CHAPTER 17

Infrastructure

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Infrastructure

This chapter content is essentially that of the 1993 edition (Garner, 1993), but it has been revised and updated to recognise the industry-wide changes that have occurred in the intervening period. Evolving relationships between government and industry and the community and industry have contributed to changes in social, and in some technical, aspects of a project's infrastructure. Changes introduced as a result of industry mergers, the development of short-life mineral deposits, an increasing tendency for mining operators to outsource non-core activities, and the move to larger and more cost-effective equipment – from the mine to the customer – together with advances in technology, all contribute to revised thinking in terms of a project's infrastructure needs. The revisions to this chapter reflect an assessment of the requirements for a project's mining and supporting mineral processing facilities in 2010 (ie at the time of writing).

Infrastructure needs are project-specific. Infrastructure costs as a percentage of a project's capital cost can vary widely and are influenced more by location than are the costs of mine and processing facilities. Any estimate of the cost of the project infrastructure must be based on a realistic assessment of the infrastructure requirements. Identification of the relevant infrastructural items is necessary prior to establishing the magnitude and cost of those items. More so than for most other aspects of cost estimation associated with mining industry facilities, this chapter should be regarded as providing a basic checklist of infrastructure items and as a means of approximately sizing individual elements and identifying costs at order-of-magnitude level. The application of standard infrastructural percentage costs solely related to the cost of process facilities is likely to lead to erroneous conclusions. For any other than the broadest evaluation, professional assessment of infrastructure requirements and costs is warranted and recommended.

Variability in infrastructure requirements arises from the range of items falling within this cost category. Elements of infrastructure that are mine- or process facility-dependent, for example workshops, warehouses, repair shops and administration facilities, can be related to the scale of operations. Others such as access roads, housing, communications and power and water supply are location-dependent and influenced by the availability of existing facilities and services. A further category of infrastructure costs flows from operational decisions relating to the degree of processing used and workforce availability. Operational decisions require economic evaluation following the establishment of process parameters, and particularly, consideration of the social implications of decisions based primarily on economics.

Environmental considerations are well understood. While sound environmental practices equate with good engineering and responsible operations management, infrastructure costs must adequately recognise the need to build in proper safeguards to ensure community expectations can be met over the projected mine life. Community expectations must also be met through the period following closure of the mine and/or facility, as is now required by legislation.

This chapter identifies the major infrastructure cost elements that may be encountered on any mining and mineral processing project, and a means of establishing the magnitude and cost of the infrastructure item. The approximate pricing formulas will allow the assembly of the project infrastructure cost component. The selection of relevant infrastructure elements and the sizing of those elements for each individual project are fundamental to the development of a realistic cost estimate for infrastructure, based on the principles set out in this chapter.

An orderly and systematic presentation of costs is required at all levels of estimation. It is useful to introduce this discipline into the preparation of the most basic of project estimates in order that initial projections can be later reconciled.

Specialist organisations with formal estimating systems have established listings of project components segregated into project areas such as mining, processing facilities, support facilities, support services and management costs. This work breakdown structure (WBS) is further subdivided to identify specific project elements to the level of detail required. Quantity and unit cost data allow the ready introduction of changes or the incorporation of a greater level of detail when the level of accuracy required demands a higher quality estimate.

Approval and permitting requirements for uranium-based projects far exceed those applicable to gold, base metals, industrial minerals and coal. Costs (and time implications) for uranium projects may be expected to exceed the indicative figures quoted here. All costs quoted in this chapter are in Australian dollars.

SOCIAL CONSIDERATIONS

Social performance management is one of the most complex and technically challenging aspects of a mine and its associated facilities development. Social considerations affect all aspects of project development and are especially relevant when infrastructure needs are under consideration. A source of significant stakeholder concern and business risk, the management of social impacts and opportunities demands:

- effective stakeholder communications
- management systems and processes that integrate social performance issues into project planning
- sound understanding of the social environment in which the mine will operate.

All projects, large or small, and wherever located, share similar strategic goals in social performance management. These include:

- manage risks to operations – ensure timely achievement of approvals and land acquisition, ensure security of staff and materials, minimise disruptions and ensure continuity of operations
- manage stakeholder expectations – ensure understanding of project operations, impacts and community benefits, the project's role in the region and the nature and limits of its social responsibilities
- deliver benefit – support the achievement of lasting and sustainable improvement in the lives of the project's host communities
- control costs – ensure management rigour and resource efficiency both in social performance management and social investment programs.

The external environment may be challenging, but these goals are generally achievable if effective social management systems and stakeholder values and priorities are incorporated into strategic planning, resourcing and operations.

Social considerations determine many elements of a project's infrastructure. They are difficult to incorporate in project estimates, but may be a significant contributor to project costs. Their contribution will be reflected in the cost of individual facilities where the implications of decisions made in respect of community expectations result in expenditure in excess of the minimum standards of some past projects. Even for initial global-type estimates, the cost implications of a project's social considerations must be recognised.

ENVIRONMENTAL CONSIDERATIONS

Environmental considerations, other than those embodied in sound engineering practices, were relatively unknown in Australia during the major developments in the late 1960s and early 1970s. Obligatory compliance with identified national standards first emerged in the USA in the *US National Environmental Policy Act 1969*, which embraced the concept of an environmental impact statement (EIS). Australia followed and during the 1980s, the EIS (or an equivalent document) became an essential component of development proposals. An EIS is particularly relevant for mining and mineral processing plants. EIS requirements later expanded to encompass aspects of development concerned with land use, land access and social and economic issues. EIS requirements vary from State to State and for projects under Commonwealth jurisdiction, although standardisation is currently being addressed. Specific attention to a project's EIS requirements is mandatory, even at the conceptual planning stage. This ensures that the time for, and costs of, compliance are recognised and incorporated as a realistic project cost.

The EIS process addresses the issues of the total project in regional and national contexts. In a few sensitive areas, some form of environmental statement of intent may be needed at exploration or permit stage. The specific requirements must be fully researched through the relevant agency or responsible government department and due process satisfied. Short-cutting to save time usually results in lengthening the approval process (which adds costs to the project). Under some circumstances, a preliminary environmental review (PER) may be an acceptable alternative.

Environmental impact on infrastructure

Earlier, infrastructure was defined as the non-process facilities required to support the mainstream operations. Industrial and social facilities, utilities and support services to mining, materials handling and process plants comprise infrastructure. The EIS, with its emphasis on a total concept development commencing with initial project considerations, introduces the associated benefit of comprehensive planning. Although the process dominates the project – mining, for example, is constrained by economic and long-term mining plans and processing facilities by technical and economic relationships – the balance of the facilities can be located and designed in a manner that minimises the generation of pollution, reduces the impact on the site and surrounding areas and improves a project's visual appearance.

Environmental factors can influence infrastructure for a mining project in a number of general ways. These factors include siting and sizing of facilities, capacity of the receiving environment and indirect effects, as outlined below (adapted from Jenkins, 1985).

Siting and size of facilities influence the infrastructure in relation to the:

- sensitivity of land forms that may be lost or destabilised
- significance and number of Aboriginal sites that may be affected
- significance of the fauna habitat to be disturbed

- underlying mineral deposits that may be sterilised
- value of existing land use that cannot be fully rehabilitated
- value of the vegetation to be cleared.

Capacity of the receiving environment to accommodate facility discharges must be considered, including ensuring that:

- adjacent land uses can deal with noise, dust, vibration and blasting effects
- atmospheric dispersal of air emissions occurs
- groundwater systems are not adversely affected by leachates from tailings and overburden dumps
- surface waters can accept run-off and wastewater effluents.

Indirect effects on the environment need to take into account the:

- availability of a suitably skilled workforce to construct and operate the mine and associated facilities
- capacity of the existing regional infrastructure to meet project demands (ie water supply, transport systems, sewerage and other services) capacity of the regional economic base to service the mine and increased population
- compatibility of nearby land use with the mine development
- decommissioning of plant, decontamination of land and salvaging of equipment
- drawdown effects of groundwater extraction on existing beneficial uses of groundwater
- establishment of a future land use
- planting of vegetation on disturbed areas
- rehabilitation and/or restoration of the environment on completion of mining
- visual aspects of the landscape and its sensitivity to the mine, together with its associated facilities and infrastructure.

This section highlights those environmental requirements that will influence the size and quality, and hence the costs, of project infrastructure.

Environmental requirements for mining infrastructure may include costs associated with:

- construction or operation of infrastructure facilities
- environmental studies such as baseline measurements, impact assessments, approval application documentation and processing, and public consultation
- mine closure, including rehabilitation and monitoring following closure.

However, environmental considerations should also seek to achieve project benefits. Costs can be optimised through appropriate site and process selection, and better and more economic solutions frequently result from rigorous environmental assessment. Design, construction and operation in a sustainable manner facilitates the acquisition of a social license to operate (SLTO) while at the same time avoiding the potential for prosecution, fines and project disruption. Also, mining operations conducted in a manner that ensures a suitably rehabilitated area for future land use can add value by creating a disposable asset.

Environmental studies

An initial cost is associated with the requirement for a baseline survey. The necessary program will depend on the availability of prior relevant information about the area under consideration. A structured assessment is required, addressing such issues as:

- land – existing use, capability and planning
- natural environment – ecology, vegetation and wildlife
- physical environment – soils, water and meteorology
- social and economic considerations, as required to identify likely impacts and qualify the project.

The costs of such baseline surveys vary widely, depending on the complexity of the issues, but usually they are between A$1 M and A$5 M on straightforward projects. The cost may significantly exceed these amounts on projects with special features or problems. A baseline survey usually requires field research of at least one year (to identify seasonal factors), but this period can be reduced if baseline data are collected during exploration (where this is practical and economically feasible). Some data, for example groundwater chemistry, water table levels, airlifted yields per bore during drilling and climate parameters (temperature, rainfall, wind direction and wind speeds) can be collected with minimal expense. These data can then be correlated with existing available long-term records.

Construction and operation

There is significant interaction between the environmentally critical aspects of mining and mineral processing and project infrastructure in the key areas of waste disposal, air and water pollution, noise and social impacts. Unlike the location of the ore deposit, which fixes the location of the mine, there is usually some flexibility in locating the infrastructure for mining projects. By incorporating environmental factors into siting decisions of facilities such as overburden dumps, tailings retention areas and infrastructure corridors, many environmental issues can be avoided and may not result in additional costs. It may be possible to site facilities so that potential rehabilitation costs from prior operations, or site preparation and drainage costs, are minimised.

A checklist of environmentally-related issues that require attention for cost impact and, where possible, integration with favourable operating parameters, follows.

Mining

- Archaeological site preservation or salvaging
- borrow pit location and/or use of mine waste
- dust and other air pollution control
- mine dewatering and/or pit drainage including water for processing, disposal by evaporation and road watering
- overburden disposal and dump rehabilitation
- transport of ore and waste
- treatment of residual voids or of worked-out underground mines
- vegetation removal, retention of visual screening and revegetation
- waste dump drainage, including sedimentation and treatment prior to discharge or reuse.

Processing facilities

- Emissions control, including air, water and solid wastes
- noise and dust generation control
- product waste and consumables use, storage and disposal
- solid waste disposal
- stockpile management
- tailings containment or disposal, and final stabilisation or rehabilitation
- water management, including wastewater treatment, retention, disposal or reuse.

Utilities and services

- Communications including cable, satellite, wireless and microwave
- compensation for water quantity or pressure loss due to groundwater level reduction
- contributions to the social fabric of the community, whether by providing and operating health and educational facilities or by paying a lump sum or annual contribution
- housing including integration with existing communities, stand-alone communities or long-distance commuting as fly-in, fly-out (FIFO)
- land availability and use
- power generation and/or transmission systems
- transport including air, road, rail and river or sea
- water supply and sewerage.

Mine closure and rehabilitation

Costs imposed by regulatory authorities that ensure approvals conditions are satisfied should be included. Costs include bonds or deposits for site restitution, or from in-house decisions to establish and contribute to a fund for clean-up and rehabilitation as specified during the approval process.

Costs for rehabilitation are difficult to accurately assess, particularly for a long-life mining operation. These costs will benefit from the use of risk-based analyses such as Monte Carlo probabilities of risk and confidence in the closure solution selected, and the assessment of its cost. Deposits or bonds may be required. As these vary with State, advice should be sought on the requirements to cover provisions for closure. Guarantees ranging from $10 M to $20 M could be required.

Progressive waste dump rehabilitation is preferable, with costs regarded as annual operating costs. Tailings storage facilities, however, will probably not be finally rehabilitated until their economic value is determined to be nil. Benefits in terms of land value can be achieved by creating these facilities to achieve their best practicable geotechnical stability. Temporary tailings coverage is also a beneficial measure especially where the capping reduces or reduces acid mine drainage (AMD) problems in the future. The provision of funds for well-implemented clean-up cost will, in many instances, be offset by the resale value of land, plant, equipment and facilities.

ACCESS AND SITE WORKS

This section presents cost considerations for the methods to access a site, and for site works.

Location and logistics

Infrastructure decisions for project facilities are location-specific. Currently, mining companies tend to make rational economic decisions different from those associated with the early Pilbara-type developments, which established major new communities, albeit of limited or finite life based on then-known ore reserves. The questions to be addressed include:

- Is the orebody accessible to an established town or port, and to a source of power or energy?
- Is the value of the product – metal, concentrate or ore – such that transporting run-of-mine (ROM) material for processing is warranted?
- Is the ‘waste’ content of the ore sufficiently high for initial processing at the mine site to be the preferred approach?

The establishment of a grass-roots township suitable for families is not favoured today, despite the workforce stability it encourages. Family support, education, health, shopping and recreation facilities add costs that can adversely affect project economics. Remote and isolated mining activities are increasingly serviced under FIFO or long-distance commuting options, a practice now generally deemed acceptable to governments, unions and workers. This fundamental decision, which trades off capital and operating costs, must be taken early and requires a study to assess the comparative benefits and costs. For initial study purposes, an assumption can be made that full residential facilities to support some level of mining, processing, beneficiation or concentration at the mine site, or of processing and stockpiling at a portside, may be required. Project elements, later identified as either not required or inappropriate, can be omitted in subsequent cost estimates.

Access and service roads

An initial traffic assessment determines the required quality of all project roads regarding traffic and road life, use and location. Major area roads are defined as heavy-duty roads frequently used by passenger and transport vehicles, and design standards are those of the State authority for rural roads with design speeds of 100 km/h. Roads should have a sealed 8 m pavement and trafficable unsealed shoulders of 2.5 m. In unpopulated areas, access roads may be left unsealed.

Sealed roads typically cost between $500 000/km and $2 M/km. The cost is heavily dependent on topography and drainage structure requirements. Sealing costs can be up to $150 000/km. Road geometry, line markings and road markers or signposts should all comply with State standards. Minor area or service roads are light-duty roads for either industrial or residential use. In lightly trafficked areas where dust is not a problem, roads may be unsealed. In work and residential areas, sealing is mandatory and stormwater drainage is required. In areas of short-duration, high-intensity but low annual rainfall, underground drainage systems may be omitted if the road system design provides for surface drainage. The standards include:

- 8 m width for more frequently used roads with public access
- 6 m width for other roads
- 4 m width for minor direct access tracks, generally along power lines and pipelines to water wells, communication towers, construction camps and other facilities.

Traffic on minor roads is generally greatest during construction, while operational use is much less severe. Design speeds are 60 - 80 km/h, with geometry to locally accepted standards. No design criteria apply to access tracks. Costs for minor roads vary from $500 000/km for the higher standard to $100 000/km for access tracks.

Construction traffic frequently imposes extreme loads on State and local authority roads leading to mine and plant sites. Strengthening of pavements and structures may be necessary, with appropriate cost allowances included in project estimates.

Port facilities

Frequently in remote and otherwise inaccessible areas, port facilities must be developed. A project may require load-out facilities for its product and it can be advantageous to incorporate facilities for cargo receipt in the design. Early construction of the cargo facility will assist in receipt of construction materials and equipment, especially if items are imported. Materials handling facilities, storage and probably customs facilities are needed. Port selection is a specialist task requiring skills and experience to properly identify the most appropriate location and type of facility. Port facilities are addressed in more detail later in the section 'Port and marine facilities'.

Airstrips

An airstrip is generally required unless a suitable facility is available within a reasonable distance of the worksite or accommodation and facilities. Many remote localities in Australia already have airstrips capable of accommodating small commuter aircraft. Most jet aircraft require sealed runways, which only exist at major population centres. If the workplace is more than 45 to 60 minutes' drive by reasonable road from the nearest established airport or airstrip, the inclusion of such a facility is recommended. Airstrips may be required at more than one location, for example at a mine and processing plant that are separated by more than 100 km.

The standard of airstrip required depends on the service to be provided. Cessna-type aircraft carrying up to six to ten passengers use small grassed or gravel strips constructed to all-weather standards. A FIFO operation using long-range jet aircraft requires a sealed airstrip meeting statutory design criteria. It is unusual for a mining company to operate its own aircraft, which are normally chartered from commercial operators. Aircraft selection and usage dictates airstrip design. In Australia, design is governed by the requirements of AirServices Australia, the body responsible for the control and licensing of aerodromes. A licensed aerodrome is required for all passenger aircraft services. It is advisable that remote mining facility airstrips in Australia satisfy, as a minimum, the requirements of the Royal Flying Doctor Service (RFDS). Elsewhere, medivac providers specify the minimum requirements. Reliance on helicopter access for emergencies may be neither adequate nor prudent. Civil Aviation Safety Authority (CASA) publication CAAP 92-1(1) provides guidance on airstrip geometry and aircraft type performance data. The strip length should accommodate the aircraft type proposed. Current FIFO operations may comprise long-distance commutes using aircraft of capacity up to 100 passengers. Some larger aircraft in use include the BAE 146, Boeing 717 and Fokker 100 jets, and for 50 to 70 passengers, the ATR 42-50 turbo prop. An airstrip length of up to 2500 m may be required depending on the aircraft type. The aircraft manufacturers' performance data should be consulted for recommended runway lengths.

Airstrip orientation is dictated by an analysis of meteorological conditions. The need for a cross-runway can be related to the cross-wind tolerance of the design aircraft. Aircraft manufacturers also state runway requirements in aircraft specifications. RFDS runway dimensions are shown in Table 17.1. The facilities required for these airstrips are minimal. It is

TABLE 17.1
Airstrip dimensions
(Royal Flying Doctor Service recommendation).

Runway length (m)	1200[a]
Runway width (m)	45 to 90
Approach and take-off areas (m)	2 × 1500
Runway strip width (m)	18 to 20
Grade	2% (max)

a = if shorter, restrictions may apply. For emergencies, a road of width 15 m and straight length 2 km, and blocked to traffic, is considered adequate.

normal to provide a wind indicator, threshold markers and if required, night lighting. Transportable units are provided for terminal and toilet facilities. The provision of sophisticated navigational aids depends on traffic frequency and meteorological conditions.

Site conditions, particularly earthworks requirements, determine the cost of construction. Typically, airstrip costs could range between $1.5 M for the Cessna-type and $15 M for a strip suitable for jet aircraft. These costs include allowances for facilities, but great care in their application should be exercised, particularly where major earthworks are required.

Site works

Site works comprise one of the most variable of the cost elements of a project. Site selection is critical, trading off increased travel time and materials handling costs against improved site conditions. Site requirements for project elements vary. Industrial and processing facilities require large areas of gently sloping land with good foundation conditions and drainage, and minimal rock excavation. Where steeply sloping ground can be used for crusher or conveyor installations, both capital and operating costs can be saved. Stockpiles, thickeners, industrial buildings and warehouse and storage facilities should be located in areas requiring minimal earthworks. Sites with soil conditions requiring piling for major load-bearing structures and foundations should be avoided where possible.

Site selection for residential areas is governed by different criteria. The site should be close to the workplace, but should be visually screened and located at sufficient distance to minimise noise and dust. It should offer an attractive outlook and allow the development of a pleasant living environment. The provision of services (water, sewerage and power), road works and drainage should not be unduly difficult or costly. The preservation of existing vegetation, however sparse, forms a key element in the landscaping of living areas. Recent examples of successful townships form models for planning residential areas. The costs of site works vary widely and depend on many factors, particularly the topography and presence of exposed or near-surface rock. Site works comprise clearing, stripping topsoil, grading and drainage and ultimately landscaping. For processing and industrial facilities, costs vary between $100 000/ha and $1 M/ha, while in residential areas costs of approximately 40 - 60 per cent of these might be expected.

Drainage

Adequate provision is required throughout the facility for the interception and disposal of surface water and of water generated during mining or processing. Contaminated water from mines, pits, waste dumps and industrial areas must be retained and allowed to settle to reduce entrained solids. If necessary, this water should be treated prior to reuse or discharge to watercourses. Contaminated and mine water should be reused wherever possible for dust suppression or as process water to minimise problems associated with treatment and discharge. Plants that generate contaminated wastewater, which would otherwise require treatment prior to discharge or disposal, are frequently designed on a 'zero discharge' concept. Drainage water from industrial facilities must be oil-free and oil interceptor pits must be included in the system.

Drainage requirements are developed from rainfall calculations for the region using Australian standards or other criteria and methods. Special drainage features such as bridges, major culverts, floodways, treatment facilities and retention and settlement ponds are normally costed as part of the associated facility, so surface drainage is accommodated in site works. Requirements for special features should be noted and costed accordingly.

Fencing and security

Fencing is normally confined to areas requiring security such as warehouse yards, high-value and dangerous materials storage areas, and hazardous materials and explosives storages. Frequently, entire process and support facilities are enclosed with a gatehouse-controlled single entry. This affords a base for both security and emergency services, staffed at all times, that provides control over people entering plant areas. For processing plants where hazards exceed those encountered in normal operations, such as in uranium recovery, full monitored plant fencing is mandatory.

A typical processing facility with industrial and administrative facilities could cover 5 - 10 ha requiring 1000 - 2000 liner metre of 1.8 m chain-link fencing, costing up to $100/m (installed). A gatehouse with emergency facilities, with an area of 100 m^2, would cost $250 000.

INDUSTRIAL FACILITIES

Industrial facilities support mining and mineral processing operations by providing a base for maintaining equipment and production at optimum levels. Facilities may be provided in whole or in part by the operating company but may be limited by contracting out certain activities, or by using existing commercial facilities in nearby towns. A review of the range of available services is required, noting that capital investment can be reduced, and that the workforce and the cost of family support will be less. However, some loss of control may result if those services are not owner-operated – and an increase in operating costs will probably result. Selected services may be handled in this manner. However, at initial review (prefeasibility level or earlier), a safe assumption is that all activities will be company-owned and operated. Any subsequent change will only be introduced if cost savings or other benefits can be demonstrated.

Mine policies with respect to contracting will define the repair and service facilities required. A number of mines now use long-term contracts, which normally include a requirement for the contract mining company to also repair and service their own equipment at their own facilities. A suitable location for such facilities is required, as is access to mine site utilities, which would not be economic for a contractor to provide from alternative sources. There are recent examples of contracted operations reverting to owner operations. In this case, contractor facilities may be acquired or new workshops constructed, as determined by the economics of the philosophy change.

The standard of industrial facilities also needs early definition. High-quality, well-designed facilities with structural steel framing and of masonry or steel sheeting construction are preferred, with a basic design life equating, as a minimum, the probable life of the mine. For short-life, high-value operations such as small gold mines, as distinct from long-life iron ore, copper or coal developments, industrial buildings of a lower quality are normal. Some facilities, in addition to items of process plant equipment, may be relocated when a resource becomes uneconomic. Costs of industrial facilities can therefore vary greatly and an appropriate cost level should be selected.

Workshops

Workshops include repair and maintenance facilities as distinct from those carrying out equipment servicing. They are specifically for the repair of the mine and process plant operating equipment, and are designed for the mix and size of equipment selected. Workshop definition normally follows mining plan development, equipment selection and conceptual plant design. Repair shops require allocated space for repair of:

- conveyor belts
- electrics and instruments
- heavy vehicles
- light vehicles
- plant and equipment
- tyres.

Some of these functions may be combined into a single building for effective management, use of common installed equipment and for overall economy. Specialised store areas, for example for tyres and belts, may be associated with the repair facility. Office space, tool stores, crib rooms and amenities to cater for the building workforce may be incorporated. Within or accessible to each specialised repair facility are general machine shop and fitting bays, welding and fabrication and test and quality control areas. Buildings are custom designed. Door openings and roof heights are sized to accommodate dump trucks (with tray raised), while floors are designed for loaded dump trucks and earth-moving equipment. Bay sizes and installed cranes will accommodate selected equipment and the anticipated components to be moved. Note that generally, major engine overhauls and/or equipment rebuilds are performed at manufacturers' works or off-site.

Some typical examples of workshops that have been installed in or specified for projects are shown in Table 17.2. Interpolation allows a first-order assessment of a specific project's needs, and may be used as a check on a calculated requirement. It should be noted that most mines with a forecast life in excess of eight to ten years expand production levels and additional repair and maintenance space is subsequently required. Layouts should recognise this probability.

Facility sizes vary widely. The variation reflects the equipment mix, repair and maintenance philosophy of the owners and extent of mine and plant repair and maintenance activities proposed to be on-site. Building areas are indicative, enabling an assessment of an appropriate level of support facilities for a project. Costs ranging from $\$2000/m^2$ to $\$5000/m^2$, also reflecting the location, life and projected usage of the facility, should be applied. Costs of workshop equipment, which could increase the above costs by 15 per cent to 30 per cent, must be added to the base building costs.

Servicing facilities

Scheduled maintenance and servicing practices that are computer planned and recorded are now normal in mining operations. Mine fleet servicing, including refuelling, routine servicing and tyre maintenance, is an operational function. Mobile service units attend to the requirements of equipment such as draglines, shovels, excavators, mobile crushers, conveyor drive units and items of fixed plant and equipment. Static servicing facilities include:

- heavy vehicle servicing – dump trucks, earth-moving equipment, miscellaneous trucks
- light vehicle servicing
- refuelling facilities
- washing and degreasing (and in some cases, decontamination) facilities.

Because of the limited time available for service activities, the size (area) of servicing units is based on less-demanding criteria. Sizing must be related to the equipment fleet, generally allowing off-road space for

TABLE 17.2
Sample projects – approximate facility areas (m^2).

Infrastructure capital	Project	A	B	C	D	E	F	G
	Product	Coal	Uranium	Iron ore	Iron ore	Iron ore	Gold	Gold
	Location	Offshore	Remote Australia	Remote Australia	Remote Australia	Remote Australia	Remote Australia	Offshore
	Infrastructure	Separate mine and port	Single location (incl townsite)	Separate mine and port (incl two towns)	Separate mine and port expansion	Separate mine and port expansion	Single location, nearby town	Single location
	Facility	Greenfield site	Greenfield site	Greenfield site	New orebody	New orebody	Greenfield site	Remote, alluvial
	Production	7 Mt/a	1 Mt/a	8 Mt/a	6 - 12 Mt/a	18 Mt/a	4 Mt/a	8 Mbm^3/yr
1	Mine workshop		1860	3360	3940[f]	6230[f]	1000	[k]
2	Mine office	880	240	<930> (1)	1490[f]	2050	350[j]	[k]
3	Mine laboratory			-	90[f]	190		[k]
4	Mine warehouse	2400		<270> (1)	3070[f]	4930	300	[k]
5	Mine amenities		760		2000[f]	2930	Incl (13)	[k]
6	Mine training	240		-	840	840		
7								
8	General workshop	330[b]	1820	8850	1670[g]	3020[g]	450	290
9	Railway workshop		-	<1470> (8)	9200[h]	9200[h]		
10	Vehicle workshop		Incl.	<1250> (8)	<230> (9)	<420> (9)	Incl (8)	
11	Light workshop	1440[c]						
12	Warehouse	1700	2160	<1500> (8)	2300	3060	540	330
13	Plant amenities[a]	145	860	600	930	1440	320[j]	50
14	Administration building	880	1950	1040	-	-	360	280
15	Laboratory – mineral		<360> (14)		-	-	550	
16	Laboratory – metallurgical		800	450	930	930	360	
17	Training centre	530[d]	<75> (14)		840	840	550	
18	Area offices			300[e]	740[g]	1110[g]		
19								
20	Workforce	3000	440	850	900 - 1000	1900	45	234
21	Stripping ratio	5:1	7:1	Nominal	1:1	1:1	4:1	1.2:1

Notes:

a. Bath-house, crib room, etc.

b. At mine.

c. Port area.

d. Shared community building.

e. Plant office.

f. Included (some plant access).

g. Incremental expansion.

h. New facility, size for 18 Mt.

i. Including assembly area.

j. Mine and plant.

k. On dredge.

<> indicates this area included in facility on line (.)

the number of units expected to be simultaneously in servicing, plus one.

A typical mine service facility with supporting workshop and lubrication areas could include:

- cable and belt repair 100 - 200 m^2
- drive-through vehicle service areas 200 - 400 m^2
- office 100 m^2
- shovel and drill shop 150 - 250 m^2
- store 200 - 300 m^2
- vehicle electrical repair area 200 - 400 m^2
- vehicle mechanical repair area 300 - 500 m^2
- welding, fitting and electrical work area 600 - 1000 m^2.

These requirements reflect the need to satisfy the mine operation only and would normally fall under the maintenance supervisor's jurisdiction. Structure and costs approximate those stated above for repair shops (lower end of range). Care must be taken in facility specification (eg with workshops) to avoid duplicating capacity and restrict mine servicing and repair activities to those necessary to satisfy operational short-term needs only.

Vehicle servicing requirements can likewise be estimated, based on the expected vehicle fleet, scheduled service programs and minor repair forecasts. It is prudent to segregate servicing and repairs to ensure the quick turnaround of vehicles on scheduled maintenance. Refuelling areas are frequently installed by the contracted supplier of fuel and lubricants to the mine. The same supplier may serve private users in addition to satisfying industrial requirements. However financed, adequate industrial light vehicle servicing and refuelling capacity is required. Such installations require wash pads with silt and oil interceptor traps, and parking area for 'ready' units. Wash pads may also be necessary to reduce the potential for transmission of contaminants from one area to another. Servicing facilities may be associated with crib rooms to permit servicing to proceed during meal breaks so equipment remains in use.

Warehouses and materials handling

With few exceptions, mines and mineral processing plants are located in areas remote from supply centres. It has been accepted practice for site warehouses to maintain stocks of consumable items and spare parts required for plant and equipment maintenance and repair. The value of the inventory held by mining companies is a major cost. The costs of the storage facility, its operation and the value of the materials and equipment stored must be included in estimates. Warehousing philosophies vary from site to site and require consideration of:

- accessibility to manufacturers' or suppliers' stocks
- operating philosophy on stores and inventory level and use of just-in-time or other approaches to re-ordering
- policies on minimum stock levels
- preparedness of operators in an area or region with similar needs to share 'insurance' spares
- risk assessment factors
- willingness of suppliers to hold consignment spares at sites.

Facilities provided under cover and in the open become a matter of judgement related to projected requirements. It is usual for warehouses to be close to their customers; hence specialised warehouse facilities are frequently incorporated in separate mine and processing facilities. Facilities for fast-moving spares are in service and repair shops. Indicative areas allocated for warehousing on typical projects are shown in Table 17.2.

Efficiency in warehouse operations can only be achieved by the use of appropriate materials handling equipment. Overhead cranes of adequate capacity serving unloading and storage areas, mobile cranes and fork-lift trucks for materials stored outdoors and properly designed roadways and storage systems all contribute to efficient operations. Computerised inventory controls require the provision of a dedicated computer or computer network. The complexity of the system required is dictated by the materials management system used.

Warehouse building costs will generally be 20 per cent less than steel-framed workshop buildings, depending on the installation of overhead crane(s), building height and other location-sensitive requirements. The fit-out is generally less expensive. Mobile equipment and computerised monitoring and accounting systems require individual assessment.

Mobile equipment

Dedicated mobile equipment is required for the operation of both the mine and the processing facility. In addition, mobile equipment that properly falls within the infrastructure and support category requires identification and costing. Each project requires a specific assessment of vehicles and support equipment related to the geography of the operations and the services to be provided. The assessment must reflect company policies concerning the provision of personnel (work) transport. Table 17.3 lists mobile equipment requirements and their approximate costs, and may be used to allocate a global cost to this item.

UTILITIES

Utilities include power, process steam, water and fuel supply, as well as sewerage and solid waste disposal.

Power supply

Decisions relating to power can be critical to project economics and a study of alternative approaches is required to identify a preferred option. In remote areas there may be no alternative to on-site generation, and if process steam is required, on-site generation generally

TABLE 17.3
Mobile equipment – mine and plant infrastructure.

Equipment item	Approximate cost per unit (A$)
Industrial facility	
Passenger vehicle – 4WD equipped for mine site	55 000
Truck	
Tipper, 8 - 10 m^3	200 000
Flat top, with crane	280 000
Lubrication/service	350 000
Explosives	700 000
Bobcat	55 000
Road compactor	420 000
Cranes – mobile	
80 t, rough terrain	1 250 000
25 t, rough terrain	590 000
Ambulance	200 000
Fire tender	400 000
Passenger bus	
30 seat	240 000
48 seat	300 000
60 seat	500 000
Residential area support	
Passenger bus – 12 seat	85 000
Garbage truck (compactor)	250 000
Vehicle – personnel/administration	55 000

proves attractive. Selection of the fuel – distillate, fuel oil, natural gas or coal – will also affect other areas of infrastructure cost. Consistent with the principle that mining companies should, to the maximum extent possible, focus their attention on mainstream activities, power should be obtained from a supply authority or company through an existing transmission system, or an extension of an existing system. Supply may also be sourced from other private generating installations or from a company specialising in remote-area power generation. Elimination of the capital cost associated with power generation and transmission will usually result in a tariff that reflects the cost of construction in addition to operation, and transfers capital to operating costs. Electricity tariffs, where the demand is substantial, are frequently negotiable.

Generation

Following the establishment of the process requirement, an initial assessment of power demand can be made. The magnitude of the load and reliability of supply may influence the decision to connect to a State, authority or private (or privatised) power system. Discussions on the availability and cost of power at the site will indicate whether transmitted power is potentially viable or whether alternatives need to be considered. If the choice is on-site generation, the selection of plant is influenced by:

- alternative methods of power and steam generation
- control, operating and maintenance philosophies
- fuel availability and cost
- large motor starting power requirements
- reliability, standby needs and redundancy
- steam requirement, if any
- type of loads
- type of plant.

The load assessment must recognise all connected loads, the likely operating load, diversity, seasonal factors and peak demands, and the types of loads; for example, arc furnace loads present significant difficulties to islanded powerplants. A power study will identify an optimum fuel and the preferred method of generation (and of producing steam) appropriate for the specific site conditions. Set size selection is based on units loaded to around 80 per cent of full load capacity for most applications. Operational efficiency, online capacity for demand surges, and the de-rating effects of high ambient temperatures can readily be accommodated. The number of sets selected must allow for satisfying normal load, for standby, and for servicing or maintenance of equipment.

Generating sets for mining operations typically less than 30 MW are completely self-contained, rigid-base (skid) mounted, fully enclosed in noise-attenuating enclosures and suitable for outdoor operation. They are also usually equipped with automatic start-up and shutdown controls and have load-sharing capacity. Auxiliary equipment is fitted to each generator. Central controls for high-voltage switching and for engine and generator control are required. The generating voltage is stepped down to 415 V for station auxiliaries.

Projects with a substantial electrical demand, such as alumina plants, aluminium refineries, iron ore processing plants and electrowinning plants, require conventional power generating facilities. Effectively they need a connection to the power grid, and an approach involving long-distance transmission is usually more feasible and economical. If on-site generation is adopted, the standards used should be compatible with regional electricity practices to allow for future possible connection to a power grid or for transfer of the installation to a power authority.

Transmission

Power must be supplied to user facilities through a transmission and/or distribution system. Transmission systems comprise those extending from the power station high-voltage switchyard to substations at main load centres that lower the supply voltage to the working voltage.

Electrical characteristics, transmission distance and economics influence the choice of transmission voltage. A transmission voltage of 11 kV is frequently used. However, for long distances this may be 220 kV or 132 kV, although transmission lines at 66 kV and 33 kV have been used. Transmission line design is commonly supplied by specialist companies offering design and construction services. Steel or timber pole structures may be used; they are selected according to line life and the environment. Typical transmission line costs are shown in Table 17.4. Higher costs relate to broken country, where steel (tower) structures are used and where access is difficult.

TABLE 17.4
Typical transmission line costs.

Transmission voltage (kV)	Cost (A$/km)
220	500 000 - 800 000
33	200 000 - 400 000
11	50 000 - 100 000

Power transmission lines must comply with the requirements of the Electricity Supply Authorities of Australia Code of Practice for Overhead Line Construction.

Distribution

Power is distributed at the transmission voltage (usually 11 kV) to substations at main load centres. Pole-mounted, pad-mounted (with switch and fuse) or cable-connected transformers provide power at the required working voltage. Substations serving discrete areas include switch gear, motor control centres and protection equipment. The plant voltage is usually 415 V (but increasingly 690 V and 1000 V) and distributed substations may be required to limit cable runs to acceptable lengths. Drive motors for large equipment such as primary crushers, ball mills and semi-autogenous (SAG) mills, may require a supply voltage of 3.3 kV or 6.6 kV, and appropriate transformers and switch gear are required. Power is generally transmitted via overhead lines to transformers, then by underground cable or cable tray to equipment.

In terms of cost estimates at the preliminary stage, the electrical system distribution costs may be factored from the cost of the equipment or facility it services. This is in contrast to generating facilities and transmission lines, which should be costed on a unit basis. Power distribution costs, including switch rooms, can be between five per cent and ten per cent of the total installed cost of the overall installed plant cost.

Process steam

A number of processes require steam for heating or injection to maintain specified temperature conditions, to facilitate process reactions or to control product mobility. Steam must be generated on-site, and it is frequently practical to do so in conjunction with power generation by the use of back-pressure turbines. Other options are to use waste heat from the process or from power generation, or to include a separate steam production system.

The requirement for steam will in any case be process-controlled, and a pressure and quantity will be specified. Closed heating systems (coils or exchangers) permit high condensate return and limit make-up. Direct steam injection wastes steam and thus requires greater feedwater preparation capacity. Steam generation requirements are project-specific and, if steam is required, the demand and the means of generation must be optimised, preferably as part of a study considering cogeneration. Steam may be required at varying pressures in a single plant, and systems with multiple take-offs or separate generating systems may prove to be most economic under project conditions.

For initial estimating purposes, steam production costs may be approximated as:

- low-pressure steam – $100 - $300/kg/h
- high-pressure steam – $120 - $360/kg/h.

More accurate figures may be obtained from specialist equipment suppliers.

Water supply

Factors to consider for water supply include the source of suitable water and its availability, water quality, storage and distribution.

Sources

The availability of water varies from project to project and is heavily dependent on factors such as site location, topography and climate. All sources should be considered in order to select the optimum. The main criteria for selection relate to system economics, reliability and quality of supply. Potential water sources include:

- groundwater from wells or a borefield
- rivers and streams
- run-off
- a combination of the above.

An investigation is required to confirm the suitability of a water source, including pump tests and borefield modelling for groundwater supply. Meteorological records and streamflow data can be interpolated to confirm the sustainability of supply. The demonstrated water yield must provide adequate insurance for meeting demand. Authority approval for water use is necessary to ensure prior obligations or commitments on the source are not adversely affected or, in the case of groundwater, that unacceptable depletion will not occur. Domestic potable demand may be assessed as a minimum of 150 L per person per day where the supply is limited. Usage will be much higher where water is freely available. Process and industrial demand must be separately ascertained. Fire demand is normally around 1500 to 2000 L/min at 120 kPa. On many projects, particularly those located in remote arid areas, water management is a key issue, resulting in major project costs. In most areas, discharge of contaminated run-off or processing water cannot be tolerated. Consequently, the emphasis is on the development of a water management system that optimises the use of water for process, industrial and residential uses, limits discharges and promotes the reuse of water of suitable quality. A zero discharge system is desirable.

Quality

Water quality is of prime importance in the provision of potable water. It is also important for process applications where the presence of certain contaminants may adversely affect the process, reagent consumption or product recovery. Standards for potable water are clearly established by the World Health Organization, and are now reflected in Australian standards. Treatment may be required to meet these standards. In general, both river and groundwater will require some form of treatment, but stored water from vegetated catchments may be of potable quality.

Simple water treatment plants using chlorination only can be installed for costs of around $80 000 to $100 000/ML/day treated. More complex plants using improved technology for water treatment (eg desalination or reverse osmosis) cost $500 000 to $800 000/ML/day. Treatment of recycled or reclaimed process water must be evaluated on a case-by-case basis, with requirements varying from complex treatment to direct reuse without treatment. Treatment of water generated by operations, such as from mine dewatering and run-off from waste dumps, and from stockpile or processing plant run-off, will as a minimum require settlement to remove solids, and perhaps further treatment. It is preferable to reuse water of this quality in its original environment, such as for dust control on haul roads, at transfer points on materials handling systems or as process water. This approach minimises treatment costs.

Storage

Water storage requirements are calculated on the basis of maintaining a continuous supply of water to meet normal demand during source interruptions. Storage volumes are factors in the water management strategy and should be approximately as follows:

- one month (minimum) potable water for residential usage, but related to continuity of supply
- 24 hours (minimum) process water usage, subject to security of supply and with annual make-up requirements guaranteed
- eight hours fire water storage based on the system demand (minimum of 4500 kL)
- as-calculated for other uses such as dust suppression and road watering.

Costs of storage per megalitre of water vary widely. Earth or rock fill dams capable of storing large volumes of water and satisfying seasonal variations in availability may incur costs ranging from $5000 to $10 000/ML stored. These costs are heavily dependent on the site and availability of embankment material of suitable quality. Steel and concrete tankage costs are more predictable with costs around $200 000 to $300 000/ML. Costs for elevated tankage are higher. Tankage costs may be reduced by combining the fire storage requirement with other storage, provided its integrity is maintained.

Distribution

Water distribution systems are custom designed for projects. Many projects have independent process, potable and fire water systems, with flows, distances, topography and pumping requirements influencing both design and cost.

Assigning a realistic cost in the absence of a conceptual design is difficult. Conceptual design only emerges from the water management plan and a project or plant water balance. Order-of-magnitude costs for distribution and supply systems should include:

- $15 000 to $75 000/ML/day for pumping installations
- around $800 000/km for pipeline costs for large-diameter steel pipelines
- $250 000/km for pipeline systems of generally smaller diameter.

Fuel storage and distribution

Fuel may be used in a project for:

- mine equipment
- transport – equipment, materials and personnel
- power generation
- process steam and heating (if required).

Requirements vary with the project and on-site storage is assessed for the specific project. If grid power is available, mine use and transport needs dominate the requirements. Storage volumes are assessed based on:

- 'insurance' requirements to safeguard operations
- potential for interruptions to supply
- proximity to source of supply
- unit delivery volumes and frequency.

The siting of storage facilities is influenced by delivery considerations, the major user locations and by topography. Reasonable storage volumes for distillate (diesel fuel) are:

- main storage – two 500 000 L tanks
- mine fuel storage (main) – two 50 000 L tanks
- mine refuelling installation – one 25 000 L tank
- power station and process steam (10 MW) – two 50 000 L tanks
- workshops and service and fuelling facility – one 25 000 L tank each.

Fuel storage tankage should preferably be above-ground and bunded. Service station type operations frequently store fuel underground. Leak detection is required.

Tankage at refuelling installations represents only part of the cost, and dispensing facilities and civil work may substantially exceed tankage costs. The cost of tankage, installed and with piping, for receipt and discharge would be approximately $250 to $350/kL of storage. At least one, possibly more (two to three), petrol outlets are required. Receipt, storage and handling facilities are required for other fuels such as diesel, aviation fuel and liquefied petroleum gas (LPG) as well as lubricants. Provision will normally be included for storage of lubricants in warehouses. The need for petrol at remote sites may be minimised by standardising on diesel engine transport units.

The transfer of small quantities of fuel between isolated tanks by pipeline is seldom economic and, if such transfer is contemplated, a road tanker should be added to the mobile equipment list. Tank sizing should permit the delivery of full tanker loads direct to every major storage site.

Frequently, the oil company contracted for the project fuel supply provides commercial type refuelling installations. Also, on-site storage installations may be handled in the same manner, but installation costs will inevitably be recovered over a fixed period in the form of increased fuel costs, and will be reflected in higher operating costs. It is prudent to consider the cost of fuel storage installations as a project cost in initial assessments.

Sewerage

An effective sewage collection and treatment system must be installed in each populated or work area. Isolated installations within a plant or mine area serving relatively few people may be serviced by appropriately sized conventional septic tank systems. For larger communities such as residential areas, townships, process plants and mines with bath houses and amenity blocks and a substantial working population, treatment plants are required. Options for treatment are packaged plants or aerobic lagoons. Lagoons prove more economical and easier to operate where lagoon effluent may be disposed of by evaporation or discharge to a natural watercourse. Systems should be installed to accepted government standards to satisfy health requirements and to allow for possible future local authority resumption.

Design flows for residential treatment plants are 150 - 200 L per person per day. For process plants, flows are around 100 L per person per day. Package facilities, including collection, treatment and disposal, cost around $3000 - $6000 per person.

Solid waste disposal

For the disposal of solid wastes (except mine waste, tailings, etc) from offices, industrial facilities, process plants and residential areas, landfill techniques using town site type collection equipment is most common. Sites are selected to minimise the effect on operations and to meet environmental criteria. Existing practice is to recycle as much waste, including paper, plastics, metals and packaging, as possible. This is not a major cost item.

Special care is required if the disposal facility is to accommodate radioactive waste, as from a uranium production facility. Government regulations and standards apply.

This is further discussed in the section 'Waste disposal systems'.

COMMUNICATIONS

Communications is a vital component of mine site operations, requiring consideration during the planning stage of a mining project. Frequently, communications is not given sufficient consideration mainly because it is not one of the largest capital cost items. It can, however, become a big cost item when it impedes the safety and operational capabilities of the mine. An inadequately designed communications network can also result in excessive operating costs at a later date. This is quite separate from the legal, social and financial implications of failure to provide minimum requirements in regards to duty-of-care.

As with all other components there is a growing requirement to assess the environmental impact of each project element, including communications. Communications may be considered a service that already provides significant technology. When used appropriately, it can save energy; for example, video phone conferencing requires less energy than travelling, and data transfer over communication linkages requires less energy than courier. Global environmental concerns demand that we go even further and consider all aspects including the relative power consumption of these devices. A specialist reliable, responsible and sustainable communications engineer can advise on appropriate cost savings and environmentally responsible decisions.

The requirements for communications facilities may vary during the project. Typically, this means that the requirements during construction would be different, maybe even greater, than those required during operations. Therefore, it may be necessary to provide an increased level of service during construction or ramp-up periods. It is also prudent to investigate leasing equipment and/or planning for the reuse of communications equipment after ramp-up is complete.

Communications facilities fall into two broad areas: those that relate to the provision of external services and are subject to government regulatory issues, and those that relate to the provision of internal services (ie within the mine and plant). External services comprise connections to the public network and hence back into the wider world. These require negotiation of bandwidth leasing from one of the many telecommunications service providers in the Australian market. Where projects are located overseas, the question of government regulation may be even more complex. Consequently, any project developer should become familiar with the requirements of the telecommunications regulator in that country before committing to an approach for providing services.

Internal communications services are generally not subject to regulation. However, Australian standards must be adhered to when designing a communications system; that is, for the cabling of buildings, plants or townships. There is also a requirement to obtain licenses for frequency allocations for radio equipment such as mobile radios, microwave frequencies and entertainment distribution (public radio and television) systems.

External communications

Costs associated with connection to the external network will vary with the remoteness of the development site. Only high-speed data links are acceptable for this purpose. The possibilities are:

- Direct connection by the public carrier. This option will usually only be available when the carrier has infrastructure within reasonable proximity of the mine. The developer may be required to make a contribution towards the capital cost, with the level of contribution determined by the distance from existing infrastructure, duration of service and the volume of potential business for the carrier.
- Private microwave link provided to a connection point where it can interface with the public network. This would usually only occur if there was no telecommunications carrier infrastructure reasonably accessible. Private microwave systems over extended distances are usually only considered when there are complementary requirements, for instance signalling control along a railway line, or supervisory control and data acquisition applications along a pipeline.
- Private fibre network provided to a connection point where it can interface the public network. This option could also involve leasing dark fibre (unused spare capacity) on other private fibre networks. Fibre can be laid in the right-of-way along roads or pipelines, attached to pipelines or even attached along overhead power line infrastructure (aerial). The add/drop technique can be used to provide services along the fibre route.
- Satellite earth station with access to the hub earth station installed at a selected major centre (usually a capital city). This option is becoming more attractive, especially for initial infrastructure and short-term ramp-up solutions. The hardware technology is far more advanced, smart software has been developed to allow higher speeds and there are more satellites available for connection, resulting in cheaper access and usage costs.

The decision on which method is used to connect to the public network will be based on factors including:

- capital cost of providing the infrastructure
- number and type of circuits (ie voice and data) required – this information will assist in determining the operating costs
- recurrent costs of circuit rentals.

Internal communications

A very important consideration of this design component is the introduction of and growing trend towards unified communications. The integration of communications services and applications into one environment offers a simpler, more effective user environment. Internal communications for a mine development can be considered under each equipment type, as outlined below.

Telephone services

In most developments, the most cost-effective means of providing general phone access is by installing a private branch exchange (PBX) large enough to meet the needs in terms of extension capacity. The PBX will support all internal telephone communications and will be interfaced with the public network for external calls. Most PBX systems now use voice over internet protocol (VOIP) technology. Consideration should be given to the number of terminals needed to meet standard user, management, conference and outdoor requirements. Facsimile services can be provided as extensions on the PBX or by unified messaging applications. Although the facsimile is somewhat superseded by portable scanners, laptops and data transfer services, it still remains a suitable low-technology solution for initial use in field locations for the immediate transfer of non-verbal information.

Data services

Internal data services are usually divided into two areas: process data and non-process data (inventory management, supply, payroll, etc). Process data is commonly included as an integrated plant facility and normally has a stand-alone network facility, independent of non-process data.

When assessing the requirements for data services it is important to understand the type of data user, which may be either fixed or mobile:

- Fixed – the transfer of data from a fixed location such as the terminal user physically connected to a local area network (LAN) inside a building, which requires special high-bandwidth cabling systems to carry the data. It also extends to remote static locations that may be connected to the line by any of the transmission mediums described in this section. This could also include closed-circuit television (CCTV), supervisory control and data acquisition (SCADA) and automatic control system (ACS) data.
- Mobile – includes the transfer of data over special purpose radio networks that can be accessed around the mine site. It involves the transmission of information from a source that is mobile such as vehicle fleet reporting on speeds and engine temperatures. Modern technology such as WiFi, WiMax and even satellite can be used for this purpose.

The approach is dependent on the particular requirements of each development. The transmission of data off-site (eg to a mainframe computer) is catered for by allocating channel capacity on the external communications links.

Site transmission network

Where a mine needs to connect physically separated sites for voice, video and data purposes, microwave, optical fibre technology or cabling are used.

In some developments it may be necessary to provide microwave radio bearers within the project area, particularly where the mine site and accommodation area might be separated by a significant distance. Typical considerations are:

- accommodation
- antennae placement on towers
- channel capacity (bandwidth)
- frequency allocation
- path obstructions
- power requirements
- tower heights.

Optical fibre comes in a variety of capacity sizes, commonly referred to as a strand count. The number of strands will depend on the service to be provided and the expectation of future requirements. It is far better to overdesign a fibre link due to the costs involved in replacing or upgrading an existing link. Optical fibre has become an increasingly used option because of the speeds (now measured in gigabytes per second), security and low operating cost. The optical fibre needs to be 'lit up' using optical fibre high-speed transmission equipment. Normally routers, data switches, modems and voice switches are connected to create end-to-end applications.

Cabling is required to a degree that is determined by the size of the operation. The cabling scheme is usually designed to be of sufficient size to cater for all current and projected data and voice transmission requirements. The considerations for cabling schemes include:

- cable routes – dependent on population centres within the development
- cable sizes – dependent on the number of services required
- cable types – armoured or nylon jacketed, etc
- method of installation – conduits, hard buried or tied to cable tray, etc.

Voice mobile radio

For most mining operations mobile radio services are required both for in-vehicle and hand-held operation. Coverage is usually required for the whole site so that the positioning and number of repeater sites need to be carefully planned. The issues to be addressed in the design of a mobile radio system include:

- accommodation
- licensing requirements
- number of frequencies required (capacity)
- number of mobile and hand-held terminals or users
- power requirements
- specialised requirements such as leaky feeder for underground deployments
- system design considerations – locations, antennae heights and antennae design.

Information technology

Consideration should be given to the type and quantity of information technology (IT) equipment that will be required to support the communications infrastructure that has been designed. With the growing emergence of the unified communications concept there is also an increasing requirement for suitable IT equipment to support it. Provision should be made for servers and user equipment.

Triple play – voice, video and data

Construction and permanent camps need to provide voice, video and data to the accommodation units. Either active or passive optical networks connected to head ends provide the voice, video and data servers to the optical network units in the dongas and shared accommodation areas. The telephones, internet data points and televisions provide the end-user facilities.

Supporting infrastructure

Consideration needs to be given to the supporting infrastructure that will either house or hold the equipment described in the section 'Internal communications' and in Table 17.5. Suitable floor space in common buildings or stand-alone buildings may be

TABLE 17.5
Approximate costs of communications equipment.

Equipment	Approximate costs (A$)[a]	Opex considerations[e]
External		
Satellite earth station	$8000 to $32 000+	$700 to $3200 per month – high
Public carrier access	$100 000[b]	$/Mb of data, leasing costs – medium
Private access transmission	Refer 'internal' transmission costing	$/Mb of data, spectrum licensing – medium
Internal		
Telephony system		
IP/PBX	$600 (plus cabling) per extension	Operations and maintenance O&M – minimal
Fax	$600 - $1500 per unit	O&M – minimal
Voice mobile radio		
Hand-held	$1500 per unit	O&M – minimal
Mobiles	$500 per unit	O&M – minimal
Repeaters	$50 000 per unit	Spectrum licensing, O&M – minor
Fixed data network		
Routers	$20 000	O&M – minimal
Switch	$300 per point	O&M – minimal
Cabling (internal only)	$200 per point	O&M – minimal
Triple play (voice, video and data)		
Head end equipment	$250 000	O&M – minimal
Subscriber unit	$400 per subscriber	$/Mb of data, leasing costs – medium
Site transmission network		
Microwave radio	$200 000 per terminal[c]	Spectrum licensing, O&M – minor
Fibre-optic cable	$50/m[d]	O&M – minor
Optical transmission equipment	$50 000 per link	O&M – minor

a. The approximate capital expenditure costs do not include engineering or management costs. There are many variants and issues to providing costing; therefore, these costs are only approximate and will vary according to a project's specific requirements.

b. Public carriers may ask for a contribution toward providing connection for remote locations.

c. Includes shelter, masts and antenna. Number of terminals/links depends on many issues such as distance, terrain and path redundancy requirements.

d. Accounts for the provision of 48-strand optical fibre buried in the right-of-way (ROW) of a mine access road.

e. Operations expenditure has been given as a statement of considerations rather than costing due to the number of variants applicable. O&M = operations and maintenance.

required to protect the equipment from environmental conditions or provide physical security. Designers should ensure that appropriate space is allocated in the accommodation or ancillary buildings. Special requirements for cooling and power must be taken into consideration.

Estimates must include realistic costs for communications towers. The primary types of towers used in the mining industry are stand-alone towers and guyed masts, each with advantages and disadvantages, and an appropriate selection must be made. Additional costs for installing and maintaining remote and isolated towers should be recognised.

PORT AND MARINE FACILITIES

For major projects and where convenient port access is not available, it may be necessary to develop facilities for the export of product. In such cases, multi-use port installations are frequently of value. The main types of port facilities likely to be required for a minerals development project are:

- general cargo wharves
- offshore mooring facilities
- roll-on, roll-off facilities
- small boat harbours

TABLE 17.6
Vessel characteristics.

Vessel	dwt	Length (m)	Beam (m)	Draft (m)
Handy/Handymax	<60 000	150 - 200	24 - 30	Varies – up to 10
Panamax	60 000 - 100 000	225 - 275	32	12
Capesize	100 000 - 200 000	280	37 - 45	<19
VLBC	200 000 - 300 000	300 - 330	50 - 58	19 - 21
ULBC (typical)	300 000 - 550 000	365	63.5	23

Notes: VLBC = very large bulk carrier; ULBC = ultra large bulk carrier.

- tanker or bulk materials terminals for
  - export of product (coal, ore or concentrate), liquefied natural gas (LNG), etc
  - import of fuels.

General cargo wharves

Where a general cargo wharf is necessary, it should cater for ships of 10 000 - 20 000 t capacity. These ships are adequate for materials and construction equipment and need a water depth of up to 10 m. Table 17.6 provides some typical characteristics of various sized vessels.

Normally the heaviest requirement for the general cargo wharf is during the construction phase and because of this, speed of construction is frequently important, particularly in remote locations. The nature of wharf design is typically determined by the subsurface geotechnical conditions. If the material close to the surface has reasonable lateral capacity and pile-founding levels are deep, then a sheet pile wharf is usually more economical and attractive than a piled structure. They are quick and easy to construct and are less susceptible to damage from the very heavy loads likely to be encountered during the construction phase. Also, it is normally easier to create a large area behind the wharf. In the long-term, the sheet pile wharf also has the advantage of being fairly insensitive to changing cargo-handling methods. It is important to provide adequate space behind the wharf (1 - 3 ha) for offloading and temporary storage of material. During construction it is generally not practical to remove all materials from the wharf area as quickly as they are unloaded from the vessel. Once the facility is complete, the requirement for the general cargo wharf decreases, unless used for the export of a particular type of product.

Tanker or bulk materials terminals

The main types of tanker or bulk materials terminals are for export of mined or processed material such as coal, iron ore, crude oil or LNG. A similar facility may be required for the import of fuel oil if the operation has a substantial power requirement. Tankers and bulk carriers can be up to, and exceed, 150 000 deadweight tonnage (dwt) and require a depth of water of up to 20 m. Where a tanker terminal is required for product export, the selection of the location is one of the more critical aspects of the design of the onshore facilities. Suitable offshore locations for fixed tanker terminals are rare. Therefore, quite often a major economic study is needed to determine whether the land transport link should be extended, perhaps up to 100 km, to meet up with a suitable location for an offshore tanker terminal.

Small boat harbours

For any remote mining development, there will be many more small boats near the wharf facilities than originally estimated. The types of boats include:

- employees' recreational craft
- ferries
- line boats
- maintenance contractors' work boats
- tugs
- work barges.

All of these small boats require protection; hence the provision of harbour facilities behind a breakwater needs to be considered at the beginning of the project.

Roll-on, roll-off and heavy lift facilities

Construction materials and equipment and operating supplies may be transported to remote sites using barge-type vessels designed to discharge cargo through a bow ramp. A roll-on, roll-off facility consisting of a simple ramp adjacent to the wharf with direct vehicular access is required. For containerised supplies and for modularised (plant) components, 'drive-off' capability simplifies the unloading process. Roll-on, roll-off facilities can become complicated in areas of high tidal range. Loading out of containerised product can be facilitated using similar bow loading vessels. It is unlikely that larger drive-on, drive-off shipping needs consideration.

With process plants now modularised and imported as a series of large units requiring transport to site, having a heavy lift section of the wharf, or preferably a separate facility, can contribute to substantially reducing plant site construction costs. Heavy lift wharves should have their deck level about 2 m above high water spring tide level and have about 5 or 6 m of draft alongside. Particularly heavy items such as rail locomotives are frequently shipped in vessels equipped with on-board heavy lift cranes, which removes the need for similar shore-based equipment. Wharf decks and handling facilities must be designed for all loadings anticipated.

Offshore mooring facilities

If liquid products including fuels are to be imported or exported using larger tankers, often the most practical and economic solution is a single- or multiple-point mooring with an underwater pipeline connection to the shore. Selection of a floating mooring system over a fixed berth offshore requires consideration of the cost of a pipeline versus the cost of a pier and the mooring, as well as the lesser sensitivity of a mooring system to changes in wind direction. Mooring systems therefore have higher availability.

Depending on the nature of the material being exported, consideration should be given to loading through a slurry pipeline. This is particularly attractive where significant dredging close to land is required, but operating costs will be higher due to the need to dewater the transported material. The slurry pipeline, either buried or on the seabed, would typically discharge into a floating storage facility (retired Capesize vessel or similar). Where dredging costs are high, trans-shipment via barge with either direct loading to ships or discharging to a floating storage facility is also an option.

Port equipment

Many ships unload cargo using a ship's own gear. Under most circumstances, it is preferable for the wharf not to provide specialised fixed facilities for cargo unloading. Normally mobile cranes with prime movers and trailers move cargo away from the wharf face. Large fork-lifts are convenient for moving containers but are expensive and considered economic only when there are very large numbers of containers passing over the wharf. As a general principle for mine wharf facilities, it is preferable that all wharf equipment be mobile, allowing the facility to be upgraded as conditions change. As most wharf equipment is used intermittently, it can then be used in other places around the harbour or in nearby areas in the absence of wharf cargo. Fixed equipment and facilities such as sheds, lights, toilet blocks and fire-fighting equipment and stores should not be located on the wharf or the immediate lay-down area behind the wharf. Fixed installations near a wharf tend to be damaged when containers and other equipment are moved. These comments are not applicable for wharves equipped with conveyors and load-out facilities for bulk product.

Customs and bonded storage

If the mine area is the first port of entry into the country, customs and storage facilities must be provided for bonded goods. This can be arranged by having the whole of the wharf area and the lay-down area behind the wharf fenced from the general public, and by having a customs clearance gate behind the lay-down area. It is generally unnecessary to have a large building for bonded storage. Most equipment requiring protection will be shipped in containers. If the whole port area is fenced off adequately, it provides customs and bonded storage as well as security for goods that are not containerised. Security against theft is a major concern in any port facility. Table 17.7 summarises the approximate costs of marine facilities.

Port construction

As indicated above, where wharf facilities are required they should be provided early in the construction phase because of the need to import materials and equipment for the establishment of the mine and infrastructure.

The following principles should be applied to the design and construction of the port facilities:

- Work that can be done over land rather than over water is usually much quicker and much cheaper.
- Modular construction with large units fabricated onshore and lifted into place can save time and money.
- Unless the facility is very large, major dredging should be avoided. The cost of mobilising a conventional dredge to a remote location is high and the process including environmental approvals is time-consuming. Adequate depths on a relatively small scale can frequently be provided using excavators or draglines either barge mounted or from land.

WASTE DISPOSAL

Waste is generated by a number of operations in mining and mineral processing, and its handling and disposal attracts a cost. Waste disposal systems are here considered as infrastructure, but have a close association with both mining and processing. Capital, operating and maintenance costs of the construction and operation of waste facilities must be correctly identified within overall project infrastructure estimates, since synergies frequently exist between all elements of a project's waste management.

Most aspects of waste disposal systems are project-specific and a rule-of-thumb approach to order-of-magnitude system costs is likely to be misleading. Estimates, even at this level, require an appreciation of the concept to be used and of the relevant cost-contributing factors.

Waste handling, treatment and disposal techniques are heavily influenced by geochemical, process chemistry and environmental considerations. Normally an EIS is required. It will involve a detailed assessment of the approach to the operations involved in waste management. Once approved, the EIS will commit

TABLE 17.7
Approximate costs of marine facilities.

Facility		Description	Approximate costs (A$ M)
General cargo wharf	Vessel size	10 000 - 16 000 dwt	50 - 200
	Water depth	10 m	
	Construction	Steel pile, concrete deck or sheet pile	
	Vessel size	To 20 000 dwt	50 - 200
	Water depth	10 - 12 m	
	Construction	Steel pile, concrete deck or sheet pile	
Offshore bulk materials	Vessel size	150 000 - 200 000 dwt	Up to 500
Loading terminal	Water depth	20 m	
	Construction	Open piled head and approach way (1000 m)	
Small boat harbour	Vessel capacity	5 - 10 work boats and barges	10 - 25
	Wharf frontage	50 - 100 m	
	Slipway or boat lift	Capacity 100 t	
	Moorings	12	
	Water depth	5 m	
	Breakwater	Required	
Roll-on, roll-off facility	Capacity	Standard containers	20 to 40
	Water depth	3 - 4.5 m	
	Construction	Additional to cargo wharf	
Single buoy mooring	Vessel size	100 000 - 200 000 dwt	Up to 100
	Water depth	25 m plus	
	Loading rate	4000 t/h	
	Shore pipeline	Excluded	Separately costed
Shore facilities	Offices	Customs and harbourmaster	5 - 15
	Store/store yard	Bonded, undercover	
		Bonded, open lay-down areas	

Note: Costs of marine facilities are dependent on several factors that can impose a wide range of costs for the particular project requirements. These include water depth and geotechnical considerations, approach wharf length and dredging requirements, tidal and weather ranges, degree of shelter and seismic and cyclonic considerations. The estimates above are notional only and should be tailored for the specific conditions faced. Supporting infrastructure such as power, water, waste disposal, stockpile management, accommodation and road or rail access are not included.

the operator to specific approaches in the treatment of waste and to quality and quantity emission conditions that are acceptable within policy, or are agreed to by the regulatory authority. It should be noted that approved conditions are regarded as the minimum acceptable and may be subject to review should unacceptable or adverse conditions later emerge. Ahead of an EIS, an appreciation of the project requirements is required and early planning and understanding of the options available in waste management is essential. Selecting an approach that can be practically and economically implemented is also essential. Consideration should always be given to the potential for achieving complementarities within the waste disposal systems that contribute to greater levels of waste and contaminant containment and control.

Overburden and waste rock

The planning and management of overburden and/or waste rock dumps is integral to underground, open cut or alluvial mining operations. The quantities of material generated are dependent on the stripping ratio, reduced only by material that can be beneficially used for other purposes. Waste will be far greater for open cut mines than for underground mines. Suitable locations for dumps require a compromise between haul distance (minimal), topography (catchments) and site development. Haul road location, the intersection or diversion of watercourses and the management of dump run-off and infiltration to groundwater are important. Prior to finalising a dump location, drilling to ensure no economically recoverable ore exists below the proposed site is prudent. The geochemical and geotechnical characteristics of material placed in dumps require assessment; the extent to which components are acid-producing or neutralising and liable to generate contaminated leachates (the source of AMD problems) should be evaluated. An additional factor that may be important is the potential for the waste rock to be reclassified as ore at some future time due to changes in treatment efficiency or increased value of the contained mineral. This may be achieved by dumping into defined zones.

Dump configurations will be dictated by material characteristics and the costs associated with the selective deposition of stripped material. Factors such as the material, grain size, clay content and expected moisture content will influence waste dump stability and will dictate the selection of dump external slope angles. The dump ultimately must provide a future stable landform and satisfy authority criteria.

Mine and dump rehabilitation requirements influence dump design and which placement techniques can be used. These may include end-tipped dumps varying from those placed in layers and compacted with haul equipment, the creation of capillary break and acid-neutralising layers and carefully engineered capping and/or artificial soil layers to serve environmental considerations. The use of oxygen-restricting layers in the subsoil is becoming more common where AMD issues exist. This layer may be derived from composting of vegetation removed during overburden stripping or by using other materials available from the site. Project estimates need to account for locating, preparing and placing these materials.

Wherever possible, progressive dump rehabilitation should be achieved by completing profiling, topsoiling and planting in those areas where the dump has reached its design limits. Run-off must be directed to sedimentation traps prior to discharge to streams and watercourses, and the natural drainage patterns left unencumbered. Local flora or flora native to the area should be used whenever it is available and practicable for the revegetation of dumps. The establishment of a nursery is usually desirable to ensure an adequate supply of healthy and suitable plants.

Costs of dump management will vary but may be treated as operating costs with an annual allocation identified as a percentage (usually five per cent) of the costs of placing waste material. Alternatively, it can be costed out on a labour and equipment basis.

For long-term open cuts, mining plans should consider if and when it is possible to place waste material back into worked-out areas of the pit. Likewise for underground mines, waste material should be used for underground fill to the maximum extent possible, on both economic and environmental grounds. Project estimates should allow for the management of the dump following closure of mining operations until such time as the regulators release the operator from further responsibility. Where the dump is located on freehold land the value of the rehabilitation effort might be recoverable in the post-closure land value as a productive unit for other purposes.

Water management

Facilities designed on the zero discharge system eliminate many of the problems associated with discharging contaminated water into natural watercourses or to groundwater. Climatic conditions, water availability and water use in the mine, in addition to process plant and infrastructure systems requirements, will determine the overall project water balance. Early evaluations of water demand including potable, process, dust suppression, fluming, rehabilitation and irrigation requirements, matched by identification of potential sources both on and off-site, are necessary. This assessment will determine the need for treatment and reuse of water collected from mine dewatering and water recoverable from process facilities, including water reclaimed from tailings facilities. The chemistry of available water will need to be tested for suitability in relation to factors such as corrosion, compatibility with metallurgical processes and mineral resource recovery, and for any problems that may prevent or limit the disposal of water treatment reject streams. These may result in the modification of concept designs and/or the modification of metallurgical processes to accommodate adverse water chemistry where treatment is not economic or environmentally acceptable.

An EIS will also be required in this area also; hence the need for early and comprehensive consideration of all options available. The objective of any water management system is to:

- contain all contaminated liquids
- optimise water use
- prevent contamination of groundwater and surface water by seepage or overflow
- segregate clean from contaminated water
- use water resources economically and efficiently.

Regulations specifying conditions in water management and water resource use efficiency vary from state to state but the basic principles are similar. Each project must be analysed for its particular conditions. However, management systems that recognise the project-specific requirements and comply with regulatory constraints must be developed.

Tailings

Tailings are waste materials generated by mineral beneficiation or concentration processes, or from coal washing. Tailings may consist of material of grain sizes of 0.2 mm (sands) through to 0.002 mm (slimes).

Tailings are generally disposed of in slurry form, with the moisture content (or percentage of solids) of the stream dependent on the process techniques, and largely influenced by any requirement for water recovery. Tailings quantities (dry tonnes) can only be determined from the plant throughput and from process considerations. Depending on the properties of the tailings, the density in a tailings retention facility (TRF) could vary from about 0.8 to 1.5 dry tonnes per cubic metre. TRF storage volumes may be assessed on this basis, making allowance in calculations of the volume of free water, including the possible contribution of rainfall and for freeboard.

Tailings should be tested to determine consolidation properties and the chemical and leachate characteristics. TRF designs are entirely site- and project-specific, and estimates based on relationships with process facility costs are likely to be grossly misleading. Site selection is critical, with substantial impact in two areas of capital: earthwork volumes and length of tailings and return water pipelines. Pumping costs for tailings and return water would be included as operating costs. As environmental criteria must be satisfied for the EIS, a suitable site must be identified for initial estimates.

The TRF volume required depends on the annual dry tailings quantities and the mine life. The operating volume may be increased progressively by raising the TRF walls. One of several methods can be used, depending on such factors as availability and cost of suitable material and the strength of the tailings. To improve consolidation of tailings, subaerial deposition and beaching methods are used. These techniques require adequate area and slope for the removal of most of the free water from the surface. When tailings are thickened in the process plant, central discharge to the TRF may be considered as a means of reducing the size of containing embankments. TRFs are constructed to suit the topography of the site. A TRF may be one or a combination of the following types:

- cross-gully dam
- hillside dam
- turkey nest dam.

TRFs should not be located in a stream that permits flow of water over the tailings. They should not be located in areas subject to caving from underground mining or above subsurface karst environments. Equally, sites for TRFs across former stream beds or where a stream has been diverted must be fully evaluated to ensure that underlying permeable alluvial deposits or calcrete deposits are not present. These deposits are common in many parts of Australia as a result of past more temperate climates. Allowance for these investigation costs needs to be included in the prefeasibility study costs.

On completion of operations, a TRF should be well consolidated and capable of ready rehabilitation. The exposed surface area of the tailings, to promote consolidation by desiccation, should be approximately 40 ha/Mt/a of tailings production. Climatic and other site or regional factors will influence the area actually required. TRFs must be designed as water-retaining structures, using appropriate construction materials. A geotechnical investigation is required to assess the site and material suitability, the possibility of leakage from the dam, and any potential for infiltration of contaminants from the tailings to the groundwater or nearby streams during the life of the operation and beyond. In most mining and mineral processing operations, the reuse of decant water from the tailings is necessary to achieve project economies and restrict the process water make-up requirements. Water recovery is dependent on:

- evaporation from tailings and water surfaces
- rainfall and catchment area
- slurry density
- tailings consolidation.

TRFs in high rainfall areas may 'make' excess water, while others may have little reclaim. Reclaim volumes vary with seasonal factors and care is needed in applying average-year conditions when satisfying daily plant requirements. For initial assessment, it may be assumed that water make-up requirements approximate 1 m^3/t of tailings. At the completion of the mining and processing operations, TRFs require rehabilitation and revegetation to ensure that:

- no discharge of contaminated leachate or surface run-off occurs
- no erosion of the dam that permits tailings to be exposed or dam destabilisation occurs
- the resultant landform is acceptable and/or capable of reuse as in its original configuration.

Generally, the application of topsoil is necessary to ensure adequate revegetation. Costs associated with such treatment of a TRF are considered operating costs in the year incurred or are paid for from a rehabilitation fund established from project cash flow. Note that where the tailings are clays or are very finely ground, the water table developed within the tails may be quite shallow (<6 m) and there will be potential for capillary rise of what is commonly poor-quality water into the root zone of the rehabilitated surface. This problem can be offset by the use of coarse-grained capillary breaks below the soil surface. Such layers can represent a significant cost in selecting, crushing and placing waste rock, especially where this must be done over low-strength materials.

Solid wastes

Solid wastes accumulate as a result of operational activities. Wastes of different types require individual treatment. The following provisions are required:

- Combustible wastes, including oils, can be disposed of by remote incineration where recycling is impractical.

- Non-destructible wastes may be disposed of as above, with consideration for recycling or salvaging of metallic wastes, tyres, plastics and paper products, subject to transport economics.
- Organic wastes from residential areas, offices and amenity blocks including stabilised sewage sludge are usually disposed of by traditional landfill techniques. Alternatively, the organic wastes may be composted and beneficially used in rehabilitation of waste rock and TRFs as a part of oxygen-reducing layers or in starter soils to stimulate revegetation.

Equipment and facilities for collection and disposal are required. Apart from initial capital, waste disposal costs are generally considered as operating costs. Costs need to be identified as part of early project evaluation as they can be substantial in some States and locations.

ADMINISTRATION FACILITIES

Company policy will determine which functions occur in a head office or at the mine site, or are performed externally under contract. Such policy decisions will be based on project issues including the size and expected life of the mine, its location, existing (and accessible) 'sister' mines, infrastructure and facilities and the ability to attract and maintain the skill sets required. Policy decisions are also affected by company issues including size, the extent to which corporate functions are centralised (eg purchasing, contracts, payroll, long-term planning, project management), future expansion plans and the level of risk.

All mine sites need to establish facilities for a base skill set, which is likely to include:

- administration
- environmental management
- finance
- geology
- human (including labour) relations
- mining engineering
- operations management
- processing (metallurgy)
- safety, including first aid
- surveying.

All mines have distinguishing characteristics for concentrations of particular skills for projects. Examples of specific project needs are given below.

- Highly variable ore or coal quality may require on-ground geologists to supervise all excavation. Typically one geologist may service three mining faces.
- Some underground and surface operations present particularly challenging geotechnical conditions requiring the services of several engineers. Services include daily monitoring of working faces, long-term strategies and design and project work.
- A mine producing a range of products requiring tight control over production faces will need several surveyors for day-to-day operations and for weekly, monthly, quarterly and annual reconciliation reports. Other surveyors may be needed for new projects including mining pits, infrastructure, environment and community-based work.

Various office configurations are popular. The decision is determined by the personal choice of the manager or it can be established during the development phase of the mine. For a new project it may be desirable to create open plan space to allow staff to interact with and better understand the job requirements of their colleagues. This open space would generally be supplemented by meeting rooms of various sizes. A more mature operation may have mostly single-person offices (typically 10 m^2); group offices for production geologists, surveyors and field-based environmental staff (typically 35 m^2); meeting rooms (four-, ten- and 20-person); and open plan areas for project groups and visitors.

Facilities may be combined or grouped. Economies can be gained in building and services costs by combining functions within a single structure, despite current communications systems rendering this less essential. A logical process must be followed that identifies functions and working relationships, assesses the specific project requirements and combines or locates these in the most cost-effective and practical manner for that project. The management philosophy needs to be considered as part of the design. Significant thought should be given to a layout that provides flexibility for later changes in the scale of the operation. Due to the cost of materials and labour, facilities at mining projects are generally of higher cost than in near-city locations. Fit-outs should allow for the most up-to-date technological features combined with basic and functional fittings and furniture. Mine site administration facilities could cost up to \$3500/m^2.

Administration buildings

Space requirements are derived from project staff lists. Allowance should be made for expansion and for consultants, project teams and corporate personnel visiting the site. When designing the layout of the administration offices, consideration should be given to factors such as:

- building amenities with free, landscaped space and shade for meal and work breaks
- consideration of sustainability principles in design, including water collection and reuse, and design to optimise heating, cooling and lighting
- easy access for staff who move often between field and office, to reduce noise and dirt
- easy access to car parks for field-based staff
- easy interaction, particularly for production focused staff

- expected life of the mine and processing facilities
- location of all staff in a single building, not distinguishing between operations and management personnel
- meeting rooms and meeting spaces for various sizes of work groups
- relocatable buildings allocated for future projects
- traffic management for visitors and regular users of the building.

Laboratories

Geological or mineralogical testing associated with mine reserves definition is generally not (project) time-dependent and is most commonly contracted out to external laboratories. On-site laboratories are generally required for production control to maintain grade and refine short-term mine planning. Laboratory testing is also required for process plants to understand ore feed and maintain product quality, and consideration needs to be given to the frequency of testing required to monitor and maintain the process. Environmental testing in the form of air, water and geochemistry is essential to maintain appropriate standards within the regulatory and operating environments. The most appropriate regime for water quality testing may be automatic samplers that are placed in-stream, with solar-powered data recorders and wireless download capability. The frequency of testing in all cases should be designed to move from a reactive to a proactive response.

Adequate storage space for test samples and tested samples is required for site laboratories. The space requirement is based on the size of the samples taken and the sample retention time. Consideration should be given to:

- a separate tested sample storage space away from the laboratory
- the durability of the materials in which samples are stored
- the risk to the environment of long-term storage
- the cataloguing system for easy and accurate retrieval.

The sample retention time is linked to potential future uses including:

- additional geochemical testing to model properties not initially considered significant
- contract penalty clauses relating to time for transport, storage and use of products by end-users
- geological re-interpretation and confirmation.

Storage facilities for drill core may also be required.

Laboratories may be incorporated within other building complexes such as in the process plant. However, given the varied nature of the testing undertaken, and the likelihood of future additional testing requirements, a stand-alone laboratory is generally recommended. In designing the layout, attention needs to be paid to traffic management, pedestrian and vehicle interaction, sample handling (based on toxicity and injury concerns), preparation and storage areas and noise attenuation and ventilation systems. Laboratories associated with uranium mining and processing facilities demand special consideration.

Training facilities

Training is becoming an increasingly important function in mining and processing operations. Mine owners recognise it is their responsibility to provide a safe work environment and need to satisfy themselves that their employees work (and are able to work) safely. In boom times the demand for skilled mine workers lags behind the supply, and companies must themselves develop the necessary skilled workforce. The communities in which mines are located are frequently in areas with limited essential services and mining companies assume a responsibility to provide emergency response outside the mine gate. Through labour shortages and recognition of social responsibility to provide local direct employment, companies may find they have fewer skilled people to deploy across a range of activities. Mines are often located within the land of Indigenous communities, incurring an obligation to employ workers from that community. Companies are committed to providing new types of training, including new ways of training, multi-skilling and customising of jobs.

All of this leads to a significant demand for on-site training facilities. The modes of training are:

- emergency training for fire, accident, environmental incident and external community response
- external courses including generic inductions, skill-specific advanced training courses, multi-skilling and management
- on-the-job training including induction, mentoring, in-house seminars on specific procedures and practices, operator training, site certifications (manual and written), site policies and procedures
- safety training and basic first aid
- statutory training obligations including community relationships.

On-site training facilities required to deliver training may have common elements. Facilities include:

- classrooms to accommodate groups of up to 25 people
- designated fire-fighting areas including for extinguishers and larger fires
- emergency (environmental) response vehicle and equipment, with space for training and storage
- emergency response vehicle with space for first aid treatment and training, and storage of additional equipment
- syndicate rooms for smaller breakout group work.

A training complex should comprise, in addition to offices for the training staff and amenities, up to three classrooms and smaller syndicate rooms of total area around 500 m^2.

Emergency response facilities

Emergency response is a requisite function of most mines due to their generally remote location. Typical emergency response capability will be required for:

- accidents – first response on the mine site and near the site
- fire – response capability is generally restricted to extinguishers, fixed facility fire hoses and frequently, the provision of a fire tender
- environmental incidents – hydrocarbon and chemical spills.

Each of these functions requires appropriate equipment. A site ambulance should contain most elements of a community ambulance supplemented by vehicle extraction equipment, ropes, stretchers and site-specific items. Hydraulic metal cutting equipment should be located in the emergency vehicle or in a secure storage area. Appropriate lengths of fire hose and nozzles should be stored in fire hydrant cabinets. Fire equipment and installed fire systems need to be tested regularly. Hydrocarbon spill kits should be packaged and kept in various places on-site. Generally, larger capacity spill response equipment will be housed in the designated emergency area and be available for use on a regional basis. These facilities may be co-located with a staffed security centre (and included in that facility cost).

Bath houses

Bath houses and change rooms tend to be much smaller than those used in earlier projects. There are fewer manual labour tasks and many employees prefer to wash and change away from the worksite. Men's and women's showers (with individual shower cubicles for approximately ten per cent of the workforce) need to be provided, signalling a move away from the older communal men's bath house. Individual storage lockers remain a necessary part of the facilities provided. Bath houses with toilet facilities are stand-alone structures and on small projects may be in a single building, which may also contain the lunch room facilities. They are frequently located close to plant entrances, allowing direct access from car parks and debussing areas through the bath house to the worksite. Unit construction costs are higher than for offices and may be best equated with laboratories because of the complex plumbing and waste disposal requirements.

Lunch rooms

Lunch rooms may be of reasonably simple construction and located at centres of worker aggregation. They often serve the additional purpose of a meeting facility for larger groups. They may be included within operating facilities such as workshops and are usually located strategically across the mine to minimise downtime during meal breaks. Equipment and fit-out will be determined by company policy for providing meals at meal breaks for the workforce. Ablution and toilet facilities are provided. Sizing criteria are based on the number of equipment operators per shift at around 2 m^2 per person. It is not usual to budget for additional workers for projects or major shutdowns, as staggered meal times allow use of the same facility. For one shift plus day workers, space should be allowed of around 2 m^2 per occupant. Unit costs can be assessed from comparable buildings.

Safety and medical facilities

These features are generally combined with, and included in the cost estimates for, previously specified items. Safety managers are important members of the operational management team and are located in the administration complex. Mines have a statutory requirement for a first aid room and an ambulance as a minimum, and a number of qualified first aid attendants must be employed across the site. Many mines combine the ambulance station with the gatehouse, which ensures personnel are available to attend incidents at all times. In remote locations, first aid services should complement local and RFDS regional facilities.

Security facilities

Security measures are required to protect plant and property, and to fulfil duty-of-care obligations on mine management by ensuring that people unfamiliar with the hazards of a mine site are excluded from these potential hazards. Security measures include fencing, gatehouses with controlled entry, CCTV in high-risk areas and signage. Security includes patrols in areas such as explosives magazine storage, gold recovery, bullion stores and inflammable products storage. Facilities mining and processing uranium ores are subject to more stringent security requirements than those handling more benign materials.

Adequate security provisions would normally be incorporated in plant design. Unless special features were required, no additional specific allowance would need to be built into the preliminary estimates.

TRANSPORT

For remote-area projects overland transport of mineral products is a vital link in the development of the resource. Transport can, in extreme cases, contribute up to 75 per cent of the total project cost. Consideration and evaluation of the available transport options is essential with both the capital and the operating costs of the options requiring evaluation to ensure optimum system selection. Broad parameters have been developed, allowing the most appropriate system to be identified for any particular project. The options are discussed and preferred criteria for use given in this chapter. Transport systems available for consideration include:

- road
- rail
- slurry pipeline

- overland conveyor
- sea or river
- cableway.

In selecting a preferred system, project-specific characteristics must be identified. First approximation comparisons can readily be made, but many associated factors will influence transport system selection. Costs of operations personnel, product preparation for transport (particularly if not required for process reasons) and loading and unloading facilities, together with related materials handling requirements, all influence system selection.

Road transport

Road transport's major application is for short hauls and low annual tonnages. Its advantages are flexibility and manoeuvrability and a greater grade capability. Road systems are particularly exposed to inflation in view of the high capital cost of replacement equipment and the labour-intensive nature of the operation. Road standards and costs have been discussed in the subsection 'Access and service roads'. The major capital cost is the fleet cost. Fleet size is a function of haul distance, equipment selection and annual mine capacity. Economy results from the use of large unit sizes and from road trains. Road trains may have payloads of up to 200 t with a configuration length of up to 36.5 m for double road trains and 53.5 m for permitted triple road trains. The direct operating cost is a function of vehicle payload, so economies of scale can be expected. Regional restrictions apply to the use of road trains or articulated combinations, and local regulations should be reviewed.

When existing (government) roads impose restrictions on payloads and vehicle dimensions, and access is available, a parallel haul road for exclusive mine use may be constructed. One Northern Territory mining operation uses a prime mover with six trailers, where the fourth trailer is equipped with a drive unit, transporting 270 t of ore over round trips of 80 km at speeds of up to 70 km/h. This configuration can dramatically improve the cost-per-tonne per kilometre haulage efficiency.

Rail transport

The principal application of rail transport in the mineral industry is for large and increasing quantities of materials hauled over flat to moderate terrain in dedicated unit trains. A wide range of material sizes (ore, concentrates or coal) may be handled, and rail systems are flexible in respect of both increased tonnage and extension. Capital cost elements include formation and rail bed, drainage structures, signalling and train control systems, track laying and rolling stock.

Formation costs are primarily a function of terrain. The major cost factor arises from the need to maintain a maximum grade of around 0.5 per cent against the load and one to two per cent against an empty train for economic operation. The use of additional locomotives on steeper (loaded) grades can in some cases reduce the initial expenditure. Track length increases because of the need to maintain these grades. Bridge work in broken country adds to formation costs.

Track materials and laying costs vary less, but are a function of loading and use.

Western Australia's iron ore railways, owned and operated by the producers, typically use heavy rail (66 or 68 kg/m) for standard gauge systems and concrete sleepers are now preferred to timber. Train lengths vary, the maximum currently in use comprising more than 200 ore cars, each carrying in excess of 100 t of ore (26 000 t in total) and pulled by three or more 3300 kW locomotives. Maximum axle loadings are 35 to 40 t. A locomotive of this size costs around $6 M. The length of a train of this size is 3.75 km. Smaller trains of up to 90 ore cars can be pulled by a single locomotive. Rolling stock requirements depend on tonnage and haul distance. Economies of scale can be achieved as unit train payloads increase.

In Queensland, New South Wales and South Australia, all coal is transported by rail to users and to export ports on government-owned railways, although a private operator may provide the service. Around 50 wagons of 120 t gross capacity comprise a normal train, although trains of up to 80 wagons are regularly used. Rolling stock, including coal wagons, is usually operator-owned. Producers are responsible for loading facility costs and users or terminal operators for unloading facility provision and costs.

Rail transport of product is project-specific and a producer's options will be limited by regional practices and by regulations. Early consultation to determine the concept for the project is necessary, and decisions are required on the extent of the owners' commitment. Operation and maintenance may be contracted out, transferring some capital cost to operating budgets.

Maintenance staff and facilities for rolling stock, track, structures and traffic control systems must be adequate to support the minimum acceptable level of service.

Slurry pipelines

Slurry pipelines for the transport of ore, concentrate or coal have applications where:

- adequate surface, ground or sea water is available
- any additional material preparation costs for the solids component can be tolerated
- dewatering or placement characteristics of the transported material are satisfactory
- large tonnages are to be handled
- transport distance is not a determining factor.

While terrain is less significant than for road or rail, an access track is required. This can be the track used construction access, but upgraded. Pipeline grades may be limited to 15 to 25 per cent based on the slurry specific beaching angle to avoid potential pipeline blockages. Slurry pipelines are capital-intensive but are less exposed to escalating labour, maintenance and operating costs. They often satisfy environmental criteria more readily than other systems but are relatively inflexible with respect to changes in throughput. The capital cost is primarily a function of capacity, which in turn determines the pipeline diameter. Operating costs are a function of annual capacity and static head requirements. Long-distance slurry pipeline transport usually favours the use of positive-displacement pumps, which operate at high availability and energy efficiencies usually exceeding 90 per cent. Due consideration must be given to the availability, cost, treatment, disposal and recycling of the water used as the transport medium.

Overland conveyors

For the transport of large tonnages over short to medium distances, belt conveyors provide an optimal solution. Small tonnages on narrow belts create operational difficulties. While belt conveyors have the inherent advantage (as do slurry pipelines) of continuous operation, the major constraints are material top size and grade (15 per cent). A belt conveyor system is insulated from inflation, as it is less labour intensive than competing systems. Capital cost is essentially a function of capacity, reflected in the belt width and speed. For most minerals and coal, capacities of between 200 and 10 000 t/h can be achieved with a belt width of 600 to 1800 mm. Operating costs are significantly influenced by the frequency of belt replacement, as belts often contribute up to 25 per cent of the initial capital cost.

Where longer distances are involved, special or proprietary designs such as cable belt systems may be appropriate. Such conveyors have been used for distances of up to 30 km. These conveyors can also incorporate horizontal curves in their alignment.

Sea or river transport

Where geographic factors permit, barging or coastal shipping may be an economic option, given the large-scale bulk handling capabilities of these systems. Channel dredging and terminal construction may increase the system costs equal to, or in excess of, costs associated with competing systems. Operating costs will generally equate with those of a rail system and are primarily a function of the vessel size. Choice of the material handling system, which is bulk, containerised or bagged (individual or palletised), significantly affects system capital and operating costs.

Consideration must be given to the implications of the introduction of water-borne transport in respect of union-imposed crewing requirements on Australian coastal shipping.

Cableways

Cableways, or aerial ropeways, have a specialist application for low-capacity material movement over inaccessible or rugged terrain, and in some cases, over built-up areas. Cableways have attracted limited interest in Australia, but their use should not be discounted in appropriate circumstances. Cableways may be built to any length by the introduction of intermediate drive and tension stations but, as for multi-flight conveyors, a failure in one part of the system takes the entire operation out of service. In India, cableways are used to transport commodities such as coal, limestone and phosphate at rates from 60 to 600 t/h over distances ranging from 1 to 20 km.

Other systems

Satisfying project-specific criteria may require solutions that combine the systems described above, particularly where terrain conditions dictate a change in the preferred approach on economic grounds. For small quantities of high-value product, the use of aircraft with suitable loading and landing characteristics should not be discounted. To select an appropriate system for a particular project, the variables of product value and quantity, top size, distance and terrain require consideration. Also, the capital and operating costs of competing systems require assessment and comparison. Some broad cost and selection parameters are included in Table 17.8.

In summary, preferred systems can be initially selected on the bases indicated:

- road – low tonnages, short distances and flat to rolling terrain
- rail – high tonnages, long distances and flat terrain
- slurry pipelines – competitive in all cases where preparation costs are not a charge against transport, particularly for large tonnages over long distances in difficult terrain
- belt conveyor – high tonnage, short distances and medium terrain.

Other systems would only be selected in project-specific circumstances.

TOWNSHIPS

Recent industry trends, influenced by an increasing number of limited-life mines and by some expansion in existing regional facilities, have resulted in stand-alone 'company towns' becoming less of a feature in emerging projects. Mining towns, constructed as an essential component of early longer life remote-area projects, are now administered by local authorities. Many of the houses and commercial establishments have been sold to occupiers. The expansion of existing regional towns, while not fully satisfying industry demands, has permitted new project developers a wider range of options for workforce accommodation. Together with the increasing trend of mining and process facilities being staffed on a FIFO basis, townships have assumed a diminished role in project

TABLE 17.8
Product transport systems – cost and selection parameters.

System	Product characteristics	Distance	Terrain	Capital costs $ × 1000/km (a) $ × 1000 Mt/a × km (b)	Operating costs (cents/t/km)	Comments
Road	No limitations	Only limits are economic (shorter distances preferred)	Grade limitation – 5% (steeper introduces cost penalties)	Road – 500 - 3000[a] Fleet – 40[b]	5 - 12	Sealing roads adds to Capex – but may reduce Opex: • fleet size escalates with haul distance • labour intensive
Rail	Most minerals and concentrates, coal. Top size, variable to 25 mm.	250 - 500+ km (optimum)	Grade limitation – 0.5% (against load)	Track – 2000 - 7000[a] Rolling stock – 100[b]	1 - 2.5	High costs in difficult terrain: • add bridge costs • flexible system for increasing capacity • inapplicable for government railways
Slurry pipeline	All concentrates, some minerals, coal Top size limits sg <2 - 5 Solids <40 - 65%	To 250+ km	Few restrictions Grade limitation – 15% (may be greater for certain products – test)	400 - 2000[a]	1 - 4	Check costs of: • material preparation • dewatering systems • water availability • access track required
Overland conveyor	All minerals and concentrates, coal	Up to 25 km	Grade limitation – <15%	5000 – 12 000[a]	2 - 5	Check applicability of special systems outside range
Sea or river	No limitations	No limitations	Not applicable	Case specific, develop	Develop	Individual cases to be considered

development – except for large-scale, long-life projects where there is no practical alternative.

Townships and residential accommodation represent one of the most controversial aspects of project development. It is prudent to engage professionals, starting with conceptual design, if a substantial investment is involved. Location, size of workforce, mine life, existing nearby communities and company and government policies will influence decisions relating to the residential and community facilities required, and these issues must be addressed in conceptual development plans. Operating options such as FIFO should be evaluated against a conventional family-style township with the essential level of infrastructural support. A mine working on FIFO principles usually introduces work rosters with extended shift hours, and workforce numbers are less than those with a conventional three-shift system.

If the preferred approach is not immediately clear, workforce residential facilities must be recognised as a project cost, accepting that alternative approaches, which may be introduced later, must generate cost savings if the option is to merit consideration. Some issues pertinent to the selection of suitable sites have been discussed earlier. Environmental factors and engineering suitability within the limits of acceptable travel distances are the main selection criteria. Sites are usually selected for topographic interest, and native vegetation is preserved to the maximum extent practicable.

The facilities described are for the construction of a town with support facilities and amenities. New townships, or substantial additions to existing towns, must satisfy established planning standards and criteria. They must be readily transferable from an ownership and administration perspective from the company to (local) government. Township sizing is based on the size of the workforce with allowance for consequential development. Assumptions based on prior industry experience of the mix of married and single workers, family sizes and housing preferences form the basis for planning. Typically, based on ensuring a stable workforce, 15 to 25 per cent of single workers are employed and consequential employment, either government or private (community services), may constitute around ten per cent of the town population. Increasingly, projects rely on employing dependants as a means of reducing accommodation constraints. Whether it is a government or company town, an administrative unit is required, although the functions and responsibilities may vary. Usually, a relatively simple facility is included as the town centre. The concept described assumes that the town is constructed, operated and maintained by the mining company, with maintenance and services provided through the company structure.

Housing

Traditionally, the mix of housing with respect to size, standard and type has been defined on a hierarchical basis, typically:

- senior management style
- senior staff style
- a range of two, three and four-bedroom houses
- single-person quarters as self-contained flats, duplex accommodation or motel-type units.

Increasingly, discrimination in housing standards is being eliminated and for initial cost estimates, reasonable building costs can be determined by applying unit costs based on house areas. For individual houses, transportable type units may be favoured owing to the lesser requirement for site construction labour. Housing costs may be established by the selection of an appropriate unit cost, area or house type. Indicative constructed costs are as shown in Table 17.9. In townships associated with extended-life mines, site-built housing units are preferred and there is a tendency to encourage occupants to purchase houses. Design and construction standards reflect this trend.

TABLE 17.9
Indicative remote accommodation costs.

House type	Transportable	Permanent (A$)
Management	See note[a]	$300 000 - $1 M per house
Senior staff	See note[a]	$300 000 - $1 M per house
Staff housing	See note[a]	$300 000 - $1 M per house
Single-person quarters (per person, permanent)	$50 000 - $130 000 per person	-
Single-person quarters (per person, construction)	$20 000 - $100 000 per person	-

Note: a = costs for permanent accommodation depends on location and availability of 'town services', which are not included here, although subdivision costs are included. For transportable-style accommodation, these costs include all costs relating to camp construction, including common messing, laundry, water, power and waste treatment facilities. Links such as access roads, power and water are not included.

Roads

Standards and costing of roads for residential and commercial areas roads have been discussed in the section 'Access and service roads'. It is frequently convenient for initial estimates to consider the costs of a 'serviced lot'. This will include costs associated with access roads, site preparation and the provision of drainage, water, power and sewerage.

Services

Mining towns are usually developed allowing for major expansion, provision being included in planning at the conceptual design stage. Services to be made available to each residential and commercial unit include:

- access
- drainage
- power
- sewerage – either central or individual systems
- water of potable standard.

Town services are desirably, and as far as possible, integral or compatible with those required for mining and/or processing activities. This will minimise the need for additional operating personnel and reduce the maintenance, spares, standby or storage requirements. Economic transmission distances will influence this requirement and it can be a major consideration in town site selection.

Utility systems should allow for planned expansion but not at the expense of substantial incremental initial capital cost. Standards of installations should equate with those of the government authority of the State, region or country to ensure that integration is possible when considered desirable. If government services such as power from a grid or water from existing systems are accessible, using such services will reduce the capital impact. Costs vary widely depending on the standards applied, the site locality and conditions, and the extent and availability of existing services.

Individual serviced block costs are $80 000 to $200 000.

Recreation facilities

Remote and isolated townships normally incorporate recreational facilities comparable to those readily available in urban environments. The range and extent of facilities provided will reflect the interests of the planners and residents. A frequent approach is for the company to provide basic facilities and to respond to demand by supporting the initiatives of residents for funding assistance for additional features. Most remote communities appreciate swimming pools as a very desirable asset.

Costs of recreation facilities vary widely and are site-specific. Historically, good value for money has been obtained where playing grounds and golf courses have been integrated with site works, but specifically designed facilities costs reflect market conditions. Allowance costs for recreational facilities, as might be expected for a township of approximately 1500 residents (workforce about 250 people), are as indicated in Table 17.10.

Shopping facilities

Towns developed on a family concept must provide for shopping for essential goods and services. Initial planning requires the incorporation of retail facilities providing a selection of food and other relevant consumer goods. The facilities should be adequate to support a reasonable lifestyle but do not offer the range of options available in capital cities or urban areas.

Approaches to the provision of shopping facilities vary. It is usual that building costs associated with the facilities are project costs. Costs may be recovered through operating concessions, or operators may be offered access rights requiring them to finance buildings. This initial assessment tabulates shopping facilities for a township with a population of around 1500 people. Indicative requirements for shopping facilities are listed in Table 17.11.

An average cost representative of the mix of building and fit-out requirements would be about of \$2000 to \$4000/m^2. Costs of providing services equivalent to, say, ten serviced lots, and for car parking must be added.

Medical facilities

The provision of family medical facilities is essential, but the services vary widely. Improved transport and communications and the development of central or regional hospitals has eliminated the requirement for fully equipped hospitals to be constructed at most new population centres. The level of service provided is usually agreed in consultation with government medical or health authorities, but currently the requirement is generally restricted to emergency and non-critically ill patients. Outpatient or consulting rooms equipped for medical and dental services, together with minimum ward accommodation of say six beds for a 1500-person town, would be regarded as appropriate in most cases. X-ray, casualty, and pharmacy and dispensing services should be included and equipment must be appropriate to the level of service.

TABLE 17.11
Shopping facilities.

Type	Facility	Area – typical (m^2)
Supermarket	Retail area	600
	Bulk store	400
	Cold (refrigerated) store	150
Shops	Newsagency and bookseller	100
	Bank	160
	Post office	80
	Pharmacy	80
	Milk bar	80
	Other shops (2)	100
	Laundrette	50
Total		1800

A hospital or clinic to this specification would be around 400 to 500 m^2 in area, air conditioned and of substantial (masonry) construction. Department of Health criteria prevail. Construction costs of \$2500 to \$5000/m^2 can be expected, exclusive of equipment, which should be separately costed. The facility should complement the industrial requirement at the mine and/or processing facility. Ambulance or emergency vehicle coverage of worksites and residential areas is required. The ability to call on RFDS services is important.

Educational facilities

Commitments to the provision of family-style accommodation imply acceptance of the requirement for educational facilities meeting the requirements of the relevant State education system. As a minimum, primary school facilities will be required. It is usually advantageous to also provide a preschool centre. Secondary schooling would only be considered in a large town of between, say, 4000 and 5000 residents.

In all cases government education design criteria must be satisfied as a minimum. Normally, facilities provided in whole or in part by mining companies will be staffed and operated by the State education

TABLE 17.10
Recreation facility costs.

Facility	Description	Approximate cost (A\$)
Community centre	Hall, library, meeting rooms, etc	500 000 - 1.25 M
Swimming pool	Lap pool, facilities, fencing and filtration plant	500 000 - 650 000
Tavern and beer garden	Tavern, amenities, beer garden, etc	500 000 - 1 M
Cricket and multi-use sports facility	Netted cricket pitch and sports court facility	200 000 - 500 000
Golf facility	Driving nets and putting green	50 000 - 100 000
Squash courts, gymnasium, badminton	Standard, with lighting and change rooms	500 000 - 1 M

authority. School layouts meeting departmental requirements will include:

- classrooms
- library
- offices and staff rooms
- service areas.

Special areas should be set aside for craft, home economics and manual activities. If combined with preschool facilities, a dedicated and separate secure area specifically designed for preschool children should be provided. Air conditioning is desirable. To serve a town of 1500 residents, a total school area of around 1500 m^2 would be required. About 15 per cent of this area may be committed for preschool facilities. Costs for the facility over and above the site works could be approximately \$2000 to \$4000/m^2.

Service industries

Refer to the section 'Light industrial area'.

Existing town option

A new project may be sufficiently close to an existing town so that incorporation of the incremental requirements to service the mining operation is practical, economic and socially desirable. In these cases, care is required on the part of the company and the authorities to properly plan and manage the integration of a substantial number of immigrants to the town. The advantage, apart from the availability of a resident workforce, is that infrastructure costs will be substantially lower as much of the social and commercial infrastructure, and the ability to service the additional development, will already be in place. Capital expenditure for on-site works is replaced by operating expenditure (as payment to councils). New capital expenditure is limited to residential units, which may be negotiated through a developer if stock is available, or provided by the public housing authority. Housing costs, as earlier listed, can be applied to the assessed requirement.

In most cases where existing towns expand to accommodate a substantial influx of personnel for a new project, town authorities will expect a capital contribution towards meeting the cost of additional technical services and community infrastructure. Such a contribution will be substantial but usually significantly less than the costs of the provision of grass-roots facilities. Contributions of between \$2 M and \$5 M have been made in the past. A cost allowance of this order might be appropriate if the number of personnel is likely to have a significant impact on the town's services and facilities.

A checklist of the necessary town site facilities is provided in Table 17.12.

TABLE 17.12
Checklist of town site facilities.

Residential units	Houses (all types)
	Flats
	Single-person accommodation
	Motel type
	Duplex housing
	Multi-storey
	Transit – including caravan park(s)
	Commercial – hotel, motel, etc
Commercial and community facilities	Administrative centre, including maintenance and storage facilities
	Cemetery
	Club – with dining, liquor facilities and provision for cinema, drama productions, etc
	Community centre – including meeting rooms and library
	Community hall, art and craft centre and childcare facility
	Fire station
	Government (state and federal) facilities
	Hospital or clinic and emergency facilities
	Police station
	Preschool centre
	Primary school
	Secondary school
	Service station
	Shopping centre, including supermarket or retail store, news agency, milk bar, pharmacy, travel agency, bank and post office
	Single-person's mess, wet canteen and laundry
	Sports and recreation facilities, including swimming pool(s), sports grounds (cricket/football) and golf course; and tennis, squash and basketball courts with change rooms and amenities
Services	Municipal maintenance services
	Power supply (including street and security lighting)
	Sewerage disposal system
	Waste (garbage) disposal facility
	Water supply

LIGHT INDUSTRIAL AREA

The current trend is for companies to concentrate on core activities and allow others to perform peripheral or specialist tasks. Activities diverting resources or capital from mainstream functions can frequently be more economically handled by contractors, which are free of mining company overheads and constraints. Should the project site be located reasonably close to a town with industrial support infrastructure, the use of existing facilities may be encouraged, resulting in some capital cost savings to the mine owners. Where the project is remote, the owners have the following choices:

- perform fringe activities with company staff in company-provided facilities
- provide facilities and contract out operations
- provide a serviced area in which contractors providing both facilities and personnel can operate.

In the last case, an area usually designated as light industrial is provided as a base from which the needs of the project can be satisfied. Facilities provided by organisations operating in such areas may cater for additional markets. Activities critical to mainstream activities should be under the direct or indirect control of the mine owners. Other activities may be contracted to individuals or organisations that require a base for the service industry supporting the mine, plant or town. Typical of the activities centred on a light industrial area are transport contractors, fuel and spare parts storage facilities, servicing and repair facilities for equipment suppliers or agents with regular demands, light fabrication shops, concrete and aggregate plants, and industrial and domestic repair facilities such as for air conditioners.

Site selection requires a well-graded, drained area that is reasonably accessible to the mine, plant or town; is subdivided; and has road access and power and water (at least). Connections to a central sewerage disposal system or a local plant are desirable. The site should be suitably screened from, or located clear of, populated areas. Noise and dust should be factors in its selection. The site should allow for expansion and for probable changes of occupancy. Agreements should recognise this latter fact and include site clean-up and waste disposal provisions. Typically, a minimum of 12 to 15 industrial lots with areas 1500 to 2000 m^2 would be provided. A road system with site access only, power (415 V) and water availability at each lot are the normal limits of company provisions. All other facilities will be provided by the contractor. However, the company should exercise some control over the standards, ensuring that they meet regional planning authority criteria.

Consideration may be given to placing some of the construction facilities, such as the batch plant, fabrication shop and lay-down and storage areas, in locations consistent with their continuing use in a light industrial area, but only where the selected location is appropriate and cost-effective. Costs of a light industrial area are not usually significant in terms of the total project capital cost, but substantial savings can occur if later development is at the expense of the occupier (contractor). These savings will result in related items such as employee housing, transport and amenity provision. There will be an increase in annual operating costs as a consequence of these capital reductions. The real cost of the light industrial area, on a per-hectare basis, can range between $250 000 and $1 M, assuming reasonably level ground and ready accessibility.

CONSTRUCTION FACILITIES

Projects in remote locations impose excessive demands on available facilities during construction. Consequently, personnel levels, equipment and logistics requirements and road and wharf loadings are frequently substantially more than operational needs. Construction requirements have historically accounted for some five to six per cent of project costs, broadly spread over the provision and operation of construction labour accommodation and of temporary construction facilities. In situations where, because of the availability of a contractor's or a third party's accommodation units, responsibility for the provision of construction labour accommodation is assigned to a contractor, the cost will appear in the unit construction costs of constructed facilities. The non-inclusion of a cost figure in the appropriate account code (WBS) item does not imply that the costs are not incurred.

Construction camps

Most remote-area sites require single relocatable accommodation units, landscaped into a reasonable setting with provision for messing, recreation and services. Personnel planning, if properly done, will minimise the size of the facility to be provided. Some accommodation for married couples, in transportable form, should be provided as early as possible in order to attract and hold high-calibre and permanent management staff and contractor supervisory staff. A fully serviced caravan park will assist in reducing the demand on construction camp accommodation and will be an asset to the community at the completion of construction.

Safety and health standards demand that the quality of the facilities and services and their installation meet established criteria for permanent living units. Attempts have been made on projects to bring forward the construction of areas of permanent housing to allow for their use as temporary construction accommodation, but planning is rarely sufficiently advanced to allow this. Thus, the cost of refurbishment is substantial and the total savings achieved, if any, are small. Industry demand has resulted in the establishment of specialist organisations with the capability to design, manufacture and install complete construction camps. Such organisations will usually provide indicative quotations for preliminary project estimates.

An average project construction period would be around 18 to 30 months, and a construction workforce of 500 to 2000 people might be employed at peak. Major projects in the 1960s and 1970s employed construction workforces in excess of 4000. Present-day construction techniques aim to minimise the use of site labour in the interests of containing costs.

The construction camp should include the following facilities:

- accommodation units – in Australia this will be single-person units with en suites
- laundry units
- mess – including kitchen, diner, dry goods and cold store
- recreational facilities – including swimming pool, gymnasium, sports areas and outdoor cinema
- wet canteen, subject to owner's policy
- camp store
- camp administration
- 'mini' shop.

Water supply, sewerage, power supply and fire protection systems must be designed to urban standards. While temporary, these must satisfy regulatory authority requirements in respect of installation standards. Car parking should be external to the accommodation area. Current trends are for increasing numbers of women to be employed on mining sites, and segregated facilities should be provided for female workers.

A specialist contractor usually operates the camp under appropriate direction. A substantial number of industrial disputes have their origin in construction camps, particularly in catering, so it is vital to eliminate this as a trigger for such situations. Complete construction camps might be expected to be purchased for up to $80 000 per person accommodated.

Second-hand units are available and facilities may also be rented or leased to reduce the capital outflow. On disposal, construction camps rarely return better than 20 to 25 per cent of the original investment. Camps are sometimes retained for use during plant expansion and rehabilitation.

Catering (including cleaning) costs per person per day range up to $120, and are dependent on the numbers of people in the camp at any one time. This amount is frequently recovered from contractors but, if this approach were adopted, the costs would be included in and passed back through unit construction costs.

Temporary facilities

Grass-roots developments require the provision of temporary facilities adequate to permit the most economic completion of permanent facilities. Facilities may be provided by either the owners (manager) or contractor; in either case costs accrue to the project.

The location of temporary facilities must be coordinated with the permanent installations served. To minimise costs, it is sometimes possible to use permanent facilities in a temporary construction role, such as site offices in warehouse structures. However, on short-term high activity projects, this leads to difficulties as operations personnel take up their functions prior to commissioning. The following facilities are required for a typical project:

- access roads and services, such as water supply, power supply, drainage and sewerage
- area engineers' offices – on large sites only
- construction equipment, where studies indicate this to be the most economical approach to availability and use
- crib room(s)
- lay-down areas for owners' and contractors' supply materials, located close to the facility to be built
- piping fabrication area – roofed if necessary
- precasting area – civil contractor
- secure areas for contractors – sheds, materials and equipment
- site office for owners or manager with meeting room, reproduction (copying, printing, photography) and service facilities (approximately 500 m^2)
- toilet facilities – located throughout the site
- warehouse with receipt, issue and storage facilities, and fenced external storage with crane and fork-lift availability.

Construction standards will vary, but most facilities will be subject to high levels of activity over a short duration and thus compromise in construction standards is possible. Around two per cent of the project cost will be incurred in the provision of construction facilities and equipment. The equivalent cost for the construction contractors will be included in their all-in charge-out rate.

SPECIAL ISSUES

Many aspects of infrastructure discussed have been referred to as site- or project-specific. In each case there is a need to properly study the alternatives in order to identify a technically acceptable and preferred option. At the prefeasibility study level this option may not be an optimum solution, but further and more detailed evaluation should only introduce changes if reduced costs or some other tangible benefit results. A number of innovative approaches appropriate to particular situations can result in improved project economics. Some of these approaches are discussed in this section. Design, administration and supervision costs are also considered.

Modular construction

There is an increasing tendency to approach remote-area construction projects using techniques that minimise the requirement for on-site construction labour. Statistical data demonstrate that the cost of a remote-area person-hour can be three to four times that of an equivalent person-hour of work performed under controlled fabrication shop conditions.

Use of prefabricated accommodation units in the 1960s demonstrated possible savings in time and cost, and introduced the potential for cost recovery on disposal. Since that time, increasingly innovative approaches have been proposed and used. These approaches involve prefabrication and modularisation of complete process facilities (much 'borrowed' from the petroleum industry) and almost eliminate site fabrication. Developments in handling techniques have allowed plant sections in excess of 20 m wide × 50 m long and up to 20 m high, weighing up to 2000 t to be fabricated off-site.

Site works are limited to the movement of modules into place on prepared pads, and to the connection of pipework, electrics and instrumentation cabling. The concept has the potential to substantially decrease the site labour content of plant construction, albeit at the cost of additional steelwork in module substructures and the extra cost of shipping and land transport of prefabricated modules. Recent steel design has substantially reduced the extra steel requirement.

In remote areas where good-quality construction labour is neither readily available nor economic, modular construction, site conditions permitting, is a viable and proven construction option. Consideration should be given to its use, after proper study, as an alternative to the more conventional 'stick-built', approach.

Transport factors dictate module size. A frequently selected option is to base modular construction on the use of standard container-sized modules of 6.1 m × 2.4 m × 2.6 m. Modules for road transport on State highway systems are limited to around 80 t, even if these loads conform to permit constraints. Studies have indicated that significant savings in time and cost can be achieved. Predicted savings include ten to 15 per cent in cost and 20 to 40 per cent in time.

Some 15 per cent or more of project person-hours may be transferred from the field to the shop, and better quality workmanship may be expected. Transferring person-hours from the field reduces the construction workforce by allowing the use of higher productivity shop fabrication capability. Prefabrication, including full quality assurance and testing, should be exploited as a means of cost and time savings.

Fly-in, fly-out operations

The mining and mineral processing developments of the 1960s were often characterised by the construction and operation of one or more towns per project. Relocating a workforce required the provision of living accommodation and related amenities (shopping, medical, educational, recreational, etc) and infrastructure (water, power, waste disposal, etc) for communities of around 3000 to 5000 people. Township costs on a historical base consisted of five per cent to 20 per cent of total project costs in addition to the ongoing operating commitments. Substantial resources were also devoted to supporting the town infrastructure, partly because governments insisted on town development and partly because the project economics of that era allowed such development.

Escalating costs associated with the provision of on-site accommodation and supporting facilities have led a number of companies to adopt the FIFO approach to staffing a remote operation. Present-day projects frequently lack the robust economics associated with those earlier developments: smaller rich orebodies are being developed and projects frequently have a much shorter life span. Moreover, concerns over the longer-term sustainability of mining towns – and the significant community disruption implied in mine closure – have contributed to the shift away from residential developments. Despite early (State) government and union opposition, the FIFO principle has been accepted and there are now many instances where this concept is applied successfully. Today, some of the most significant social and infrastructure developments associated with mining projects take place in established centres such as Perth, Townsville and Mackay, distant from the mining operations. The approach should not be accepted without completing a study that evaluates the business, economic and social costs and benefits of the options. The advantages of the FIFO approach are:

- assured availability of staff during rostered work periods
- broader pool of potential recruits and greater flexibility in enabling staff to move between sites with less disruption to family life
- elimination of non-core operational functions
- reduced social disruption on mine closure
- reduction in workforce (support staff)
- substitution of single-worker accommodation and mess for township and supporting facilities and services.

The disadvantages include:

- absence of FIFO employee from his or her family life
- additional operational workforce (unless lengthened shifts are worked by agreement)
- adverse government or union action
- constraints on personnel availability based on single status positions only
- constraints on primary caregivers participating in mine site employment
- costs associated with charter aircraft operations
- difficulties in mine personnel participating fully in the social life of their home communities
- increased pressures on housing, services and facilities in established centres providing FIFO personnel.

The decision, assuming acceptance of the principles associated with a FIFO operation and of management's ability to cope with its shortcomings, is essentially economic. The decision should be taken prior to the feasibility study stage to allow the most realistic cost elements for the project to be identified.

Present indications are that there are few constraints on either the size of the workforce or the commuting distance for long-distance commuting to be economically attractive.

Social concerns associated with regional community development and the generation of employment opportunities for local residents, including young people, appear to be important deterrents to long-distance commuting. The effects on staff families and home communities, and on staff ability to maintain a long-term commitment to FIFO operations, also needs to be considered. However, these concerns are being increasingly over-ridden as projects seek to minimise investment costs.

The modified and limited residential, service and recreational requirements of projects using long-distance commuting can be identified using an appropriate selection of costs associated with single-person quarters. Recreational and other facilities can be listed as optional elements in residential facilities.

Design and construction management

Infrastructure costs have contributed substantially, but in widely varying percentages, to projects completed in Australia in the past 50 years. Infrastructure must bear its share of the design and construction management costs associated with the (constructed) cost of the project, and due allowance is required at any level of estimate.

Costs may not be totally visible, but reference to historical data will indicate that, for large greenfield mining projects, engineering design, procurement and project management costs will be between eight per cent and 12 per cent of the direct cost with additional costs if substantial site investigations and surveys are involved. This percentage excludes EIS costs, which on a major project can be some millions of dollars. Site construction management costs will be around five per cent to ten per cent of the direct cost. Brownfield and smaller projects will generally have a higher design and construction management cost as a percentage of the direct costs.

The typical and unit type costs listed throughout this chapter exclude the design and management costs, but do include costs associated with contractors' overheads, construction equipment utilisation and profit. From time-to-time, and particularly in the infrastructure area, cost savings are forecast by using techniques such as design and construction, or by requiring contractors to prepare detailed drawings. Approaches such as these do not necessarily introduce overall savings, as design and other development costs are then reflected in tender prices. Such approaches also frequently pass the control of many other aspects of design to the contractor, including quality. If this is a tolerable situation, minor cost savings may result. Generally, however, the result is a reallocation of costs only.

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