CHAPTER 1

Using the Handbook

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Using the Handbook

INTRODUCTION TO THE SECOND EDITION

While the need to revise this handbook – first published in 1993 – had become glaringly obvious, its general format, level of detail and breadth of coverage has proved to be of enduring value. The original work focused on the Australian mining industry, but it has become clear that its market has been much wider than that over the years, and the authors have tried to keep that in mind in this update.

Thanks to the efforts of venerable institutions such as our own Australasian Institute of Mining and Metallurgy (The AusIMM – The Minerals Institute), the mining industry has become more professional over the intervening years. It has also become more cross-disciplinary in nature. It is hard enough to keep up-to-date in our own specialist fields, or commodities, let alone understand what is happening across the wider industry. Nonetheless, if there is a common language that everyone speaks, it is that of economics, as this is at the heart of decision-making at every stage of a mine's life from its discovery to closure. Thus, while this volume will provide some technical basics, this is not its greatest aim. Rather, its mission is to help technical specialists from different backgrounds better appreciate the dimensions across the broad spectrum of justifying the potential for developing a mining project, selecting the best alternative from many, detailing the favoured case and securing finance to take that project forward.

This author came across the first edition around 1996 when on a consultancy assignment to Angola, and was greatly impressed with the value it provided for that job in making some rapid checks on the status of a project. That same edition has served many professionals now for some 20 years. While it was in need of updating, its basic format and intent remain the same – to provide mining industry professionals including engineers, technologists, scientists, researchers, academics, students and other personnel from associated disciplines with tools to enable them to perform cost estimations, ranging from the total cost of developing a complete new mine to investigating the feasibility of changing a single piece of plant equipment.

Its value has been demonstrated time and time again in that this author's copy was regularly 'borrowed'. Even as recently as 2011, when a team on a copper project (who had not seen the handbook before) referred to the handbook, they found the section on revenue calculations very enlightening. This author has also heard from several bankers that they used it as a reference when doing at least initial checks on prospective investments.

Then, as now, cost estimation is an everyday part of a practising mining professional's life. Our communication and computing power have grown exponentially in the intervening period, but the fundamentals still remain. The ubiquitous nature of the internet and data access have prompted many changes in the intervening period. Generally these changes have been positive, in that out of necessity we are more cost conscious than before.

Most of us have had to live with the cyclical nature of the industry, and have ridden the roller-coaster of boom and bust cycles. This in itself has meant that there are gaps in the demographics of the mining workforce as people move away from the industry during downturns, and new graduates have not been attracted in the numbers that are required to keep pace with growth. Inevitably this creates a lag, and once commodity markets rise again, there are labour shortages. At the time of writing, many of the most experienced leaders of the industry who opened up areas of the Pilbara, or helped develop iconic projects such as Olympic Dam, have retired or are about to do so. We all benefitted from those stalwarts of the industry who had facts and figures at their fingertips. As they are often no longer down the corridor in the office, trying to capture a body of knowledge such as this handbook attempts to do helps practitioners keep some degree of continuity in the industry.

This second edition has had to deal with many changes in the almost two decades since the first edition was first mooted. New technologies and processing routes have been introduced, and the overall scale of operations and unit size and capacity of equipment have had to increase to be able to derive economic value in the face of falling grades and ever more-remote locations. Overall these changes have brought step-changes in cost structures. Labour practices and organisation structures have altered significantly in the intervening years to increase productivity and create more meaningful careers, and workforce expectations and management styles have shifted to match. Our standards have become higher, and thankfully the focus of attention on health, safety, environment and community (HSEC) have made for a safer, better, healthier and overall more sensitive and sustainable industry.

The Editorial Committee commends this volume to you, and trusts that it will be just as valuable a reference as was its predecessor. We hope too that you will feel free to comment and provide additional examples and good practices that can be used in subsequent updates, to ensure that it retains its relevance as long as possible. In revising the first edition, some inconsistencies and perhaps less-than-clear explanations were uncovered. We hope to have addressed most of these, but if some have slipped through the cracks, we welcome your reporting back to enhance the value of this new edition.

WHO SHOULD USE THE HANDBOOK?

It is not the intent of this handbook to turn mining professionals and study managers into either professional estimators or legal counsel. However, these professionals should at least be provided with some additional knowledge so that they are aware of the issues that need to be addressed. In this way, discipline engineers and study managers can seek the necessary professional assistance where matters are more complex than they can deal with using their own experience.

One of the main purposes of the handbook is to help the study manager and members of the study team ask the right questions and plan their work so as to provide information in the correct format, and at the level of accuracy in calculation and supporting drawings to allow professional estimators to do their job.

In this sense, as well as the critical nature of the actual numbers involved, capital and operating cost estimates are communication documents within the study team. These estimates demonstrate that the scope of work has been captured, that suitable methodologies have been applied and that the underlying assumptions are realistic and generally accepted.

The chapters in this volume are intended to provide guidance on how capital and operating cost estimates are derived and give some pointers on what topics need to be covered. It is not meant to be all-encompassing, and every study and project is different depending on the scope, commodity and stage of the study. As in the past, this volume will form a basis for continuous improvement as new lessons are learned and we can add them to the general body of knowledge.

The first edition presented examples of the needs of potential users of a cost estimate so that readers would understand the levels of detail needed when preparing the cost estimate. The second edition also illustrates required levels of detail using examples, which might include the following:

- An exploration or geological manager planning and budgeting an exploration program needs to understand the likely size of resource that must be defined to support the project. The manager can make some rough estimates of the likely costs of mine, plant and infrastructure – perhaps at different production rates – that may guide him or her in decision-making to plan the location and spacing of drilling.
- A lead process engineer planning a test work program can quickly get a sense of the costs of new equipment needed to improve recoveries and determine what levels of improvement will be required to justify new investment.
- Students may gain a better understanding of the costs of different mining or processing methods to increase their understanding of the value and applicability of those alternatives, and lend context to their studies.
- A proposal manager can make some rapid calculations of a project's likely capital costs, and then use 'rule-of-thumb' estimates to determine an appropriate number of hours to carry out engineering to achieve the necessary level of accuracy of cost estimates. This could then be used as a 'sanity check' against derived bottom-up estimates.
- A study team can give due recognition to non-technical costs such as those associated with addressing community and social issues, and planning for sustainable operations, including their ultimate closure.
- Even for professional estimators and financial analysts, the handbook may serve as a good general review, as they cannot be expected to be familiar with every mining-related discipline or commodity.

This author has found the handbook particularly valuable in running quick 'what-if' cases – sometimes known in the trade as 'optioneering'. This term is a good description of achieving a balance between looking at a number of different business cases without necessarily having to go into too much engineering detail.

This chapter is written by way of an introduction to the new handbook to provide an overview and context for the detail provided in the individual chapters that describe different parts of the mining industry value chain. The reader's attention is particularly drawn to the early Chapters such as Chapter 2 (Basis of Studies), Chapter 4 (Capital Cost Estimation) and Chapter 5 (Operating Cost Estimation) which go into detail as to the purpose of different levels of study, and the levels of definition associated with each class of estimate.

A variety of methodologies, rules of thumb, and best practices are described which should prove useful to a range of practitioners.

There is no substitute for detailed industry knowledge, practical experience and of course good design and estimating. The mining industry has been badly affected by economic cycles such that a map of the age distribution of both operating and engineering companies shows a gap in the generation aged (in 2012) in their late 30s to early 50s. The mentoring and learning that those of mining professionals now past that upper bracket received in their early careers is harder to come by, and was often knowledge not formally written down. This handbook may help bridge both the knowledge gap and the generations.

IMPORTANT CHANGES SINCE THE FIRST EDITION

Over the past few years, we have seen major changes and massive growth in our industry. Fifteen years on at publication of this new edition, a $150 M project of the late 1990s has now probably grown to at least four or five times that. Reasons include escalation (especially in labour rates), more risk aversion, tighter legislation, higher standards of engineering and environmental management, increased degrees of instrumentation and control, more complexity and sophistication (perhaps to deal with lower grades) and the need to acknowledge community issues such as social licence to operate (SLTO) and sustainability. In a matter as seemingly simple as construction and site camp accommodation, what was once an acceptable standard – the ubiquitous ‘donga’, and shared ablution blocks – has now morphed into a comfortable en suite modular room with at least some trappings of home. Camps have to provide high standards in recreational facilities and catering if they are to attract and retain their workforce, especially where fly-out, fly-out, (FIFO) or drive-in, drive-out (DIDO) rosters are in place. All these changes affect both capital and operating costs of projects and operations.

Quite rightly, improved safety, environmental and sustainability considerations have gone into designs. While these may have imposed additional upfront capital costs, the benefits associated with these improvements usually have a net positive effect on operating costs over the life-of-mine. These improvements may also simply make it possible to attract labour, meet regulations and obtain the necessary SLTO.

Billion-dollar projects are the rule rather than the exception. Increasingly, such numbers reflect the lengths needed to develop new mines in remote locations, and to address the challenges of infrastructure – be they power and water supply, or the logistics of bringing in supplies or taking out product.

Fortunately, for the most part, commodity prices have risen to allow projects to absorb such rises. Spurred by seemingly insatiable demand from China for iron ore and copper, and the relative scarcity of new world-class deposits, these conditions have created a supply–demand imbalance such that investment continues to flow into the industry. However, mining has historically enjoyed booms and suffered busts, and these have to be accounted for in understanding capital and operating cost structures, and in making realistic future price forecasts.

Moreover, there has been increasing evidence of great uncertainty in the world following the Global Financial Crisis (GFC) of 2008, the Eurozone Crisis of 2011 - 2012 and the Fiscal Cliff (2012-13). Mining is not insulated from such global impacts, and even so-called super-cycles reach a natural limit. It is interesting to speculate what sort of future we are now entering, and whether the Editor of the Third Edition will read these words with amusement and say ‘how wrong they were back then …’

Emerging mining regions such as Mongolia present great challenges in dealing with the extremes of temperature. A resurgence of interest in the great gold, silver and copper wealth of Latin America, and the greater political stability in countries such as Colombia and Peru, have opened up mines in remote and high-altitude locations. The rich, and formerly highly productive, African mining regions of the Democratic Republic of Congo (DRC) and West Africa – once beset with brutal civil wars – are hopefully becoming sufficiently stable once again to encourage international companies back. All these factors bring with them new challenges when it comes to estimating capital and operating costs.

NATURE OF ESTIMATION STUDIES

Although study management is covered in greater detail in a subsequent chapter (Chapter 2 – Basis of Studies), it is important to provide a context here for the discussion that follows on different study phases, and the ranges of estimate accuracy that might be expected in each.

In this regard, studies can be seen as part of the project development spectrum shown in Figure 1.1. They occur at the early stages as a part of project evaluation – where the greatest influence in shaping the project can be exerted before designs are frozen, and the much greater financial commitment is made to move into implementation.

In researching this field, it became apparent that there is a great deal of inconsistency in the terminology used and in the inferred purpose, meaning, content, level of detail and validity of different study and project stages. Table 1.1 attempts to rationalise the confusion that has previously arisen in the industry relating to basic terminology. For consistency, it uses terms that have been generally adopted in this handbook, and which have widespread currency.

Table 1.1 is an overview relating to Capital Costs; for more details, the reader is referred to Table 4.5.

Comments are made in Table 1.1 on typical estimating methodologies. It also includes the levels of accuracy that may be expected, and the likely range of contingency that needs to be applied to such estimates. The reader is also directed to the notes that appear at the end of this Chapter under References and further reading.

FIG 1.1 - Study management spectrum.

TABLE 1.1
Generic study classification guide.

Terminology used in this handbook		Scoping study – Phase 1	Prefeasibility study – Phase 2	Feasibility study – Phase 3
Front end loading		FEL 1	FEL 2	FEL 3
Different titles that may be used to describe this level of study	Conceptual	Concept	Preliminary feasibility	Final feasibility
	Opportunity assessment	Order of magnitude (OOM)		Basic engineering
		Identification phase	Selection phase	Definition phase
	Screening	Scoping[a]		'Bankable' feasibility
	Scoping (see footnote)			Definitive feasibility
		Capacity factor	Equipment factor	Forced detail
		Preliminary evaluation	Intermediate economic study	
Estimate type (AACE)		Class 5	Class 4	Class 3
Expected accuracy range of capital cost	±35% to ±100% Typically ±50%	±30% to ±35%	±20% to ±25%	±10% to ±15%
Expected estimate contingency range	30% to 75%	20% to 35%	15% to 25%	10% to 15%
Level of definition (% of complete engineering (see Table 4.5)	Minimal, generally based on other operations, or in-house 'database'	1 - 2% Basic general layouts	10 - 15% Preliminary take-offs	15 - 25% Detailed drawings and take-offs
Typical estimating methodologies (but refer Table 4.5 for detail by line item)	Capacity factored Parametric models, judgement or analogy Stochastic estimating methods, including cost-capacity curves, and various factors	Equipment factored or parametric models. Some 'first principles' estimating related to early scope definition	Semi-detailed unit costs, and more deterministic estimating methods Preliminary MTOs (Some) budget pricing	More detailed unit costs and MTOs Budget prices and vendor quotes Higher degree of deterministic estimating methods Line items, and forced detail where definition is lacking

Notes: a. Although the term 'scoping study' can sometimes be used synonymously with a study at a level before FEL1, throughout the rest of this handbook, it is used to indicate a study generally before that of a prefeasibility study (PFS). FEL = front end loading (Independent Project Analysis Institute (IPAI)). MTO = material take-off.

So having established that there remain some inconsistencies between terminology used in describing different classes of estimates, and that the subject area is broad, practitioners need to be cognisant of these differences and seek to develop some internal consistency such as shown in Table 1.1. This has been found to be generally acceptable within the mining industry with individual variations depending on company policy and practice. The ranges of accuracy and contingency quoted in Table 1.1 do vary among companies, especially when comparing those used by the major mining houses, and those often adopted by 'junior miners', and there are also variations according to the type of project (greenfield versus brownfield), complexity, commodity, location, size of project, and many other factors.

Table 1.1 replaces two tables in the previous edition of the handbook – Table 1.1 'Study' accuracy (Reynolds, 1990) and Table 1.2 'Estimation' accuracy (Frew, 1990). In the new Edition, Table 1.1 is somewhat more conservative with regard to not over-stating the accuracy of estimate that can realistically be

TABLE 1.2
Plant component ratio method (after Mular, 1978).

Notes	Capital cost estimate item	Multiplying factor (range)			Capital cost $ M
		Min	Max	Factor used	
a.	Total direct cost of major equipment , roads, power line, major buildings, township, airstrip etc.				1000
	'Factored elements', such as:				
b.	Piping	7%	25%	15%	150
c.	Electrical	12%	25%	15%	150
d.	Instrumentation and control	3%	10%	5%	50
e.	Spares	1%	5%	2%	20
f.	First-fill	1%	3%	1%	10
	Infrastructure				
g.	Architectural and auxiliary buildings; minor infrastructue	7%	15%	9%	90
	Total direct cost for the plant				1470
	Indirect costs				
h.	Owners' costs	5%	15%	7%	103
i.	Freight and taxes	3%	10%	4%	59
j.	EPCM	5%	30%	18%	265
k.	Construction camp, temporary facilities, catering, etc	4%	10%	6%	88
	Total indirect cost for the plant				515
l.	Contingency (on direct and indirect)	15%	40%	30%	595
	Total installed capital cost for the plant				2580

a. As derived by methodologies described in this handbook.

b. Only for 'small' pipes and piperacks; larger pipes will normally be separately estimated under direct equipment costs.

c. Electrical cabling; racking; connections; small motors, large and variable voltage variable frequency (VVVF) motors generally part of equipment.

d. Instrumentation and control for minor aspects, not major capital expenditure (Capex) such as a supervisory control and data acquisition (SCADA) system.

e. Dependent on project and strategic decisions on spares holding.

f. Often calculated. Includes reagents and mill balls. Sometimes part of working capital.

g. Minor buildings only; major buildings are normally separately estimated.

h. May be very small for junior company, and significant cost for major players.

i. Country and location dependent.

j. Dependent on form of contract, complexity of project and location.

k. Appropriate to the location and size of workforce.

l. Usually derived on individual line items of direct cost depending on degree of definition. Variable depending upon study phase.

achieved. For example, an accuracy range of ±10 per cent to ±15 per cent is now quoted, rather than a ±5 per cent level of accuracy previously referred to at final feasibility study level. Currently, it is highly unlikely that suppliers would provide price quotations to such a level for all but the most standard of equipment, and for a very limited period of validity.

Similarly, it would be unusual to see 30 per cent of the engineering completed at prefeasibility study as was previously stated. The trend today is much more to ensure that the focus on this phase of study – which in some quarters has the appropriate title of 'selection phase' – is that of making a *selection of the best option* among several possibilities, and then conducting sufficient engineering on that 'go-forward business case' to mitigate risks and focus on a realistic execution strategy and schedule so as to be reasonably sure of having taken account of all relevant costs. Doing too much engineering can be as bad as not doing enough because it wastes time and money, which in turn erodes project net present value (NPV) by expending unnecessary time and effort on detailing options which will be discarded.

However, as Frew (1990) indicated, 'The accuracy of any estimate will be directly proportional to the quality and quantity of data available and to the time and effort put into its preparation'. Thus, the more meaningful work put into the estimate, the more that estimate can be relied on as being a sound reflection of the likely outcome of project costs. There is no real substitute for achieving a level of project definition through study and engineering detail in order to obtain a certain accuracy of estimate.

This concept is illustrated in Figure 1.2, where the coloured bands generically demonstrate the range of variation in estimate accuracy between studies falling into the same class, and similarly the way in which as the degree of project definition increases so do the accuracy levels of the estimate. In reality, there may be overlaps between these bands, but they are a good guide to typical estimate accuracies. The degree of project definition for different levels of study can be seen by reference to the ranges shown in Tables 1.1 and 4.5.

Only at total project definition (ie when the job is done) can the estimate be considered to be 'fully accurate' with zero variation range. Looking at this in terms of the time needed to conduct such different study levels, both the elapsed time and number of hours that go into different levels increase with moving down the study spectrum so as to achieve the required level of project definition. Project progress generally follows the shape of an S-curve, and it is to be expected that the hours expended on any given study as it progresses through different phases increase to reflect the additional effort all round that goes into achieving improved accuracy levels. More is said about this later in the section headed 'Costs of a Study' in this Chapter.

It goes without saying that independent of any considerations regarding accuracy, one is looking also to reduce and/or mitigate risks as the project progresses through study phases.

Furthermore, one of the worst things that can happen during the course of a study – certainly in the eyes of the owner and financier – is that there are significant increases in costs between phases. Although as described in Chapter 2 each study phase has somewhat different objectives, nonetheless, we are looking at basically the same project. So, if what might have looked like a potentially positive business case during the Prefeasibility study (what *should* it be, when we have selected the best case?) becomes marginal at Feasibility stage (what *will* it be when we consider all the relevant factors?), and an uneconomic white elephant when the project is built and finally commissioned – when we come to extract the value, and find it has disappeared – Houston, we have a problem!

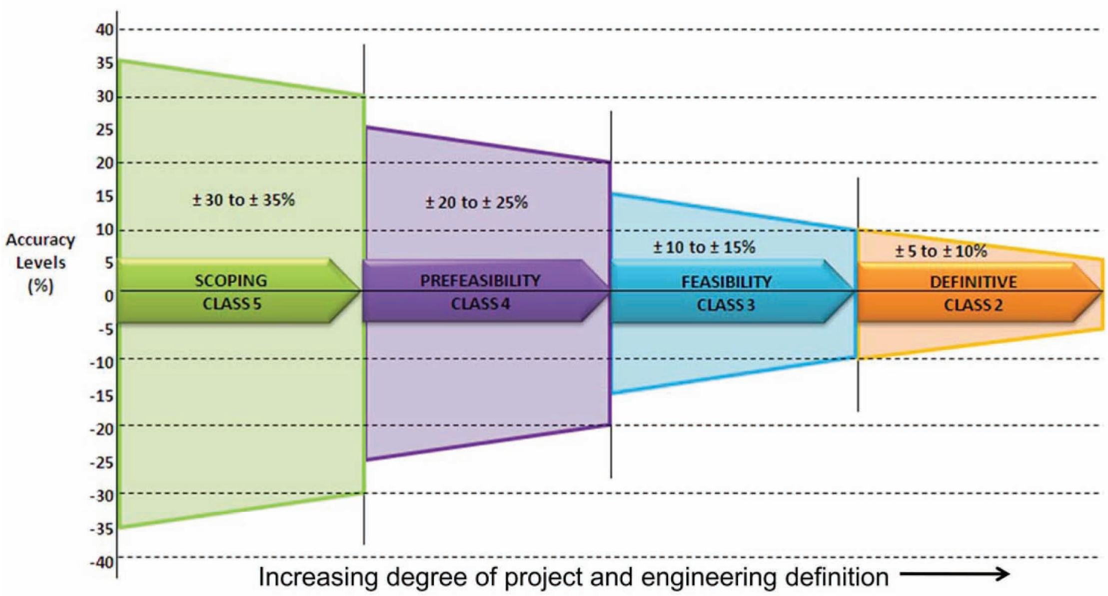

FIG 1.2 - Degree of engineering definition related to the level of accuracy of an estimate.

This can be as a result of many causes, including unrealistically optimistic capital and operating cost estimates at the early stages; by missing out cost elements; underestimating execution realities; not having done enough drilling or test work; applying unproven technology, or having done no or insufficient pilot scale continuous process testing; building in unrealistic price, recovery, or grade projections; or for a whole host of other reasons that sadly happen all too often. These are the elements that have to be examined during the study itself. It is no good having carefully calculated the costs of a process stage with great precision if that part of the flow sheet is unsuited to the range of material characteristics it is being asked to treat. It is thus important that all assumptions, exceptions, battery limits, and ultimately project scopes are kept constant, or are meticulously recorded when they do change for whatever reason. Otherwise, the goalposts inevitably keep moving!

LANGUAGE AND TERMINOLOGY OF ESTIMATION

Any volume such as this communicates across different disciplines. As the first edition did for several years, it is valuable in breaking down barriers and allowing mining industry professionals to talk a similar language – that of economics.

Such it is with estimating. We may feel that we have rather a lot of unknowns to deal with, and hopefully this volume may help demystify the subject somewhat, courtesy of the many learned and experienced minds that have contributed to bringing this together.

The level of accuracy required for a cost estimate is a topic on which there is much debate. The first task in the preparation of a cost estimate is the determination of what level of accuracy is required. What this handbook does is guide the reader through the steps necessary to prepare an estimate to a given or selected level of accuracy. It outlines the method of developing the cost estimate, shows how the equipment design criteria are chosen and the equipment sized, and provides guidelines for the costing of the selected plant using prices current at the time of publication.

There is no substitute for the skills and experience of professional estimators, particularly when it comes to compiling the necessarily more accurate estimates that underpin definitive feasibility studies and beyond. However, correctly used, this volume can get the ball rolling to help bridge the gap between those who provide quantities and take-offs to estimators and the process of cost estimating itself.

Having a realistic project execution plan (PEP) that adequately captures costs associated with specific circumstances of access, altitude, climate and SLTO are crucial if costs are to reflect what has to be constructed and operated.

Specific definitions, such as those for contingency, allowances, growth, escalation and other terms that often cause confusion if not controversy are explained further in the detailed chapters that follow.

FACTORED COST ESTIMATES

'Factored cost estimates' in which we extrapolate or interpolate one (unknown) project from another (known) project according to scale, throughput or other dimension, are perhaps the most basic way of getting an estimate, and are thus a good starting point. A few examples of such methodologies are presented here.

They should be viewed as rules-of-thumb, first-pass or sanity checks, and as such mining professionals have to know when not to use them as much as when to do so. It is fair to say that in all these methodologies, the two projects or installations being considered must be similar; if not, the 'special adjustments' one to the other will overwhelm the comparison.

The six-tenths rule

For the moment assume that an initial (±35 per cent) estimate is being prepared for a scoping study of a prospective mining operation. Estimators may initially determine the magnitude of the project cost using what is commonly referred to as the six-tenths rule described by Mular (1978):

$$\frac{\textit{Unknown Cost (Plant Capacity 1)}}{\textit{Known Cost of Plant with Capacity 2}} = \left(\frac{\textit{Capacity 1}}{\textit{Capacity 2}}\right)^{0.6}$$

This simple rule states that the capital cost is estimated by substituting the capacity of the operation being studied into this formula together with the capacity and the known capital cost of a similar operation but different throughput. The emphasis is on similarity, so as not to stretch the friendship too far.

As a realistic working example, this author recently worked on a copper project. Approximate capital costs were needed for a pyrite-burning sulfuric acid plant that generate acid for a large-scale heap-leach operation where the costs of importing acid would be prohibitive. The logistics of delivering what might be up to 4000 t/d to a remote location at 2500 m above sea level (asl) along poor roads would pose severe logistical and environmental challenges to say the least. From another study done two years earlier for that same company, this author had a capital cost for a much larger (8800 t/d) installation.

Applying the six-tenths rule, conceptual – or perhaps even order-of-magnitude – we derived cost estimates for plants of different sizes to a level of accuracy that allowed decisions to be made about the economics of building a captive acid plant. The accuracy achieved also allowed different configurations and capacities to be compared. In turn, the economics of having sufficient acid available to increase leach recoveries could be modelled.

Annualised cost per tonne

Another rule-of-thumb method used –the annualised cost-per-tonne rule – uses the capital cost of a known operation calculated on a per-tonne basis as below:

$$\text{Annualised cost per tonne} = \frac{\text{total capital cost}}{\text{capacity in tonnes/annum}}$$

This factor is then directly applied to the new operation under consideration. For example, if a 20 Mt/a iron ore processing operation has a capital cost of $800 M, the annualised capital cost is $40/t. A new mine in the same area with approximately the same configuration, but producing 25 Mt/a, might be expected to cost $1000 M, using the above formula. Using the six-tenths rule, the estimated cost would be $915 M. Given the level of accuracy that both methodologies produce, these are within the same range.

As with the six-tenths rule, this estimation method cannot be extended indefinitely, but if the input data are carefully selected, and the operations are broadly similar, the rule can produce indicative estimates that are within the required accuracy levels. Where it breaks down is when significant step-changes in unit process capacity occur, such as the need for a new primary crusher or mill line. Also, it will diverge from the results obtained through using the six-tenths rule when getting too far from the base production capacity, as this is a linear relationship, while the six-tenths rule uses an exponential factor.

These differences are apparent in Figure 1.3, which uses the different methodologies based on using exponential factors (0.6 and 0.7) or linear annualised cost to derive capital cost estimates from a known base. No one method is right, but inherently more or less conservative estimates may be generated as a result of the straight mathematics of the process.

To take this one step further, there is evidence that where there are effectively no economies of scale, other than perhaps in design, such as a second identical mill or flotation line, the factor should be 1.0. For an extension or expansion to a module, where common infrastructure and/or services are shared, factors around 0.6 to 0.7 are acceptable. For expanding a power line where there is already a large investment in the civils, first principles judgement is best applied.

Unit capacity

Capital cost estimates for unit operations are calculated once the unit operation is sized – usually for capacity on a tonnage or contained-metal basis. In the chapters in this handbook, the authors have tried to present methods of costing this operation as a mathematical formula, graphical representation or table.

Cost factors are also used as a means of estimation based on some suitable parameter of the unit operation and are expressed (usually) in straight-line logarithmic functions between set limits (eg Mular, 1978):

$$\text{Cost} = aX^{b}$$

where:

X selected parameter (eg motor power, equipment dimension, etc)

a capital cost constant

b scaling constant

Constants a and b are derived from historical raw equipment data collected by the estimator over time. Some tables of the constants have been published for countries such as Canada, South Africa and the USA (Mular and Parkinson, 1972; Ruhmer, 1987; Clement *et al*, 1977). However, it is necessary to take particular care in extending this too far back: there have been step-changes that have recently changed the rules because of fundamental changes in market supply and demand factors.

Total installed cost

In many of the examples shown in this handbook, the capital cost estimates derived are the direct costs

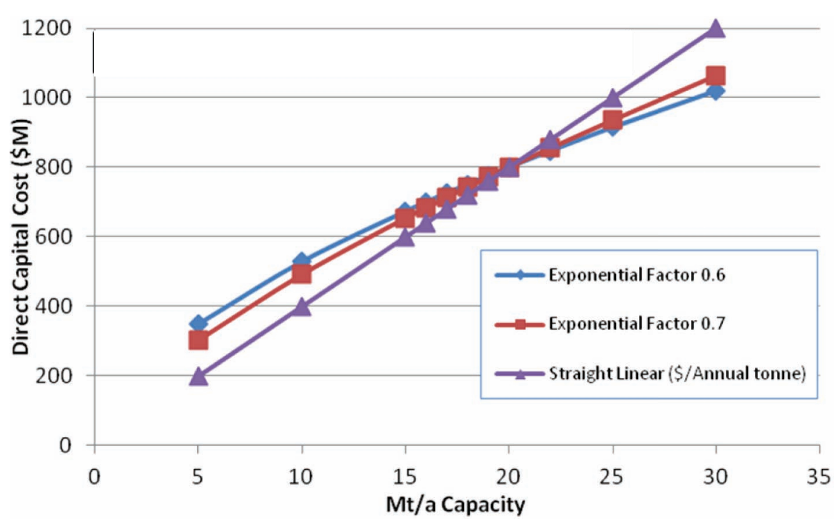

FIG 1.3 - Comparison between factored estimating methods.

related to particular pieces of equipment, or unit processes. However, what is normally of interest is the total installed cost (TIC), which reflects the fact that there are still significant costs necessary for project completion – collectively referred to as Indirect Costs. These are the costs to design, ship to site, pay taxes and duties, install and commission the plant, train people, house and transport the construction workforce, and a whole host of necessary costs required to provide a working project. At study phases, there is still uncertainty associated with cost estimation that has to be allowed for, and this is dealt with by contingency and allowances. Subsequent chapters cover these in more detail.

In the first edition, the authors used an example based on the Mular (1978) methodology of the factored estimate method (sometimes referred to as the 'plant component cost ratio method'), demonstrating how the procedure operates. Although the methodology is correct, the way that example was presented is perhaps not as clear as it could have been, and it has been updated (Table 1.2). However, there are many different corporate standards, and it is important to ensure that the presentation, but more importantly, the calculation method, are both in the correct format. No doubt many people will hold a view on the multiplying factors proposed, based on their own experiences. The authors stress that this is intended only as a guide. Suitable health warnings apply, and all figures are rounded! The example is intended to be at a Scoping study level.

Factors for the installation of piping, electrics and instrumentation are shown applied to the direct capital cost of equipment to derive those costs. Generally, factors are shown as ranges, and a typical small piping and piperack percentage might be 15 per cent. This would be quite normal at early estimate stages, where individual small pipes and the detail of electric distribution and instrumentation would not be calculated from first principles, but would be 'factors' of total equipment cost.

Spares and first fill also need to be calculated. Spares are usually derived as a percentage of equipment cost, while first fill would be a calculation based on, say, mill ball, reagent tank and diesel storage capacity.

The example went on to also use factors for process and auxiliary buildings, plant services and site work. Again, factors were used. Today, given the often significant infrastructure costs, and the specifics of site civil works, it is more likely that separate costs for these would need to be calculated. Therefore, in the example, these are only intended to represent small buildings.

Finally, percentages have to be applied to the summed cost above to derive engineering, procurement and construction management (EPCM[1]) costs. At higher levels of study, these would be derived from first principles based on proposed manning and salary and fee levels. To all of these, a contingency figure must then be applied to reflect the level of uncertainty in such estimating. The example in the first edition used blanket values for these indirect cost factors. Today, it is more likely that individual EPCM and contingency factors would apply to different parts of the equipment cost derivation according to the work breakdown structure (WBS) to reflect different levels of accuracy in their derivation. This is especially true of contingency, which varies by commodity within the estimate.

Using this estimation technique, factors for installation and for EPCM and contingency mainly come from the estimator's experience or by comparison with other similar operations for which cost breakdown data are available. However, the selected factors are very dependent on the particular project, and great care has to be taken in applying them; this should be done in consultation with a specialist estimator.

An important point is estimating the size of indirect and contingency costs as a percentage of project cost. In the example above, at $1110 M they represent an additional 'multiplier' of almost 76 per cent on direct costs ($1470 M). Clearly as the direct costs increase, this multiplying effect from indirect costs has a large bearing on the total project cost. While this is usually a very controversial area of debate between client and its engineering provider (especially in relation to the percentage of EPCM charges), the reality borne out by many hundreds of projects is that these are 'real' costs that are genuinely incurred in project development. These real costs are ignored at our peril.

As former US Defence Secretary Donald Rumsfeldt noted:

> *There are known knowns; there are things we know we know.*
>
> *We also know there are known unknowns; that is to say we know there are some things we do not know.*
>
> *But there are also unknown unknowns – the ones we don't know we don't know.*

As previously noted, the importance of tying any estimating methodology to a realistic project execution approach needs to be reinforced. Without this, installation and indirect costs are likely to be grossly understated, or in the extreme, invalid.

Social, community, closure and other costs

Mining projects are increasingly social, environmental and techno–economic in nature. Fundamentally, they need to be sustainable, balancing all these aspects with good governance. To proceed to a working operation, the correct legal documents have to be obtained – generally after submitting lengthy and expensive baseline and other studies. Most licensing processes involve community debate and consultation at national,

1. 'Term generally used to describe the engineer who independently contracts to offer such services (including study management services) on behalf of the owner.

regional and local levels. Costs for these activities have to be allowed for initially, and often in terms of ongoing currency of such documents.

In many areas, land purchase will be required to site plant, infrastructure, rights of way, waste dumps, heap-leaching pads and other facilities that may require extensive tracts of land. Communities may have to be relocated, involving purchase of existing landholding and areas to where people will be displaced. Water rights may have to be purchased, and/or alternative sources for affected communities provided. Heritage and special archaeological or environmentally sensitive sites have to be catered for by a combination of exclusion zones, avoiding the sites altogether, and possibly even relocating them. All these aspects carry cost and schedule implications.

As well as all the legal documents, mines need to have an SLTO if they are to operate in harmony with affected communities. While this may be a combination of written and unwritten contracts, it has to be earned and maintained on the basis of good performance and community trust. This means allowing costs for appropriate initiatives.

All mining projects have a finite life related to the reserve tonnage, and at the end of its economic life, a mine will close. At the time of the original volume, the debate around closure costs was usually restricted to matters such as whether to allow for five or ten per cent of the cost of equipment and steelwork to be recouped at salvage value. Nowadays, debate is most definitely around allowing sufficient capital – albeit at some time in the future – to cover rehabilitation costs, deal with acid generating streams (potentially indefinitely) and cover issues such as the payment of redundancy and social costs to workforce and affected communities. Generally, such costs are derived from first principles taking into account the physical steps needed to address the specific project issues on cessation of operations.

Battery limits – caution

A cost estimate for an integrated mining and milling operation cannot be made until battery limits and baseline assumptions have been defined. Baseline information including the geological environment, mineral resources, topography, climate, availability of water supply, electric supply, site access, availability of suitable labour and many other data are rarely available in the right format at commencement of the study estimate. Thus assumptions must be made and explicitly stated and documented. Too often estimates and studies overlook the statement of baseline assumptions and the consequent accuracy of the study is overstated. It is recommended that the first step in any estimate is the statement of the baseline assumptions, which has the secondary benefit of scoping the battery limits of the study. Any changes can then be logically and methodically documented such that these variations flow through to all estimates that are based on these assumptions.

COST INDICES

Cost estimation methods are generally based on accumulations of historical cost data available to or collected by the estimator. Cost data presented in the first edition of the handbook published in 1993 is still relevant if cost indices are used to update information. However, the implied simplicity of doing this must be treated with some caution because of the changes in costs in our industry over the past two decades. At their most simple, costs can be updated using the ratio:

$$\text{Cost now} = (\text{cost then}) \times \frac{(\text{cost index now})}{(\text{cost index then})}$$

There are several sources of cost indices available, usually provided by government agencies such as the Australian Bureau of Statistics (ABS). Some of these indices are specific to the mining industry such as the Price Index of Materials Used in Coal Mining, Australia (ADS Catalogue No 6415.0).

It is important to deal with specific indices rather than a measure of more general inflation such as Consumer Price Index (CPI). That means that the focus should be on commodities such as structural steel, platework, concrete, earthworks, copper (because it is a significant component of electric installations), industry labour rates and energy prices.

LIMITS OF ACCURACY

In the introductory comments of the first edition, the authors suggested that 'An estimate produced using the handbook properly generates a preliminary estimate for a prefeasibility study level of accuracy (±25 - 30 per cent)'. On reflection, and as a function of the many changes that this introductory chapter has alluded to, this would only be true in the case of very simple projects in relatively benign environments. It might be argued that in its true sense where a prefeasibility study (PFS) is there to 'select a single go-forward case from among several alternatives', this handbook will be valuable in helping generate costs related to those various options to allow for selection. However, it is not recommended that it be used in isolation as the sole decision-making mechanism without a good deal more design and engineering work being done. There is no escaping the shape of Figure 1.2, which shows that a certain amount of engineering is needed to achieve a required level of estimate accuracy.

The approaches cited in the chapters on operating costs produce individual unit operations' estimates to a reasonable degree of accuracy. However, as with all such methodologies, care must be taken to avoid a tendency to become 'precisely wrong'. It may be possible to calculate wage rates down to the nearest dollar, but if the organisational structure proposed is unworkable, overall costs can be highly incorrect.

In this regard, there is no substitute for experience and bouncing ideas off experienced colleagues. It is also important to state baseline assumptions so that when the main driver (such as the number of positions in the organisation) changes, costs can be updated.

COST ESTIMATION AND THE JORC CODE

An important need is to have a somewhat standardised and at least consistent system of cost estimation when applying the 'modifying factors' across disciplines in the Joint Ore Reserves Committee (JORC) Code. JORC relates to the reporting of ore reserves. This process is shown in Figure 1.4 – the common language of such modifying factors is that of cost.

The JORC Code is one of the most important concepts in ensuring that The AusIMM and other member bodies exercise control and consistency across the industry, and protect investors. The way in which dear old Pierpoint's[2] Blue Sky Mining company might want to see cost minimised and revenue maximised, irrespective of reality or viability of a mining property, might be regulated by this handbook.

CHAPTERS IN A FEASIBILITY STUDY

While study chapters may go by different names from those used in this handbook, the intent is the same – to generate a number of self-standing but consistent chapters that taken together underpin and describe the feasibility of the project to proceed, and in particular, the relevant costs and schedule. These chapters are often split across owners, engineers and other specialists so a consistent language and methodology is crucial in developing the study. Chapters might include:

1. Summary and Recommendations
2. Development Approach and Business Case(s)
3. Risk
4. Health, Safety and Security
5. Environment
6. Geology and Mineral Resource
7. Mining and Ore Reserves
8. Mineral Processing
9. Waste and Water Management
10. Infrastructure and Services
11. Human Resources, Industrial and Employee Relations
12. Technology and Information Systems
13. Project Execution
14. Operations
15. External and Community Relations (inc Stakeholder Management and SLTO)
16. Capital Costs
17. Operating Costs
18. Marketing
19. Ownership and Legal Aspects (including tax, royalties, permits, approvals, government regulations)
20. Commercial
21. Financial Analysis
22. Funding
23. Status of Studies
24. Work Plan – Future (including Operational Readiness Engineering (ORE))
25. Bibliography and References
26. Appendices

Depending upon the project, other specific headings may be used such as:

- country and regional settings (including Sovereign Risk)
- energy and climate strategy.

Chapter headings, and the weightings and level of detail given to each within the study report, change according to what is important in each project. Many large mines are giant civil construction jobs to develop access and ship product out. Sometimes the process

2. 'Pierpoint' was the pseudonym of a 1990s columnist whose Friday back page of the *Financial Review* often made reference to the darker side of the minerals industry. Blue Sky Mining was a euphemism for the more cavalier members of the industry for whom a JORC Code and a consistent approach to estimating would have been anathema. Pierpoint (possibly a different persona than before) now writes for *The Australian*.

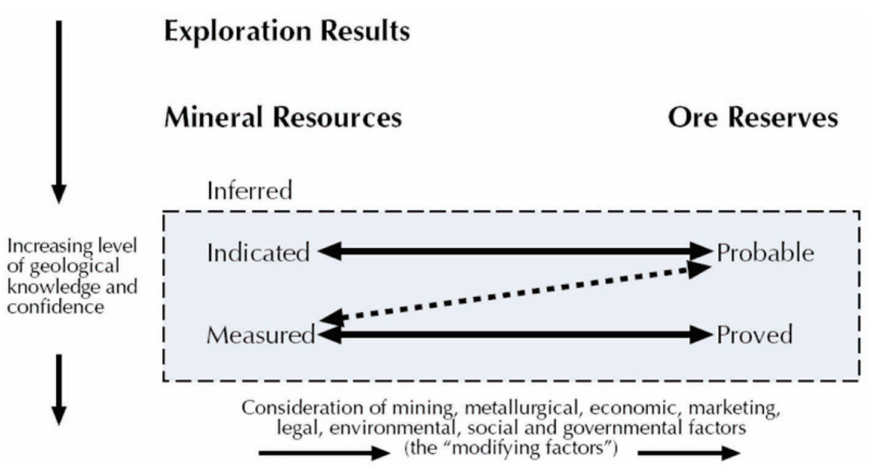

FIG 1.4 - Modifying factors converting mineral resources into ore reserves (source: JORC Code).

plant may be of lesser importance in terms of capital, but the selection of the correct process route(s) still makes or breaks project economics.

BANKABILITY OF STUDIES

The FEL 3, or definitive feasibility study, often used to be referred to as a bankable feasibility study. This conferred a degree of certainty that may not always have existed, and led to endless debate as to what constituted 'bankability'. It was encouraging that the finance and banking fraternity used the first edition of handbook for many years, and in the absence of any improved offering from their own community, the handbook became the prime reference for the level of detail that went into a study at different levels.

The general consensus nowadays is that engineers and project sponsors should avoid using the term 'Bankable', as its meaning varies depending on when and by whom it is used. If referring only to the technical completeness and level of detail in the engineer's report, this is usually not broad enough to satisfy a bank's requirements, and the project sponsor would need to analyse overall project viability and profitability, including the market analysis. A bank may be sufficiently satisfied to lend 60 per cent of future development costs, whereas the sponsors are seeking 80 per cent. Despite the accuracy of the engineering, the sponsors have not got what they wanted.

So, whilst it is fair to say that:

> *A bankable document outlines the technical risks inherent in a mining project, delineates methods of eliminating those risks, and quantifies the potential economic returns that can be attained at various commodity prices.*
>
> *… the bank itself will ultimately define what is required in a document that it will utilise to justify financing a mining project, so that realistically, one could say that there is no such thing as a bankable document* (Guarana, 1997).

Bankability is concerned with:

> *… the capacity of an owner to obtain debt or funds to construct a project with none, or limited, recourse of the fund providers to assets other than the project or resource.*

Cusworth (2012) notes that:

> *A Feasibility study is bankable only when debt providers lend investment funds, not because a study has achieved a claimed quality*

And goes on to discuss a number of conditions which should be met for meeting 'bankable quality', including the study itself being:

- generally optimised
- unlikely to vary
- able to stand- alone
- capable of being tracked to validated and fundamental bases of calculation
- able to be used as a control base line
- able to be audited, reviewed, and signed-off by the lender's independent engineers
- capable of having risks assessed and allocated
- capable of forming a project establishment document under Loan Agreements entered into.

It is the character of the investment, the sponsor and the lender who decides whether the project can be 'banked' or not, and in that sense, no engineer can contract to deliver a Bankable Study. Nonetheless, every major Engineer and Consultant has to be able to produce a study to a *Bankable Quality* (using criteria such as those above) if the investor is to reasonably be able to seek debt funding.

TIME VALUE OF MONEY

This is a concept by which the discount rate to be applied (essentially the risk-adjusted cost of project finance) means that the NPV or net present cost (NPC) of future cash flows is discounted to a smaller portion of its calculated value when brought back to present-day terms. For a project discount rate of eight per cent, a cost or revenue in Year 5 is approximately two-thirds of its stated value when brought back to present-day terms, while at a rate of 15 per cent that discounted value is only 50 per cent of its present value.

$$NPVr = \left(\frac{1}{1+r}\right)^{y}$$

where:

r cost of capital (the discount rate)

y year in question

It is noteworthy that while briefly mentioning the time-value of money, this discussion has studiously avoided getting into any debate on the treatment of taxation (including tax breaks) and matters relating to foreign exchange, hedging and other complex financial topics, which require specialist treatment and advice.

Financial modelling within studies is again a specialised subject, worthy of its own volumes. However sophisticated the tools and complex the analytical methodology, at its heart it is absolutely necessary to understand the drivers of cost and revenue. The authors hope this handbook will play its part in helping set up such models correctly.

PROCESS SELECTION CRITERIA

Before commencing with the cost estimate it is necessary to size or determine the capacity of the overall (or unit) operation by developing a conceptual flow sheet and calculating the mass or materials balance. For a treatment plant, this is usually referred to as the metallurgical balance. All the known data such as throughput tonnage, ore grades, concentrate grades, metallurgical recoveries and many other design criteria are incorporated into the balance.

The consequent process flows of solids, water, slurry, fuels and air and heat and energy balances are calculated. This exercise calls for a high level of skill and experience in balance preparation, normally by a process engineer. If there are errors in the balance, equipment will be wrongly sized and the entire cost estimate is of questionable value.

Both the capital and operating cost chapters describe methods for choosing the process parameters and procedures for sizing and then calculating the cost of the chosen operation or piece of equipment. Usually a worked example is provided to lead the reader through the procedure. In this sense, the following are the key parameters to be derived:

- process design criteria
- material and heat balances
- equipment list
- electric load list
- material take-offs (MTO)
- process flow diagram (PFD)
- piping and instrumentation diagram (P&ID)
- electrical single line diagrams (SLD).

WORKING CAPITAL

The first edition drew the readers' attention to the need to adequately account for working capital in economic modelling. As before, examples are provided to highlight:

- cycle time for operations such as heap-leaching, where a 'lock up' of 300 days of leached copper is not uncommon
- days inventory in stockpiles and elsewhere
- major and minor spares and maintenance requirements (labour and consumables such as mill and crusher liners)
- negative effect of contaminants in concentrate which, at extremes, can create significant penalties or even rejection of a shipment
- ramp-up full capacity
- reagents, commodities (such as mill balls) and raw materials (diesel and oil)
- shipping time of concentrate, and obtaining credit for the values.

These are important factors in economic modelling, where the time value of money is crucial.

REVENUE GENERATION AND MARKETING

The editors of the first edition referred to the debate about whether they should include a chapter on revenue generation given the complexity of the subject. Past users of the handbook will be eternally grateful that they did, as this has for many been a very useful reference for understanding that for a variety of commodity dependent reasons, what you see in the straight calculated percentage or grade in a concentrate is not always what you get as revenue.

The intent of this handbook is to provide a guide to those who evaluate projects. While its focus is to help those who need to estimate costs, these are rarely done in isolation without also generating revenue projections for the operation being studied. To this end, quantum and the timing of project cash flows are important. As is seen in the worked examples, smelter charges and the realisation costs associated with the marketing and delivery of product are very real costs and can be significant on a cost-per-tonne basis. Large-scale copper heap-leach projects are relatively common, and the project has to account for the long lead time – perhaps up to a year – before that copper can be recovered. Charges and timing such as these are sometimes overlooked or underestimated.

Market realisation costs are often handled in different ways in cash flow projections, depending on the structure or corporate philosophy of the company. Normally a mine is locked into a contractual agreement with a customer such as a custom smelter, refiner or end-user. However, a vertically integrated company with its own smelter may unduly weight the smelter charges against either the mine or smelter to suit its own circumstances. The estimator needs to understand how these contractual agreements operate.

In Chapter 17 – Infrastructure Capital, the realisation costs cover the sum of all transport insurance, superintendence, assaying and marketing costs. However, marketing costs associated with identifying a market for the mine product vary enormously depending on the skill of the company in identifying and analysing market trends, and other considerations. In this context, the financing of a new mining project (Chapter 12 – Beneficiation – Concentration) is often dependent on the product.

Finally, it should be noted that the effect of not meeting product specifications, or introducing deleterious product impurities such as arsenic, may have a drastic negative effect in terms of incurring penalty charges – or may even lead to the rejection of a shipment – while credit for gold and silver can be a project saviour. Also, all calculations must correctly relate to dry tonnes where this is relevant. Shipping water around the globe costs money, and usually doesn't add any value!

CENTRAL ESTIMATES

For the most part, this handbook has dealt with the development of central estimates – neither over-conservative nor overly lean estimates. However, it is perhaps useful to comment on the value of referring to a range of values, rather than single point estimates, and being explicit as to areas where estimates may be of lesser of greater accuracy. Using relatively common deterministic and probabilistic software such as @RISK allows cost distributions rather than point estimates to be used, and then for a large number of simulations to be run to determine how robust the project justification is likely to be.

The importance of weighting one or more areas of the estimate more heavily than others in determining the validity of the overall estimate may also be a way in which good judgement is just as important as the mechanics of estimating.

OPERATING COST ESTIMATES

Most of the discussion so far has been concerned with the estimation of fixed or variable with capacity capital costs. Chapter 5 goes into great detail into the methodologies relevant to the estimating of Operating Costs, and then in each of the operating cost chapters (Chapter 8 – Underground Hard Rock Mining to Chapter 18 – Waste Storage and Handling) the authors have provided typical fixed, variable and semi-variable operating costs that are likely in any mineral resource project, and have given examples of the levels of costs that might be expected.

The derivation of operating costs is an area fraught with complexity, and usually requires knowledge of the specifics and complexities of the operation such as location, wage rates, operating norms and specific organisational structures. There is no substitute for this understanding – getting operating cost estimates wrong can have a major impact on the profitability of an operation. Nonetheless, the examples given in this handbook provide guidelines that allow at least an initial pass of such costs to be developed from first principles. The examples give useful checklists for the many items and areas that need to be covered.

COSTS OF A STUDY

A common question is, 'What would a study cost and how long would it take?' The answer is, of course 'it depends', and depend it does on a huge number of considerations.

Firstly we have to define just *what* costs do we mean? Are these the costs of engaging an engineering (EPCM) study manager alone, or does it mean the 'full' study costs, including:

- access to site
- community programs such as providing services, or resettlement
- contingency
- drilling and exploration
- test work (laboratory and pilot plant)
- field investigations (including geotechnical, hydrology, and hydrogeology)
- early definition or purchase of long lead time (LLT) items
- environmental permits and approvals
- government agreements
- management fees and royalties
- owners' team (plus 'corporate')
- site camp
- SLTO
- withholding tax.

As these can be so highly variable, this author's answer is to exclude these from the metrics expressed below as percentages of the Capital Cost of a Project, and to separately calculate them dependent upon knowledge of what is required to carry out such work to the required standard.

With this exclusion, we can focus on the likely total cost of the study as a percentage of TIC, and the range of values to be expected is shown in Table 1.3. This is taken from Cusworth (2008).

In practice, the likely total cost of carrying out a study very much depends on factors such as the following 'C's':

- Client – most major miners have processes that are very rigorous, with comprehensive study standards that have to be followed. Junior minors are much more flexible, especially at early stages of study. Larger companies have extensive peer review and gating processes for approvals, which all add to cost. Joint ventures need even higher proportions because almost everything is duplicated in the review and approvals processes.
- Commodity – to a certain extent this is due to the proportion of complex engineering (process, material handling) and 'bulk' earthworks and civil engineering infrastructure. Iron ore projects are typically in the latter category.
- Country – the location of the project, the owner(s), and where the engineering is to be done.

TABLE 1.3
Expected range of study costs.

Cost of carrying out a study expressed as a percentage of the total capital cost of the project (TIC)			
	Complexity and/or size of the project		
Study Stage	Low	Moderate	High
Scoping	0.1 - 0.2	0.2 - 0.5	0.5 - 1
Prefeasibility	0.2 - 0.5	0.5 - 0.75	0.75 - 1.5
Feasibility	1 - 2	1.5 - 2.5	2.5 - 3.5
Total % of capital over study stages	1.3 - 2.7	2.2 - 3.75	3.75 - 6

- Characteristic – is the project brownfield or greenfield, and what is the status of infrastructure?
- Conditions – the status of market supply and demand conditions, as this greatly affects the cost and availability of services.
- Company – or owner, and the size and skills of the owners' team.
- Complexity – the inherent technical complexity of the project – mining and process – especially if it is new or unproven technology. Remember too that a significant proportion of costs for management and project controls are schedule-related, so the longer time frame studies rack up more costs simply down to their longevity.

Often, there is an unrealistic expectation that studies can be done faster and cheaper than turns out to be the case, and that phases can be concertinaed or skipped out to get to market quicker. The reality is that this is rarely the case, and the industry is littered with examples of project failures that could have been avoided with more and/or better study. As Chapter 2 notes, 'studies form the fundamental basis for the progressive decision to invest in developing potential projects'. It is hoped that this handbook will help in making better informed decisions, and ultimately reducing the incidence of those failures.

REFERENCES AND FURTHER READING

The general references previously used in the first edition still remain valid, despite their vintage in some cases. These include the following:

Clement, G K Jr, Miller, R L, Avery, L and Seibert, P A, 1977. *Capital and Operating Cost Estimating System Handbook for Mining and Beneficiation of Metallic and Non-Metallic Minerals Except Fossil Fuels in the United States and Canada* (USBM, STRAAM Engineers Inc: Irvine, CA).

Frew, R S, 1990. Estimating the cost of a feasibility study for a mining project, in *Proceedings Mining Industry Capital and Operating Cost Estimation Conference – Mincost 90,* pp 25-28 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Mular, A L, 1978. The estimation of preliminary capital costs, in *Mineral Processing Plant Design* (Society of Mining Engineers of the AIME Inc: New York).

Mular, A L and Parkinson, E A, 1972. *Mineral Processing Equipment Costs and Preliminary Capital Cost Estimations*, special volume 13 (Canadian Institute of Mining and Metallurgy: Montreal).

Reynolds, E, 1990. What does it mean? in *Proceedings Mining Industry Capital and Operating Cost Estimation Conference – Mincost 90,* pp 3-8 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Ruhmer, W T, 1987. *Handbook on the Estimation of Metallurgical Process Costs*, special publication no 9 (Council for Mineral Technology: Randburg).

In addition, we refer the reader to the various proceedings associated with the *Project Evaluation Conference* Proceedings published by The AusIMM in 2007, 2009, 2012 and onwards. Various papers in these volumes are valuable sources of reference, such as:

Mackenzie, W and Cusworth, N, 2007. The use and abuse of feasibility studies, in *Proceedings Project Evaluation Conference*, pp 65-76 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Since the first edition, it is fair to say that the body of knowledge and an increased interest in the subject matter relating to cost estimation has caused the sources of reference and written publications in the field to expand exponentially. No attempt is made here to catalogue all the available sources, but the reader may find the following to be of value:

AACE International Recommended Practice No 18R-97, 2000. Cost estimate classification system as applied in engineering, procurement and construction for the process industries (AACE Inc, 2000).

De la Vergne, J, *2003. Hard Rock Miners Handbook Rules-of-Thumb*, third edition (McIntosh Engineering: Tempe AZ).

Evans, D, 2008. Analysing the risk of bankable feasibility studies in today's mining supercycle, *Engineering and Mining Journal*, September.

Guarana, B J, 1997, Technical flaws in bankable documents, paper presented to *Assaying and Reporting Standards Conference*, Singapore (Behre Dolbear: New York).

International Project Studies, *International Mining*, December 2007, pp 41-46 and January 2008, p 66.

JORC, 2004. Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (The JORC Code) [online]. Available from: <http://www.jorc.org> (The Joint Ore Reserves Committee of The Australasian Institute of Mining and Metallurgy, Australian Institute of Geoscientists and Minerals Council of Australia).

Specifically, bodies such as Independent Project Analysis (IPA) maintain huge project databases to allow the analysis of factors relating to the success or otherwise of projects in meeting estimated capital costs and schedules. They provide courses and education, and consult to many companies to establish benchmarking and best practice, including measures and metrics (www.ipainstitute.com) There generate many publications, including:

Merrow, E, 2011. Industrial mega projects: Concepts, strategies, and practices for success (IPA : USA).

O'Brien, J, 2009. Performance of capital projects in Australian processing industries, presented to *IPA Asia-Pacific Conference*, June.

In relation to useful source documents in the areas of community, social, sustainability and closure, a number of Australian Government publications by the Department of Industry, Tourism and Resources (DITR) or the Department of Resources, Energy and Tourism (DRET) have been published including:

Department of Energy, Resources and Tourism (DRET), 2011. A guide to leading practice sustainable development in mining, July.

Department of Energy, Resources and Tourism (DRET), 2011. Social responsibility in the mining and metals sector in developing countries, July.

Department of Industry, Tourism and Resources (DITR), 2006. Mine closure and completion, October.

A further useful reference for closure costs is:

Community Engagement and Development, DITR (October 2006).

Kaiser, C F, Murphy, D P and Dewhirst, R F, 2006. Plant design for closure, in *Proceedings MetPlant 2006*, pp 160-174 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Finally, all major mining companies have standards for use in their feasibility studies relating to the level of detail that needs to go into their capital and operating cost estimates. In addition, independent advisors such as Enthalpy produce procedures and standards that are well worth referring to, such as:

Cusworth, N, 2007. *Minimum Standards and Basis of Cost Estimates, Quality and Definitions of Phases* (Enthalpy: Brisbane).

Cusworth, N. 2008. *Minimum Standard – Cost Estimating – Studies – PCS_CES_1111* (Enthalpy: Brisbane).

Cusworth, N, 2012. *Definition of the Quality of a Bankable Feasibility Study – Proforma 4275A* (Enthalpy: Brisbane).

Finally, some further notes on some inconsistencies in estimating practices, and sources of reference that were uncovered during the course of this research.

There was found to be many variations in the naming and categorisation of studies. For example, the Association for the Advancement of Cost Engineering (AACE International) in its cost estimate classification system of 1998 (Recommended Practice No 18R-97) uses five estimate classes. This specific addendum relates to process industries, which cover manufacturing and production of chemicals and petrochemicals, and hydrocarbon processing. However, it notes that it may apply to 'portions of other industries … such as … metallurgical', and that it 'does not specifically address estimates for the exploration, production, or transportation of mining … although it may apply to some of the intermediate processing steps in these systems'.

In the AACE Classification, Class 5 refers to what it calls an order-of-magnitude estimate, but is quite broad in its remit, and crosses the boundaries of both conceptual and order of magnitude (what the AusIMM has called Scoping) studies. Class 4 similarly spans prefeasibility and feasibility stages, and Class 3 crosses feasibility and 'detailed engineering', which is more in the province of project execution. Finally, Classes 2 and 1 cover control and check estimates, respectively, taking the estimate into the higher levels of project definition between 30 - 70 per cent and 50 - 100 per cent in these two levels.

The above reference comments on other classification practices, including:

- AACE Pre-1972
- American Society of Professional Estimators (ASPE)
- ANSI Standard Z94.0
- Association of Cost Engineers (UK) (ACostE)
- Norwegian Project Management Association (NFP).

The topic of 'Bankability' generated a good deal of controversy as it has always done, and I am grateful to private communications with Peter McCarthy (taken from 'Course Notes on Feasibility Study Types') on this subject, and with the definition provided by the inimitable Neil Cusworth (2012).