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Asset Management Manual

Part 6 - Whole-of-Life Studies

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1 Introduction

Owners and operators with aging assets that are incurring increased maintenance and operational costs are now faced with the decision on whether the assets should be upgraded, scrapped and replaced or just “run down” to satisfy shareholder value.

This document presents a methodology for assessing the “whole-of-life” performance of physical assets such as materials handling machines. It is important to consider the “whole-of-life” performance so that asset management decisions can be integrated with the business strategic plan. The long term implications of decision making on assets can be identified and appropriate responses developed.

The following characteristics need to be part of a comprehensive “whole-of-life” study:

- The methodology needs to be easy to follow, consistent and thorough
- Backing data which supports the conclusions needs to be easily traceable and clearly presented
- The concept of risk is included
- The methodology is “scalable”, that is, as better data becomes available, it can be incorporated into and plan and used to refine the conclusions
- The process can be used as a decision making tool – viable and non-viable options are clearly identified as the plan is developed
- Conclusions are clear and unambiguous – the final outcome should be a strong business case that can be presented to management

The methodology is written specially for physical assets such as materials handling machines. However, it can be applied to other “fixed” assets such as bins, coal preparation plants and conveyor structures.

2 Methodology

The methodology presented in this document follows a six-stage approach:

1. State the future requirements for the machine
2. Divide the machine into its major components.
3. List the issues for each component
4. Prepare scope of work for various scenarios
5. Estimate costs for each scenario
6. Evaluate the life cycle costs for the viable scenarios

2.1 FUTURE REQUIREMENTS

The future requirements for the machine need to be stated. These can be considered in two categories:

- Operational performance. Items to be considered include: increased throughput, higher availability, acceptance of unscheduled downtime
- Human factors. Items to be considered include: maintenance requirements, access requirements

2.2 MACHINE COMPONENTS

Materials handling machines are a complicated combination of structure, mechanical components, electrical components and control system. Typically, there is no single component that dominates the residual life of the machine - the whole-of-life issues need to be considered for each component.

Some of the major components for materials handling machines are presented in Appendix A.

2.3 ISSUES

The issues for each component need to be listed. Issues can be categorised into five areas:

- Physical condition
- Design integrity
- Operational performance
- Human factors
- Obsolescence

It has been found that a facilitated workshop using a narrative approach is a useful way of gathering historical evidence of past issues and events. Refer to Appendices B and C for a discussion of risk assessments and facilitated workshops.

Figure 1 presents an excerpt from the detailed issues register.

Detailed Issues Register - Long Travel System

Job No.:
Revision:

Client:
Project:
Description: Long Travel System
File:

Designed:
Date:
Checked:
Date:-

Upgrade Item *Long Travel System*

Requirements *The client would like a safe, fully compliant, easily maintanable long travel system which meets all operational requirements. Ideally the system design should be considered best practice, with sufficient redundancy in the system. Additionally, commonality of parts across sites is desirable for spares and confidence in design.*

SUMMARY SUB-ITEM	SUMMARY SUB-ITEM	CURRENT ISSUES	MEASUREMENT CRITERIA	REFERENCE DOCUMENTS	MOST LIKELY FAILURE MODE	CURRENT LEVEL OF RISK	CURRENT RISK CONTROLS	IMMEDIATE RECOMMENDED ACTIONS	ESTIMATED COST	RECOMMENDED ACTIONS FOR ACCEPTABLE RISK
LT 1	General - Physical Condition		Best Practice							
LT 2	General - Design Integrity		AS4324 AS1418 AS4100/AS3990 Best Practice							
LT 3	General - Operational Performance		Best Practice							
LT 4	General - Human Factors		Best Practice							
LT 5	General - Obsolescence		Best Practice							

Figure 1 - Excerpt from detailed issues register

The following table describes each of the columns in the inspection spreadsheet.

Column	Name	Descriptions
A	Summary sub-item ID	ID for the sub-item being reviewed
B	Summary sub-item	Title for the sub-item being reviewed
C	Current issues	Describes the current issues
D	Measurement criteria	Lists the measurement criteria required for this sub-item. This can be a design standard, statutory regulation, best practice.
E	Reference documents	List the reports or documents that back-up the issues listed previously
F	Most likely failure mode	List the most likely failure mode for this sub-item
G	Current level of risk	List the current level of risk. Guidance of assessing the level of risk for structural integrity issues is presented in Part 3 of these guidelines
H	Current risk controls	List the current risk controls that are in place, eg, inspections.
I	Immediate recommended actions	List any actions that may be required soon. Typically these are actions that require further information or data.
J	Estimated cost	This is an estimate of cost for the immediate recommended actions.
K	Recommended actions for acceptable level of risk	List the actions that are required to ensure that this component is operating at an acceptable level of risk.

2.4 SCOPE OF WORK

The next phase looks at various scenarios. Each scenario is list as a scope of work. Possible scenarios can include:

- Refurbishment of components on-site
- Refurbishment of components off-site
- Replacement of components

Generally, a complete scenario would include a combination of each of the options for different components.

It is very important that the different actions reflect a similar level of residual risk. It would be unfair to compare scenarios with different risk profiles.

2.5 ESTIMATE OF COSTS

The next phase is to prepare an estimate of cost for each scenario. Estimated costs should include:

- Procurement items
- Fabricated steelwork including delivery to site
- Concrete supply and repairs
- Site installation
- Site removal or disposal
- Contractors construction equipment, eg, cranes, scaffolding
- Contractors margin for set-up, insurance, site overheads, profit
- Engineering design
- Owners cost
- Contingency for unknown scope

If applicable, the outage cost needs to be considered.

The cost estimates for these concept solutions (or scenarios) are developed using @Risk (a Monte-Carlo Simulation program) and are presented as a probability range. Figure 2 presents an example: Final costs for each scenario are presented as a minimum, maximum and mean. The estimated cost and "estimated uncertainty" can be compared for each scenario.

As "better" cost data becomes available, the uncertainty will be reduced. As well, some scenarios can be seen to be not viable and further effort is not required to investigate these options. For example, from Figure 2, Scenario A – *Replace all required items* is obviously not viable. The minimum cost for this option is still significantly higher than the maximum cost for Scenario D – *Refurbish all items*.

Appendix D presents some guidelines on indicative rates to help produce an estimate with an accuracy of ±30%. These guidelines should be sufficient to produce a "first-pass" estimate".

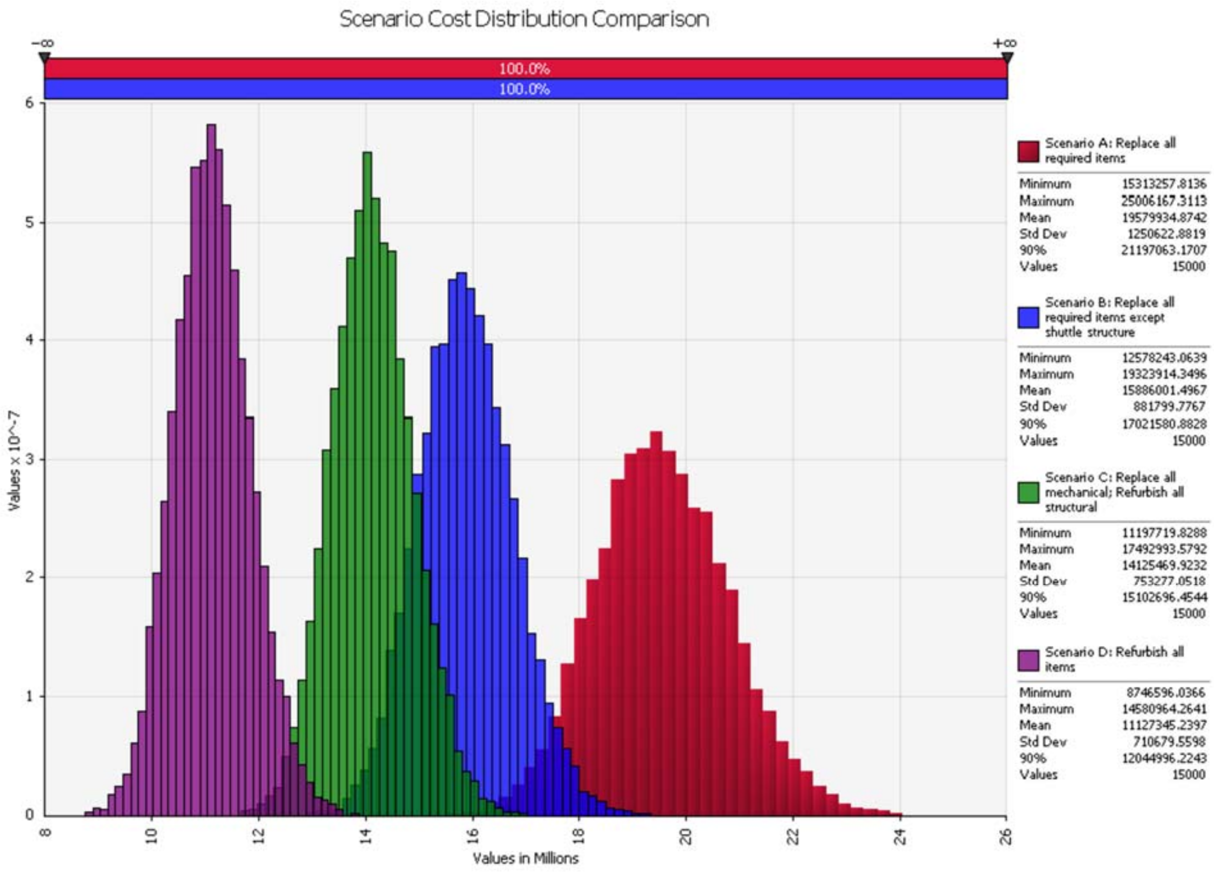


Figure 2 - Example cost estimate for different scenarios

2.6 LIFE CYCLE COSTS

The costs associated with the machine over its total life can be added together to represent a total of “whole of life” cost. Estimates of timing can be added to the previous cost estimates. Different options can include:

- Immediate replacement (generally takes about 3 years from start of justification to delivery of new machine).
- Minor refurbishment and replacement in the near future (about 5 to 8 years)
- Major refurbishment and replacement in about 10 to 15 years
- Total refurbishment to as-new condition
- Progressive refurbishment. A number of smaller outages rather than one or tow large outages.

The key parameters for using whole life costing include

- Life span of the asset: These can vary depending on the type of asset but is typically 25 years for a material handling facility or mine.
- Replacement costs: These costs include design, construction and commissioning costs.

- Operating and maintenance costs: Two main methods are available to help predict maintenance costs. These are the use of historical databases and the use of deterioration models.
- Outage cost: Outage costs can vary from zero (machine outage has no appreciable effect on production, cost of handling the material to the cost of the sale price of the material.
- Renewal and upgrading of the asset.
- Disposal of the asset.

Appendix A

Issues Register Examples

Appendix B

Risk Identification and Analysis Tools

RISK IDENTIFICATION AND ANALYSIS TOOLS

Quite a number of risk identification and risk analysis tools and techniques exist. These are summarised in Table 4-1 and each is linked to the step within the risk management process model where they are of primary use importance. A brief description of each then follows.

Technique	Step 1 Identificatio n	Step 2 Quantificatio n	Step 3 Evaluation	Step 4 Control
HAZAN	yes	yes	yes	yes
Statistics	yes	in part	yes	yes
Checklists	yes	in part	in part	in part
Risk Audits	yes		yes	yes
HAZOP	yes			
FMECA	yes			
Historical Frequency		yes		
FTA		yes		
CCF Analysis		yes		
HRA		yes		
EEA		yes		
Cause-Consequence Analysis		yes		
ETA		yes		
Hazard Indicies	yes	yes	yes	in part
FREM	in part	yes	yes	in part
CBA	in part	yes	yes	yes

Table A-1 Risk Identification and Analysis Tools and Techniques

HAZARD AND RISK ANALYSIS - HAZAN

Hazard and Risk Analysis (HAZAN) has been used as a formal technical tool within risk analysis since the 1970's. The term has also become a loose umbrella statement under which all other quantitative risk analysis techniques have tended to cluster. With the passage of time Hazard and Risk Analysis has tended to be used synonymously with the term Quantified Risk Analysis.

The overall objective of HAZAN is to ensure that any given system is adequately designed to meet defined standards of safety, reliability and durability when operated under the necessary conditions to produce the specified grade of output at the designed output rate and efficiency. HAZAN is concerned with risk, safety, reliability, maintainability, availability, quality and yield – as such HAZAN is concerned with achieving overall systems effectiveness across all domains.

The process is the same as that already indicated and entails hazard identification, probability estimation, consequence evaluation, risk evaluation and result presentation.

STATISTICS

Statistical data is central to all steps within the risk management process model. This data can be quantitative or qualitative and is drawn from any domains. Normally risk identification statistics are obtained from past incident records at the workplace, company, industry or global level.

CHECKLISTS

Checklists become a simple front line tool for risk assessment. They guide those most familiar with the workplace, process or system to critically identify possible risks and their likely consequences. Well constructed they can specify minimum acceptable levels of hazard assessment required in a specific situation.

Constructing a good checklist is not an easy task: it depends on the practitioner's experience of the author. Most checklists merely reflect a 'yes-no' related to compliance with standard procedures. They are excellent for staff reviews and for inspection and evaluation processes. However, unless they are mature checklists they universally fail to provide any indication of the relative importance of the various factors being evaluated.

All checklists should be regularly audited and updated and consideration should be given to insist on establishing a clear audit establishing confirmation of review and update prior to issuing.

RISK AUDITS

An increasing use is being made of various risk audits identify and assess major risk contributions. A risk audit provides a firm basis for workplace risk assessment and control and for development of a risk inventory. Included in such audits are safety audits and reviews which are closely linked. Such audits and reviews can range from frequent visual checks of workplace conditions and environment [emphasising housekeeping issues] through to full blown formal audits by teams of qualified risk, safety and/or quality auditors.

Typically such audits focus on identifying and evaluating major hazards, effectiveness of protective systems, operator performance, maintenance performance and management and culture issues.

HAZARD AND OPERABILITY STUDY - HAZOP

Hazard and Operability Study (HAZOP) entails systematic identification of hazards within processing plants. HAZOP originated within and was applied to chemical plant and extended to storage shipping, distribution and services facilities. Increasing its methods are being adapted and applied in other situations because of its systematic and detailed ‘What If?’ approach to hazard identification and assessment.

In its most powerful mode HAZOP requires an experienced '‘expert’ team lead by a facilitator through the plant or process using specific guide words. Of course such methods can be adapted to front lien use where the experienced experts become the front-line workteam[s] and the facilitator realising the mandate requirements of guiding Terms of Reference.

FAILURE MODES EFFECT AND CRITICALITY - FMECA

Failure Modes Effect and Criticality Analysis (FMECA) is really a combination of two specific quantitative tools namely the Failure Modes Effect Analysis [FMEA] and the Failure Modes Criticality Analysis (FMCA). These analyses involve determining the ways in which failure can occur and the effect of each on the function of the component, assembly and/or system (FMEA). When applied to risk assessment the failure mode effect analysis identifies the consequential ‘incident’ or ‘accident’ likely to result from each specific failure mode and its criticality (FMCA). Although strategically best applied in the early design stages for most economic intervention to eliminate potential sources of risk FMECA are applied during selection appraisal, installation, commissioning and in-service operation.

Probability is attached to each of the failure modes and rankings applied to the criticality of consequences.

HISTORICAL FREQUENCY

Risk analysis depends heavily on the frequency of incidents as reflected in historical records. Incident frequency information is simply obtained from the number of ‘incidents’ recorded within the required exposure period. As historical records are the source of such data and these records may be internal or external to the organisation, directly or indirectly linked to the system being analysed as structured methodology is used. This methodology comprises: define the purpose of the analysis; review the source data for relevance, completeness and independence; check for applicability; calculate the event likelihood; and validate the frequency.

FAULT TREE ANALYSIS - FTA

Fault Tree Analysis (FTA) places the hazardous undesired incident at the top of a tree comprising all the matters and/or incidents that must conspire to bring about that undesired incident. The structure within the tree reflects a logic hierarchy of any chain development of incidents required to trigger the undesired incident. Because of this logic hierarchy there is a basic time sequence running up through the tree to the top incident. Each incident can be represented by a probability of occurrence. Two commonly used representations are number of incidents per million hours or number of incidents per annum.

COMMON CAUSE FAILURE (CCF) ANALYSIS

Some systems, particularly redundant type systems, can be compromised by a single incident which causes a ‘chain failure’ of multiple components throughout the system. One common cause of such incidents is a ‘line to chassis’ fault in electronic circuitry. The consequential failed items become dependent events on the original incident and their failures are identified as common cause failures in Common Cause Failure (CCF) Analysis.

HUMAN RELIABILITY ANALYSIS - HRA

In Human Reliability Analysis (HRA) priority is placed on quantifying the contribution of human error to the incidents represented in both FTA and ETA. Human error becomes a significant ingredient in risk analysis and occurs when there is a missing, or inappropriate, response to a stimulus resulting in an accident. Conceptually all human error is potentially eliminable and therefore a worthy target for serious risk analysis.

HRA endeavours to identify the conditions that cause humans not to respond or to respond inappropriately to a recognisable stimulus and the probability that this will occur in practice. Units of measure of human error are normally expressed as ratios of actual number of errors to the number of opportunities for error to occur (probability) or of actual number of errors to the total task duration (rate) As such HRA provides a human element analysis complement to the equipment element analyses provided by both HAZOP and FMECA.

EXTERNAL EVENTS ANALYSIS - EEA

Externalities can trigger incidents or accidents and initiate series of common cause failures (CCF) and disaster incidents. Some of the ore obvious externalities are storm and tempest, natural disasters, sabotage, explosions, fire and acts of war. External Events Analysis (EEA) attempts to define these risks, probabilities of occurrence and severity. As a suite of techniques CCF, HRA and EEA can be used to support both fault tree analyses and event tree analyses.

CAUSE-CONSEQUENCE ANALYSIS

Cause-Consequence analysis combines both FTA and ETA to evaluate both cause and consequences of an incident and their interrelationships. Refer to descriptions of FTA and ETA for descriptions of each element within Cause-Consequence Analysis. The linking incident is normally taken as being that point within the time sequence model where control of the potentially damaging energy is lost.

EVENT TREE ANALYSIS - ETA

Event Tree Analysis (ETA) is a technique similar to FTA except that it focuses on what happens after an event/incident occurs. ETA identifies alternative outcomes or chains of outcomes that could be triggered by a causative event. The method of construction start with identifying the initiating event and estimating its frequency of occurrence (either from historical data or from the output of a FTA), listing all factors that could influence or affect the consequential outcomes flowing from the initiating event; identifying any risk reducing or risk increasing factors that may exist; and constructing the event tree diagram.

HAZARD INDICES

Relative ranking of the risks confronting an enterprise is important in establishing risk management priorities. Hazard Indices are used to this effect. The basic method assigns penalties to any aspect of operations that can contribute to a risk incident and credits to aspects that cab measurable nullify the consequences of a risk incident. The penalties and credits, in combination, allow creation of an index giving the relative ranking for each risk encountered.

Dependent on the risk areas of concern emphasis can be placed on specific type risks such as fire and explosion risks in chemical plants, break-in and hold-up risks in banking premises, safety risks in production workplaces and so on. Risks with high hazard indices can be evaluated for consequences in terms of cost, outcomes and priority of investment for risk minimisation.

FIR RISK EVALUATION MODEL - FREM

Specific risk analysis tools have been developed to assist in the management of fire risks. Fire Risk Evaluation Model (FREM) is a computer based model that expresses fire factors in numerical terms. Numeric values can be allocated to represent fire risk factors such as fire load, combustibility, structural barriers and incident responsiveness at both the site and fire service levels.

COST-BENEFIT ANALYSIS - CBA

Cost-Benefit Analysis (CBA) is increasingly being used in the risk management domain to present the real total costs (both quantifiable and non-quantifiable) of specific risk incidents and the economic benefits of investment in risk management alternatives. This is because many investments in risk reduction systems, if they are effective and actually prevent the risks from occurring, appear to entail significant investment to prevent something that has not happened. As such, these investments become vulnerable to cost cutting exercises when more urgent demands are placed on limited financial resources.

Appendix C

Facilitated Workshops

FACILITATED WORKSHOPS

Facilitated Workshops are a key tool in identifying hazards and analysing risks within an organisation, project or facility. The objective is for an expert group to meet and "tease out" hazards, issues and risks for a particular facility or aspect of an operation. Actions to address these risks are also identified in the workshop. Facilitated workshops could be carried out during the design phase for new assets right through to examining operational aspects of a facility or piece of equipment, which has been in service for many years.

It is most desirable to involve a cross section of people from the clients organisation in facilitated workshops, not only for their expertise in the particular process or operation, but also to build their awareness of risks and issues identified during the workshops which promotes ownership of the recommended actions.

This chapter describes the application, tools and processes for the following types of facilitated workshops.

- Vulnerability Assessment
- HAZard and OPerability Study (HAZOP) for non-fluid systems
- Design Reviews
- Workplace Health and Safety Obligations
- Development of Recovery Plans.

A key feature of the methodology is to record the workshops "live" using the Facilitated Workshop Module of REMUS.

VULNERABILITY ASSESSMENT

Vulnerability Analysis using logic trees is a useful tool for a detailed risk assessment and is particularly applicable to structural assets such as cranes, stackers, reclaimers, shiploaders, bins and wharves. Often with these types of assets there are a large number of potential events or combinations of events which could cause partial or total collapse or failure.

Study of failures has categorised the basic failure categories as:

- Deterioration
- Operational Factors
- Extreme Events
- Access, Ergonomic and Human Factors

The failure events are refined using a logic tree diagram until a basic failure scenario is determined. Generic logic trees can be developed for particular types of assets, based on experience with historical failure events, by experience of the team and by consideration of typical layouts and geometry.

Once potential hazards are identified and listed, assessment of likelihood, consequence and risk is carried out using the process described in Section 4.5 as per AS4360.1999. Controls may be developed directly from this risk assessment or further more detailed risk analysis carried out to refine controls for complex systems.

The advantage of the Vulnerability Assessment process is that it captures previous experience from design standards, study of failures, and conduct of previous studies in generic logic trees specific to the equipment or asset type being considered. The process still allows for lateral thinking amongst the group for events not included on the trees so does not have the same inherent restrictions as a checklist type approach. In this way the Vulnerability Assessment requires less time than approaches such as HAZOP where hazards are generally developed by considering the fundamental energy types acting on the system. The limitation is that this type of approach can only be used for equipment or facilities where prior knowledge exists and there is sufficient experience and information available to build logic trees.

HAZARD AND OPERABILITY STUDY (HAZOP)

A HAZOP is a detailed and systematic examination of a process and/or design to consider the potential hazards of the process and operability aspects of the design. HAZOP originated in and was originally applied to chemical plants but has been extended to cover non-fluid systems. This manual considers the use of HAZOP for no-fluid systems only.

HAZOP involves identifying hazards by identifying the energy required to do work in the system and the potential for unwanted energy releases from various sources.

- A series of guidewords are used to prompt discussion
- Discrete parts of the system are identified and considered
- Overview guidewords are then used to consider issues which relate t the whole process

For each guideword, the following questions should be asked:

- Can it happen?
- If so how?
- Is it going to be a problem?
- What are we going to do to address it?

HAZOP takes the design as a given, unresolved issues should be minuted for resolution outside of the workshop. The HAZOP should be abandoned if too many major changes are being recommended.

DESIGN REVIEWS

Design Reviews can be carried out at different stages during the design process. Some of the factors, which should be considered, include:

- Appropriateness of design criteria
- Extent of checking required/carried out
- Interfaces between disciplines
- Interfaces between suppliers
- Physical Interfaces
- Durability of materials
- Maintenance
- Constructability

- Access

Design reviews can be carried out as planning tools to pre-plan activities and sequences of activities to be carried out. Another type of design review is carried out once the design and drawings are largely completed. prior to sign off the drawings. The objects of such a review is for a diverse group to critically examine the design from several viewpoints to ensure that the design criteria ate satisfied, to ensure that the checking process have been adequately carried out and the question the inherent assumptions underlying the design loadings and structural behaviour.

WORKPLACE HEALTH AND SAFETY REVIEWS

Workplace health and safety legislation has specific requirements for designers, owners and operators of plant and equipment. A facilitated workshop is a good environment in order to critically examine and assess a new design or existing facility for compliance with Workplace Health and Safety Requirements.

PLANNING A FACILITATED WORKSHOP

The effectiveness of a facilitated workshop will largely be determined on how well it is planned and scoped as well as who participates in the workshop. The venue and facilities for the facilitated workshop also need to be considered.

Prior to undertaking the workshop, available information needs to be sourced and summarised so that it is accessible during the workshop phase. Inspections of the site may also be carried out in conjunction with the workshop.

Detailed risk studies normally include a workshop with the client's management, operations and maintenance staff as well as with design engineers from OEM and consultants familiar with the assets. A facilitator and recorder are also required. Experts in particular aspects may also be invited to all or part of the workshops.

The venue should be a well lit and laid out conference room. For larger workshops the tables should be laid out in a "U" pattern so that the facilitator can maintain control. Data projector facilities and chart paper should be provided.

It is important that participants in the workshop be taken "off line" so that they are not disturbed during the course of the workshop. A risk workshop requires a lot of concentration, hence breaks are recommended at 1½ hour intervals.

A typical agenda would include the following:

➢ Introduction and overview of the process.	Facilitator
➢ Description of facilities and assets to be considered in workshop.	Site Engineer
➢ Recap on failures and disasters.	Experts
➢ Site inspection	All
➢ Hazard Identification and Risk Assessment	All
➢ Consolidate controls and actions	Experts
➢ Presentation of results	

In order to promote lateral thinking in the risk workshop it is useful to present examples of failures and disasters, which have occurred on similar facilities.

Following the workshop a formal report should be prepared. This should include an executive summary of the main risks and actions identified together with appendices containing the detailed risk assessment records.

The value of a risk study is in the effectiveness of the actions and controls identified. This should be done in a systematic manner with redundancy and diversity. Where possible the control actions should be categorised into a small number (3-4) of mutually exclusive categories.

Appendix D

Guidelines for Estimating

GUIDELINES FOR ESTIMATING

This appendix provides some guidelines and “rules of thumb” for preparing estimates that are typically accurate to ±30%. Values are presented as the mean rate and the uncertainty. These two values can be used in programs such as @Risk which perform Monte-Carlo type simulations.

DIRECT COSTS

Direct costs include materials, site installation and removal and cost of construction equipment

Cost of steelwork – fabricated painted and delivered to site

Description	Mean rate	Uncertainty (98% confidence)
Light steel (0-30 kg/m)	$8,220/tonne	±10%
Medium (30-60 kg/m)	$7,120/tonne	±10%
Heavy steel (>60 kg/m)	$6,050/tonne	±10%
Heavy WB and WC sections	$5,810/tonne	±10%
CHS (0-20 kg/m)	$6,580/tonne	±10%
CHS (>20 kg/m)	$5,430/tonne	±10%

Cost of site installation (structural steelwork)

Description	Mean rate	Uncertainty (98% confidence)
Normal installation for “green-field” work	45 hours/tonne	±30%
Normal installation for “brown-field” work	90 hours/tonne	±30%
Difficult installation for “brown-field” work	180 hours/tonne	±30%
Rate for installation	$120/hour	±30%
Touch-up blast and paint	$2,000/tonne	±30%

Cost of site installation (mechanical/electrical items)

Description	Mean rate	Uncertainty (98% confidence)
Normal installation	45 hours/tonne	±30%
Difficult installation	90 hours/tonne	±30%

Cost of site removal (structural/mechanical/electrical items)

Description	Mean rate	Uncertainty (98% confidence)
Normal installation	10 hours/tonne	±30%
Difficult installation	20 hours/tonne	±30%

Cost of concrete repairs

Description	Mean rate	Uncertainty (98% confidence)
Concrete repair per area	$10,000/m^2$	±30%
Concrete repair per volume	$5,000/m^3$	±30%

Contractors construction equipment

Description	Mean rate	Uncertainty (98% confidence)
Crane utilisation (percentage of time that the crane is required per man-hour)	33%	±50%
50 tonne crane	$160/hour	±10%
150 tonne crane	$500/hour	±10%
250 tonne crane	$1,000/hour	±30%
Scissor lift utilisation (percentage of time that the crane is required per man-hour)	33%	±50%
Scissor lift	$250/hour	±50%
Scaffolding installation	1.5 hours/m^3	±50%
Scaffolding long-term hire	$45/m^3	±50%
Scaffolding short-term hire	$20/m^3	±50%

INDIRECT COSTS

Indirect costs include contractors margin, engineering design, owners costs and contingency for unknown scope.

Contractors margin

Description	Mean rate	Uncertainty (98% confidence)
Contractors margin includes site establishment costs, insurance, site overheads and profit	30% of direct costs	±20%

Engineering costs – engineering costs can be calculated as a percentage of direct costs + contractors margin, price per drawing or cost per hour of engineering design

Description	Mean rate	Uncertainty (98% confidence)
Minor engineering design	5% of direct cost + contractors margin	±30%
Via owner	15% of direct cost + contractors margin	±30%
Via EPCM	20% of direct cost + contractors margin	±30%
Cost per drawing	$8,000 per drawing	±30%
Rate per hour	$200 per hour	±30%

Owners costs

Description	Mean rate	Uncertainty (98% confidence)
Owners cost	10% of direct cost + contractors margin	±30%

Contingency for unknown scope

Description	Mean rate	Uncertainty (98% confidence)
Contingency for unknown scope		±30%

MAINTENANCE COSTS

Maintenance costs for materials handling machines

Description	Rate
Maintenance costs given as cost per material throughput	\$0.03 to \$0.07 per tonne

REPLACEMENT COSTS

Replacement cost for new materials handling machines

Description	Mean rate not including indirect costs	Uncertainty (98% confidence)
Replacement cost	\$35,000/tonne	±20%

Typical weights for materials handling machines

Description	Nominal throughput (tonne/hr)	Boom conveyor length (m)	Weight (tonnes)
Bucket-wheel reclaimer	5,400	60	1,250
Stacker reclaimer	8,000	60	1,500
Bridge reclaimer	4,500	50	520
Bridge reclaimer	1,100	45	245
A-frame reclaimer	2,700	28	330
Stacker	2,400	40	300
Stacker	8,000	45	480
Stacker	3,300	35	120
Radial stacker	2,200	55	135
Shiploader	6,000	50	600

Description	Nominal throughput (tonne/hr)	Boom conveyor length (m)	Weight (tonnes)
Bridge-style shiploader	10,500		1,300

Typical weights for coal preparation plant

Description	Nominal throughput (tonne/annum)	Weight (tonnes)	Cost
Coal preparation plant	10.5M	1,230	$200M

Typical weights for conveyor gantries (valid for gantry span >12m and < 18m and belt width >900mm and <2000mm)

Weight (in tonnes) = -6.6 + 3.6 x Belt width (in m) – 0.5 x Gantry span (in m)

Typical weights for conveyor trestles (valid for belt width >1000mm and <2000mm)

Height of trestle	Weight
5m	0.5 tonnes
9m	0.9 tonnes
13.5m	1.7 tonnes
18m	2.5 tonnes
22.5m	3.9 tonnes

Appendix E

Life Cycle Costing

LIFE CYCLE COSTING

This section aims to provide an introduction to Life Cycle Costing (LCC). The increasing popularity of this methodology is evidenced by the publication of the Australian Standard AS/NZS 4536:1999 - Life Cycle Costing.

Life cycle costing can be defined as a methodology to compare competing alternatives for capital that uses accepted accounting procedures for determining the total cost of ownership over the useful lifespan. In concept, all of the costs for each different alternative are accounted for over the life of the asset. A discount rate is then applied to the total estimated costs for the years of service for each alternative to arrive at a Net Present Value (NPV). This NPV represents the value today of all the costs during the life cycle of the assets.

In undertaking a LCC analysis the following questions usually arise:

- What analysis approach should be used
- What is a realistic discount rate for use in the analysis
- How are the effects of inflation and increases in individual costs to be accounted for
- Over what specific period of time are the total costs of ownership to be determined
- When is the time period of the analysis to begin
- What types of costs are to be included in the analysis and what costs may be ignored

The analysis approach or evaluation technique most commonly adopted for LCC is the discounted cash flow (DCF) methodology incorporating the net present value (NPV). The discounted cash flow method of appraisal is superior to all others as it considers the timing of cash flows and explicitly takes into account risk through the discount rate.

Future costs (*NPV*) can be normalised to present day costs using the following formula:

$$NPV = \frac{C}{(1+r)^t}$$

C	cost at current prices.
r	discount rate. This is a combination of the cost of borrowing money and anticipated inflation.
t	time in years to when the cost is incurred.

The key parameters for using whole life costing include:

Life span of the asset. These can vary depending on the type of asset but is typically 25 years for a material handling facility or mine, 50 years for a building and may be up to 100 years for bridges.

Initial costs. These costs include design, construction and commissioning costs.

Operating and maintenance costs. Two main methods are available to help predict maintenance costs. These are the use of historical databases and the use of deterioration models.

Loss of revenue. The loss of revenue attributed to maintenance is generally bourn directly by the owner. However for roads, the user suffers delays and the costs are not carried by the owners.

Demolition cost: These costs may be significant in the case of heavily contaminated sites.

Importantly when two or alternatives are compared using the same basis, the NPV can be used as a direct comparison of the cost of each. That is, mutually exclusive options with the same economic life can be ranked by the analysis in terms of their NPV's. If the economic lives of the options are different then a variation of the approach is required which will not be discussed in this book.

Consider an example of the application of the above formula. We are looking at the capital and operating costs of a new dozer over 5 years. The discount factors can be obtained from any financial text or from your "friendly accountant". Standard software such as Microsoft Excel also has the NPV functions which can be used for these exercises.

Capital cost	$1,250,000
Operating cost per year	$171,000
Discount rate	12%

Item	**Cost ($M)**	**Discount Factor**	**Discounted Cash Flows ($M)**
Year 0	1.250	1.000	1.250
Year 1	0.171	0.893	0.153
Year 2	0.171	0.797	0.136
Year 3	0.171	0.712	0.122
Year 4	0.171	0.636	0.109
Year 5	0.171	0.567	0.097
Net Present Cost			**1.867**

The NPC is simply the initial capital cost plus the sum of the discounted yearly operating costs. From this simple example it can be seen how easy it is to apply this technique to compare alternative proposals for the dozer.

DISCOUNT RATE AND INFLATION

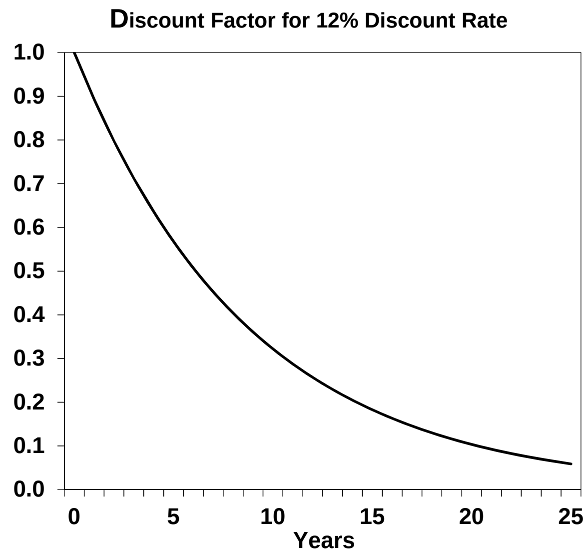
The rate used for the analysis will be established by the company and is usually the Weighted Average Cost of Capital (WACC). In some cases this figure will be adjusted for specific risks such as use of unproven technology, project in a high risk country, etc. The discount rate or WACC reflects the cost of funds which in turn reflects risk. Specifically, it incorporates the cost of debt, the cost of equity, and the risk to the equity and debt holders - in other words the cost of capital relates to the risk of the assets or group of assets.

It is important to note that there are two main discount rates that are commonly used in a DCF analysis - a real discount rate and a nominal discount rate. The nominal discount rate is probably used more often and it includes an allowance for inflation whilst the real discount rate excludes any allowance for inflation. It is important in the analysis that the cash flow figures used are consistent with the discount rate, that is, you must use real cash or cost flow figures when using the real discount rate.

EVALUATION PERIOD AND TIMING OF CASHFLOWS

The evaluation period for the analysis will depend on the expected economic life of the asset being considered, the useful life of the asset, rate of technological change, the product life cycle or the life of the business. Generally the period should be the expected economic life of the asset under current technology, as this is probably the shortest period and therefore the most conservative. The aim is to avoid selecting an inappropriate period that may underestimate the total costs.

As the analysis is based on the time value of money it can be seen that from the graph below that the effect of values beyond 25 years become insignificant in terms of size and the effect on the analysis. Also the quality of cost estimates will always be dubious in the absence of long term contracts and it is recommended that an analysis period of greater than 25 years is not warranted for most cases.



AS/NZS 4536:1999 provides a detailed breakdown of the type of cost elements in each of the above as well as recognised techniques to estimate costs. Standard proforma sheets are also provided in the Standard to facilitate the collation of cost data and the LCC.

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