedule
1																																	
2																																	
3																																	
4																																	
5																																	
6																																	
7																																	
8																																	
9																																	
10																																	
11																																	
12																																	
13																																	
14																																	
15																																	
16																																	
17																																	
18																																	

Gantt Chart Code: ⊏ Date work scheduled to start ⊐ Date work scheduled to finish ☐ Total time scheduled for work ▬ Amount of work done

(Each vertical period represents one unit of time. Use Gantt Chart Code or enter numbers and/or other indicators.)

COORDINATION AND PROGRESS SUMMARY

Originating Department ______________________

Covering ______________________ Status as of __________ Prepared by ______________________

Distribution ______________________ Reported by __________ Date ______________ Sheet __________

Task/Project. No. and/or Description Work to do; Action to be taken	Resp. Dept.	Status Code	Status & Remarks
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

Status Code:

0, Not yet begun; 1, Preliminaries underway; 2, Prelim. Complete & work in process; 3, Well along; 4, Almost done; Compl., Complete

NOTES: ______________________

____

____

UNIVERSAL PROBLEM-SOLVING PROCEDURE

Problem ______________________ Plant ______________

Date Started ______________

Area/Dept. ______________________ Analyst ______________

---

1. STATE THE PROBLEM

---

2. GET THE FACTS

---

3. RESTATE THE PROBLEM

---

4. ANALYZE AND DECIDE

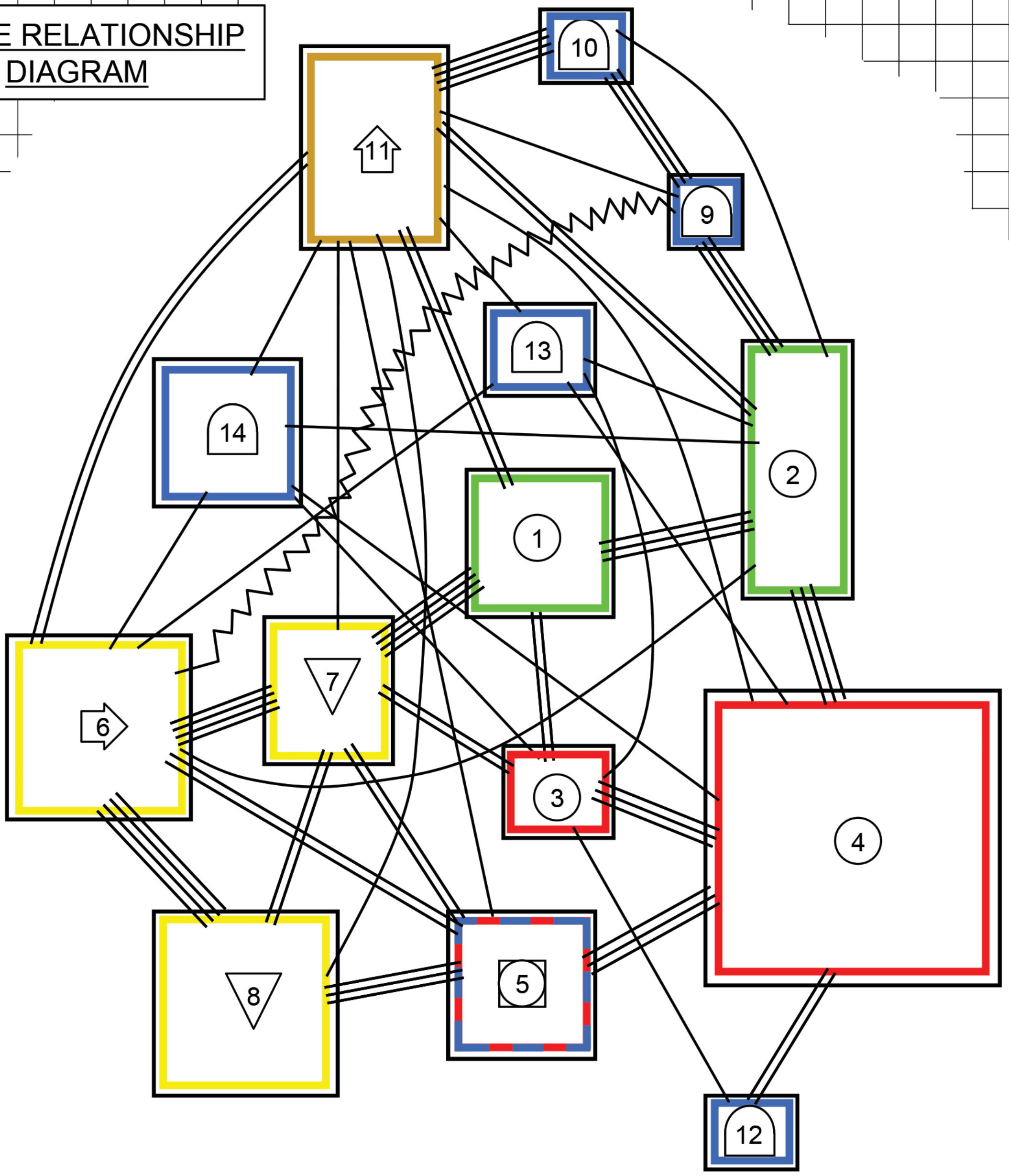
---

5. TAKE ACTION -- What, Who, When

---

6. FOLLOW-UP

SPACE RELATIONSHIP DIAGRAM

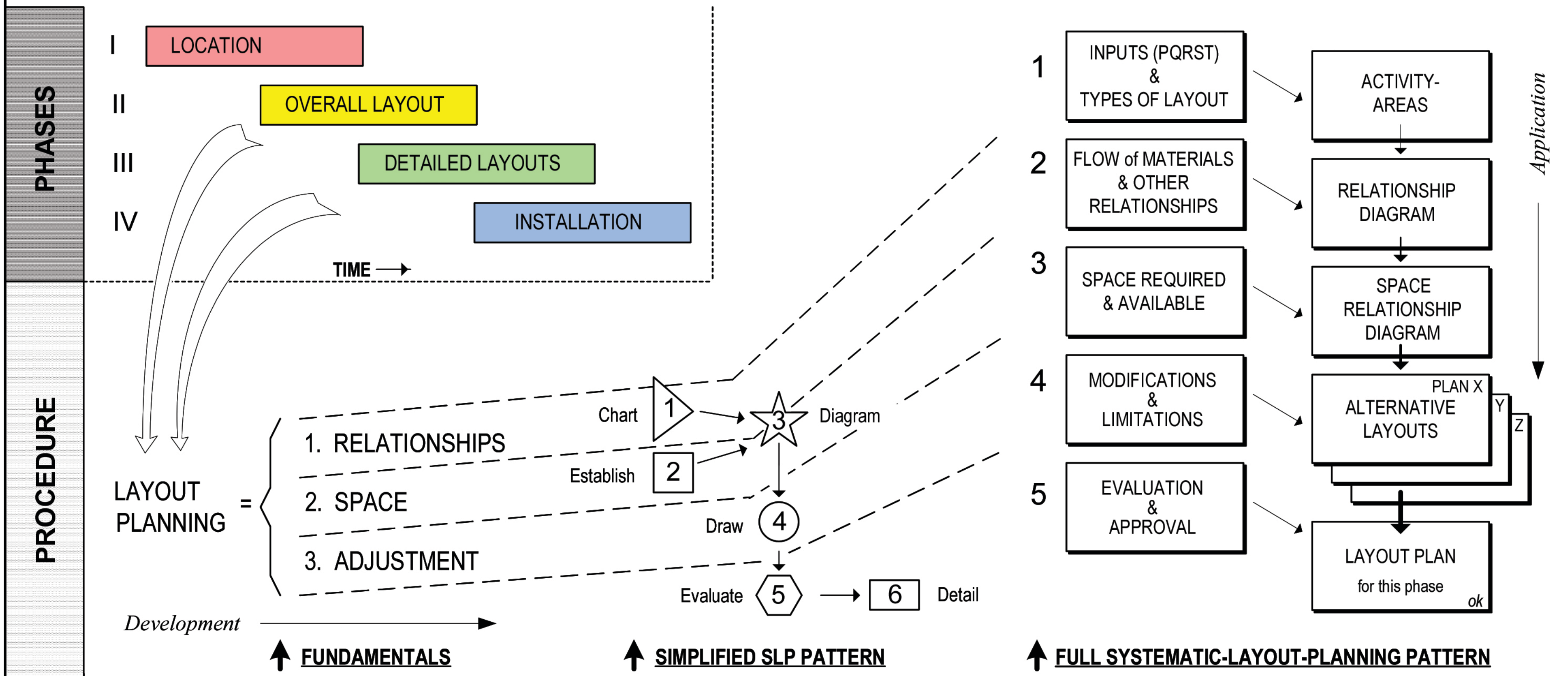


Scale: $\frac{1}{4}$" = 10'

Novelty Luggage Co.
Project 631
7/6 By J. E. H.

SYSTEMATIC LAYOUT PLANNING (SLP) -- Capsule Summary

ISBN: 978-0-933684-06-5



CONVENTIONS

Process Chart Symbols & Action*	Symbols Extended to Identify Equipment & Space	Color Ident.	Black & White**
* ○ Operation	○ Forming or Treating Equipment & Space	Green**	▧
	○ Assembly, Sub-Assembly, Dis-Assembly	Red**	▥
* ⇨ Transportation	⇨ Transport-related Equipment & Space	Orange Yellow**	░
⬠ Handling	⬠ Handling Areas -- Pick-up & Set-Down	Orange Yellow**	░
* ▽ Storage	▽ Storage Equipment and Space	Orange Yellow**	░
* D Delay	D Set-down or Hold Areas	Orange Yellow**	░
* □ Inspection	□ Inspect, Test, Check Equipment & Space	Blue**	▤
	∩ Service & Support Equipment & Space	Blue**	▤
	⇧ Office or Planning Areas, or Building Features	Brown** (Gray)	▦

* A.N.S.I. Standard
** MHMS (IMMS) Standard (Adopted as basic to SLP procedure)

Vowel Letter	No. Value	No. of Lines	Closeness Rating	Color Code
A	4	////	Absolutely Necessary	Red**
E	3	///	Especially Important	Orange Yellow**
I	2	//	Important	Green**
O	1	/	Ordinary	Blue**
U	0		Unimportant	Uncol-ored**
X	-1	〰	Not Desirable	Brown**
XX	-2,-3, -4,?	〰 〰	Extremely Undesirable	Black

Evaluating Description	Letter / Value
Almost Perfect Results (Excellent)	A / 4
Especially Good Results (Very Good)	E / 3
Important Results (Good)	I / 2
Ordinary Results (Fair)	O / 1
Unimportant Results (Poor)	U / 0
Not Acceptable Results (Not Satisfactory)	X / ?

RMA - 1154K