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Towards an Assessment Tool for Strategic Management of Asset Criticality

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ABSTRACT

Many organisations in both the private and public sectors rely on engineering assets to provide products and services. The failure of these assets, or their components, can have undesirable consequences for the organization. Failure consequences can be measured in terms of their impact on the safety of personnel, the public and the environment, and on their impact on desired levels of service or output. Existing decision tools for determining the criticality of asset failure are typically rigorous and detailed. They are necessarily time consuming methodologies. A strategic management approach seeks to focus the effort and cost of such detailed analysis more appropriately. It recognises the value of the expert knowledge of those directly engaged in operations and maintenance functions in supporting a strategic approach to the assessment of asset criticality. The purpose of such a tool is to quickly and effectively identify critical assets within a facility to assist strategic decision making. The assessment tool being trialled is to support the Maintenance function of organisations and therefore it is focussed on the Operations and Maintenance phase of the asset life cycle. This paper presents an overview of the alternative methodology being trialled and some examples of its practical application.

INTRODUCTION

Expert knowledge based assessments of asset criticality are necessarily qualitative. They are best supported by a systematic and standardized methodology that underpins qualitative rigor and enables assessment to be open to external audit. This paper (a) explores the concept of asset criticality, (b) describes the systematic approach to qualitative assessment that is being piloted, (c) outlines the results of the pilot study series completed and (d) draws some conclusions and makes some suggestions about future steps in the further development of expert knowledge based assessment tools of asset criticality.

THE CONCEPT OF ASSET CRITICALITY

Asset criticality can be determined asset by asset as part of a complete quantitative diagnosis of current state of the asset, its potential for future failure and the consequences of such failure. It may also be assessed in order to choose or sort assets into a priority list. The consideration of asset criticality in this paper is in the context of this latter, triage like, approach with a focus on prioritizing maintenance work to support asset operation and safety.

Asset intensive organisations rely on physical assets to produce products or services for end users or customers. The physical assets used by these organisations include industrial assets (plant and equipment) and infrastructure assets (drainage, water and sewer systems, bridges, roads, tunnels, and dams).

There are similar objectives identified for asset intensive organisations typified in statements by Rio Tinto [1] and Shell [2]:

- To operate profitably or economically
- To provide desired or agreed levels of service
- To operate safely in terms of consumers, the public and employees
- To operate safely with regard to the environment.

Asset performance in asset intensive organisations directly impacts on the ability of the organisation to meet objectives. The loss of asset capability through degradation or failure can impact significantly on the degree to which an organisation is able to meet their objectives. The Maintenance Engineering Society of Australia's Capability Assurance Model [3] draws a direct relationship between asset capability (function) and the achievement of organisational objectives. Kelly [4] describes the loss of asset function affecting the production and safety performance of a facility.

Asset criticality is defined in literature in different forms. Moteff and Parfomak [5] draw on numerous US sources to identify critical assets as those assets whose 'incapacity or destruction would pose a threat to security, national economic security, or public health or safety'. This definition is a more general view of asset criticality and less focussed on the physical failure of assets, rather a loss of asset function by any means.

An operations and maintenance view of critical assets is defined in the International Infrastructure Management Manual [6] as:

Assets for which the financial, business or service level consequences of failure are sufficiently severe to justify proactive inspection and rehabilitation.

This definition of critical assets is focussed specifically on decisions surrounding preventive maintenance actions arising from perceived modes of asset failure.

There are potentially many possible viewpoints of asset criticality. Examples of these viewpoints derive from the lifecycle phase of the asset [7] and organisational function that perceives asset criticality [8]. Models that describe asset criticality from all possible perspectives could be complex. The scope of the assessment in this paper is concerned with a perspective of the Operations and Maintenance phase of the asset life cycle and a view from the perspective of the Maintenance function of the organisation.

For the purpose of the initial study, the following definition of asset criticality is proposed:

A relative measure of the impact of the loss of asset function on the objectives of the organisation from the viewpoint of operations and maintenance.

This definition allows for asset criticality to be modified according to local business rules. A range of vulnerabilities is possible within the scope of the definition. This is considered to be a working definition. It is expected that this definition will be refined with experience of assessing criticality and feedback from industrial facilities.

CURRENT METHODS FOR IDENTIFYING CRITICAL ASSETS

There are few published methodologies for identifying critical assets. A search of current literature has identified frequent references to the need to identify critical assets, but little on a methodology for identifying critical assets [4, 5, 9, 10, 12].

International Standard IEC 60300-3-14 [9] advocates a preliminary 'Operation Use Study' as a precursor to developing maintenance policy. This study is to determine:

- items and systems that are important to meet process objectives
- items and systems that involve safety considerations
- operational patterns
- environmental conditions
- expected service life

There is no methodology or reference within the standard that describes how such a study might be performed or documented.

Kelly [10] describes a ‘Top-Down’ approach to identifying critical assets as a precursor to developing maintenance policy. The following steps to ranking critical assets are identified:

a) Construct a process flow diagram and establish a plant inventory
b) Understand the plant operating characteristics and the production policy
c) Rank units in order of their importance (criticality)

Kelly does not provide a methodology or reference that describes how such a study might be performed or documented.

There is evidence of asset criticality being based purely on failure consequence as used by Shell Brunei [11] to rank asset criticality. It is more common for a risk based analysis based on an assessment of asset failure consequence and probability [12] to be applied. Where failure probability is considered at component and failure mode level, as typified by Failure Modes and Affects Analysis (FMEA) [13], estimates of probability are valid. It is otherwise considered difficult to assess how probable a loss of asset function event is without a rigorous analysis of the way in which such a loss of function might occur.

Where an underlying principle is provided in support of the consequences of the loss of asset function, it is usual that criteria based assessment is applied. These criteria vary between approaches. A review of methods [8, 10, 9, and 11] identified the following criteria for assessing the consequences of loss of asset function:

- Repair costs
- Loss of income
- Loss of service
- Loss of life or injury
- Damage to property
- Failure to meet statutory requirements
- Third party losses
- Loss of image
- Location of asset
- Environmental Impact .

There are two distinct categories of criteria identified from this list. These are ‘mandatory’ criteria dealing with Safety, Environmental and Statutory requirements and ‘economic’ criteria dealing with loss of income, service or damage to property.

The method of ranking asset criticality within the criteria is also varied across the methods reviewed. This is summarised by Jay [8], who identifies three common approaches to ranking asset criticality:

- High, medium, low;
- Scoring (e.g. 1,2,3,4,5);
- Weighted scoring.

Jay regards weighted scoring as being a more discriminatory and favoured method.

There is not one single approach in the methods reviewed that is considered to meet the requirements of defining critical assets as defined in this paper. There is an opportunity to draw on the strengths of current methods to create an alternate methodology for identifying critical assets.

AN ALTERNATE METHOD FOR IDENTIFYING CRITICAL ASSETS

General Description

The aim of developing an alternate method for identifying critical assets was to draw on individual features of existing methods to create an approach to:

- Identify assets;
- Rank critical assets;
- Be easily applied and reproduced;
- Take an operations and maintenance perspective of critical assets.

The following elements of a methodology were developed:

Asset Identification – a means of identifying and representing assets for the purpose of criticality analysis.

Criteria – a list of factors against which asset criticality could be measured.

Weighted Scoring – a means of allocating scores to achieve a total score indicating asset criticality.

Scoring Guides – templates for the application of scoring against each of the identified criteria.

Application – a means of applying the scoring to the criteria within an organization.

These elements are explained in more detail in the following sections.

Asset Identification

Assets were identified visually and models prepared. Assets were clustered in groups according to logical units or process function. This satisfied the layout of the facility, and also assisted with segregating assets for analysis purposes, described in more detail in section 4.5. Asset identification is demonstrated in the block model of Figure 1. In this example assets are represented as blocks interconnected with lines representing logical process flows or operational or reliability relationships.

Initial modelling of assets was performed based on recognising logical groups of components with a clear input and output or a definable function. It was also considered important to clearly identify stockpile or storage areas, inputs and outputs to the assets and links to other systems within the scope of the assessment.

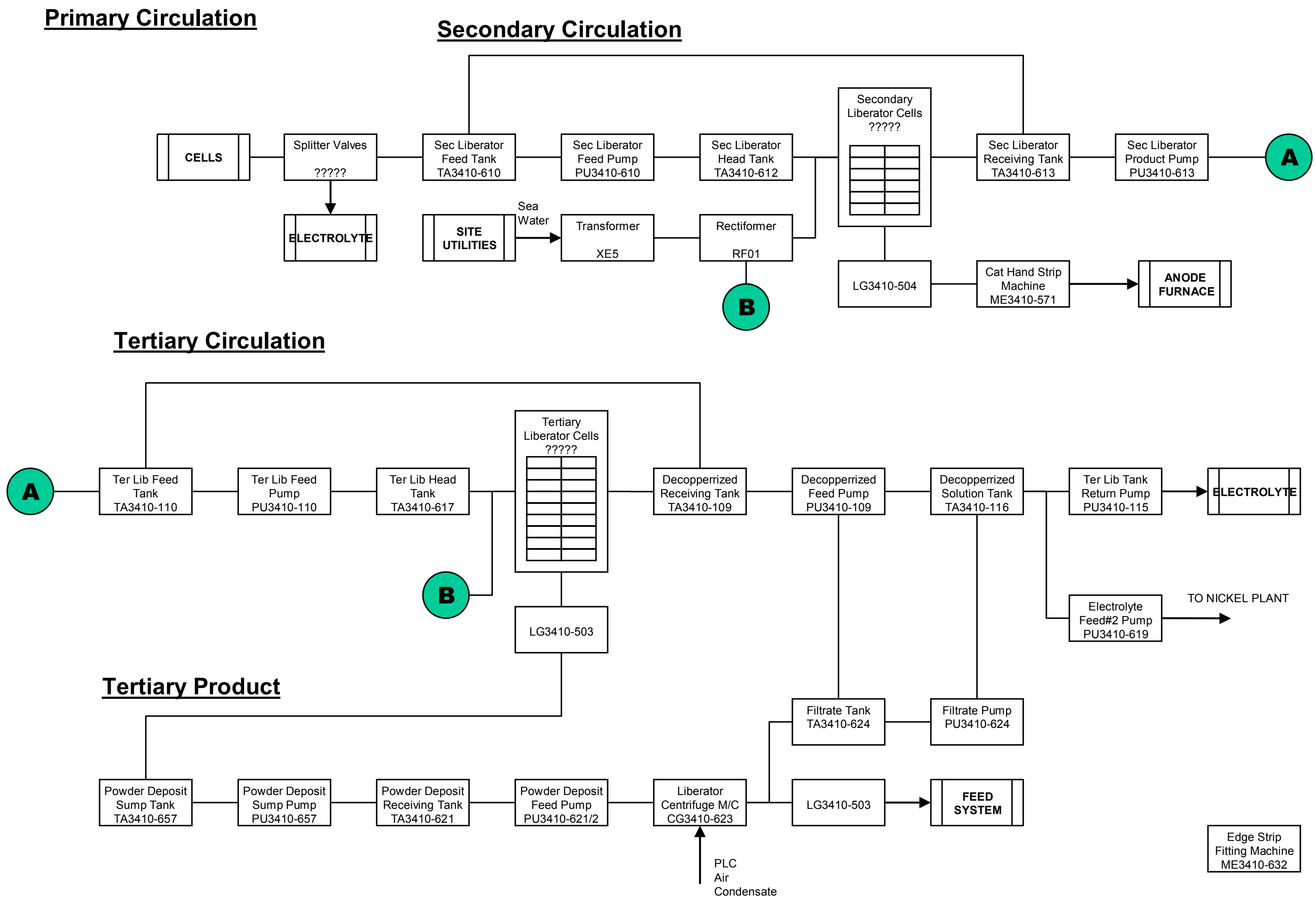

Figure 1- Asset Representation

Criteria

A criteria assessment using a weighted scoring method was selected for trial based on current methods. Initial criteria were based on the key business drivers of Health, Safety and Environment (HSE) and Output were readily identified from the function of maintenance. There was little logical basis for a ranking on two criteria. Additional criteria to assist in ranking based on probability were added to the criteria set. The criteria initially selected were:

Safety / Environment (mandatory) - the consequences of loss of asset function on the safety of personnel, the public, consumers or the environment.

Output (economic) - the consequences of loss of asset function on the loss of service levels, or the loss of revenue through termination of production, lost opportunity, loss of product or cost of reproduction or reparation.

Severity - the potential rate that the environment, process conditions or constituents can deteriorate assets.

Condition - the actual or assumed condition of the plant as determined by actual historical performance where possible.

Existing Maintenance - the actual or assumed quality of preventive maintenance actions carried out on the asset.

Complexity - the complexity of the asset according to the number of maintenance causing items that make up the asset.

A system of weighted numerical scoring was developed to indicate the degree of impact that each criteria had on the perceived criticality of each asset.

Weighted Scoring

An arbitrary scale of 1 to 10 for scoring and weighting was selected. It was assumed that a factor of more than 10 would be unnecessary to discriminate between critical assets, and that any less than 10 would be insufficient to achieve the desired spread of results.

Criteria weighting was varied to suit local business rules. This depended on the emphasis of the organisation (e.g. relative safety vs. process criticality) and the reliability of information used to conduct the assessment so that the results are not greatly influenced by information from unreliable or biased sources. Weighting was maintained separately to scoring so that results could be compared across facilities or sensitivity analysis performed.

Low scores indicate a less serious outcome within the criterion. A score of 1 indicated a low criticality against a criterion while a score of 10 indicated the highest. A weighting of 1 indicated the lowest importance of a criterion to the ranking, while a score of 10 represented the highest. Scores and weightings in between 1 and 10 indicate relative scales for comparison purposes.

The final ranking of the criticality of assets is determined by the total weighted score. The sum of each score multiplied by the criterion weighting for all criteria provided the total weighted score for a single asset. The magnitude of the total weighted score for the asset determined its overall ranking within the facility.

Scoring Guides

Scoring guides were developed to apply consistent application of scoring to the criteria. Although not covering every possible description of a criterion outcome the guides are intended to maintain a consistent scoring across a facility with regard to exposure and consequences.

Score	Description
1	No impact on environment or safety of personnel if failure occurs.
2	Nuisance impact on employees and no impact on environment if failure occurs e.g. noise, additional rectification required.
3	Nuisance impact on employees and impact on environment recoverable at minimum cost.
4	Failure results in an obvious hazardous situation but contained by equipment. e.g. Oil spill within bunded area.
5	Failure results in obvious hazardous situation, but not contained by equipment. Hazard can be seen and avoided or approached with caution. e.g. Dust leak.
6	Failure results in hidden unsafe equipment or working environment (Hazard is not visible).
7	Serious hazard to individual employee or release of environmentally sensitive substance.
8	Potential fatality of individual employee or release of environmentally sensitive substance. e.g. Lifting device failure.
9	Serious hazard to multiple personnel or wide spread environmental impact. Hazard cannot be contained or controlled. e.g. Fire.
10	Potential for fatality of multiple personnel or widespread environmental consequences. e.g. Major Chlorine Gas Leak.

Table 1- Scoring Guide - Safety / Environmental Criterion

Score	Description
1	No affect on production within repair time
2	Reduction in production capacity short time frame (without affecting ability to meet orders).
3	Loss of equipment with some contingency and buffer storage
4	Loss of equipment with significant contingency and buffer storage.
5	Loss of equipment with 100% capacity backup.
6	Failure of equipment without sufficient back up to ensure that production requirements can be met. 25% loss of facility output or equivalent loss.
7	Significant impact on ability to meet customer order quantities. 50% loss of facility output or equivalent loss.
8	Significant impact on ability to meet customer orders for specific product with no backup. 75% loss of facility output or equivalent loss.
9	Significant impact on multiple equipment or process lines. Equivalent 75% loss of output of facility.
10	Stops entire output of facility. Contributes to long outages of facility. e.g. Loss of power.

Table 2- Scoring Guide - Output Criterion

Similar scoring guides were developed for the remaining four criteria. These scoring guides are omitted from this paper due to size consideration.

Application

The preliminary steps in the application of the criticality assets were performed by a facilitator with input of management stakeholders and the assistance of a facility representative. This included:

1. Identifying and documenting asset models;
2. Building an asset list;
3. Establishing the criteria;
4. Establishing and ratifying scoring guides;
5. Weighting criteria.

Once the preliminaries had been performed, the scoring was applied in a facilitated meeting by knowledge workers from the facility under analysis. The mix of individuals in the team was sometimes varied during the application; particularly on larger sites where broad expertise was not available within individuals.

Scores were applied to the criteria for each asset. A pessimistic application of the scoring guides was applied, based on the knowledge and understanding of the participants. Discussion and consensus were sought before each asset was considered to have been assessed. The outcome of the scoring was captured as indicated in Table 3. Initial analyses were captured manually, but this was soon replaced by a computer aided data collection process.

UNIT - COMPRESSOR
ASSET - SEAL OIL SYSTEM

	Weight	***Score***	***TWS ****	***Comments***
Safety / Environment	10	10	100	Potential for multiple fatalities
Output	8	10	80	Stops Entire Output of Facility
Severity	7	2	14	Seal Oil
Condition	6	4	24	Good condition
Existing Maintenance	5	4	20	Formal maintenance program in place
Complexity	3	3	9	Simple rotating machinary
TOTAL			247	* Total Weighted Score

Table 3 - Scored Asset

RESULTS

Raw data was collected across a number of sites following the methodology outlined in Section 4. Three sites were selected as a pilot study series. The data displayed in Figure 2 represents the raw data collected during the application of the methodology. Raw data collected included:

- Asset identification;
- Score for each asset against each of the six criteria;
- Description against each criterion – this was defaulted to the scoring guide description but over written as appropriate.

The results of three sites are presented and compared in this section. These sites were:

1. Site 1 – Food Processing Plant - 454 Assets Scored
2. Site 2 – Brewery – 333 Assets Scored
3. Site 3 – Petrochemical Plant – 217 Assets Scored

Summarised results of the application of the methodology include:

- Numbers of safety critical assets (safety / environmental score greater than or equal to 7 indicating potential fatality or reportable environmental consequence);
- Number of output critical assets (Output score greater than 5 indicating a degree of loss of output or loss of service);
- Top 10 Critical assets for each site;
- Histogram of total score relative frequency of total weighted score for each site;
- Histogram of scores relating to output for each site.

All results presented were calculated with Safety / Environmental, Output, Severity, Condition, Existing Maintenance and Complexity weightings of 10, 8, 7, 6, 5 and 3 respectively.

Site 1 – Food Processing Plant

454 assets in total were scored for Site 1. 31% of assets were identified as safety critical with a Safety / Environmental score of 7 or over. 23% of assets were identified as output critical with an Output score of 5 or over. The top ten highest total weighted scores are shown in Table 4.

	UNIT	ASSET	TWS
1	PRODUCT FILL/PACK	FILLER	323
2	PRODUCT BLENDING	SCRAPE SURFACE HEAT EXCHANGER	322
3	STEAM	SERVICES BRIDGE (ADJ. PROD A)	310
4	LIQUID PACKAGING	LIQUID FILLER	294
5	PREPARATION	MIXER #2	284
6	PREPARATION	MIXER #1	284
7	COOKING	RETORT COOKERS #1 - #16	280
8	PRODUCT C	KETTLE	278
9	PRODUCT D	THERMOFORMING MACHINE	277
10	PRODUCT D	KETTLE	277

Table 4- Top 10 Critical Assets for Site 1

The relative frequency of total weighted scores is shown in Figure 2.

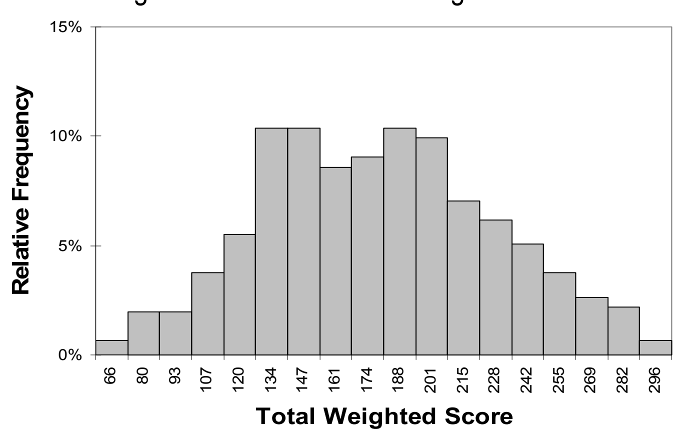

Figure 2- Relative Frequency of Total Weighted Scores for Site 1

The relative frequency of total output scores is shown in Figure 3

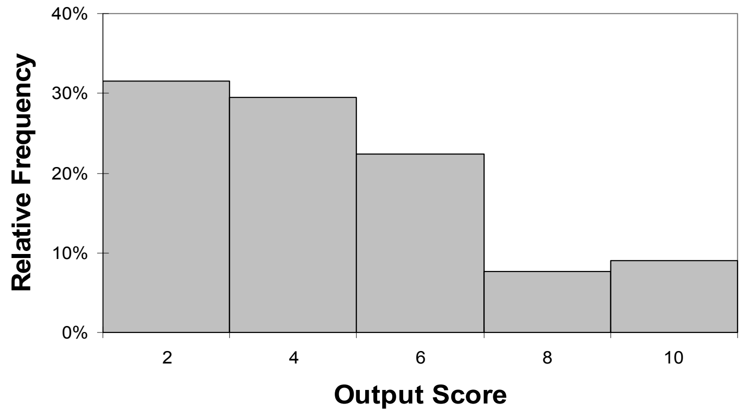

Figure 3- Relative Frequency of Output Scores for Site 1

Site 2 – Brewery

333 assets in total were scored for Site 2. 26% of assets were identified as safety critical with a Safety / Environmental score of 7 or over. 24% of assets were identified as output critical with an Output score of 5 or over. The top ten highest total weighted scores are shown in Table 5.

	UNIT	ASSET	TWS
1	GENERAL	PIPE BRIDGE	292
2	CIP SYSTEM	CIP CAUSTIC STORAGE	246
3	CIP SYSTEM	WORT COOLER CIP TANK	240
4	CIP SYSTEM	BREW VESSELS CIP TANK	240
5	BOTTLING PLANT	BOTTLE WASHER	237
6	BOTTLING PLANT	NO 1 FILLER	236
7	CANNING	CAN CRUSHER	235
8	BOTTLING PLANT	CIP SYSTEM	233
9	BOTTLING PLANT	# 1 FILLER	233
10	BOTTLING PLANT	CAUSTIC RECLAMATION	231

Table 5- Top 10 Critical Assets for Site 2

The relative frequency of total weighted scores is shown in Figure 4

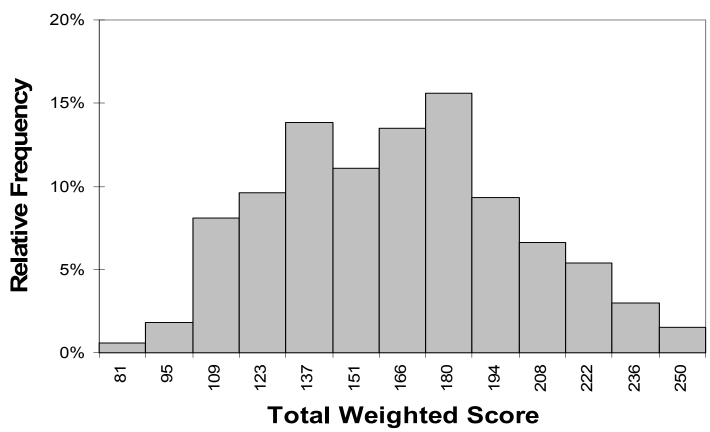

Figure 4- Relative Frequency of Total Weighted Scores for Site 2

The relative frequency of total output scores is shown in Figure 5

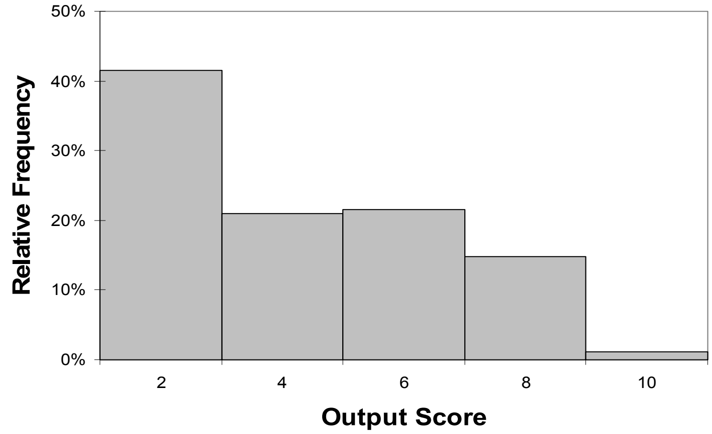

Figure 5- Relative Frequency of Total Weighted Scores for Site 2

Site 3 – Petrochemical Plant

217 assets in total were scored for Site 3. 10% of assets were identified as safety critical with a Safety / Environmental score of 7 or over. 13% of assets were identified as output critical with an Output score of 5 or over. The top ten highest total weighted scores are shown in Table 6.

	UNIT	*ASSET*	*TWS*
1	WHARF	FIRE FIGHTING SYSTEM	338
2	PLATINUM REFORMER	RECYCLE GAS COMPRESSOR	306
3	PLATINUM REFORMER	PTR REACTORS	284
4	WHARF	BLACK OIL CIRC PUMP	262
5	FLARE	MAIN FLARE HEADER	260
6	SULPHUR RECOVERY	CONDENSERS	250
7	SULPHUR RECOVERY	REHEATERS	250
8	SULPHUR RECOVERY	REACTOR	236
9	VACUUM DISTILLATION	CHARGE FURNACE	232
10	FUELS LOAD OUT POINTS	LPG LOAD OUT	224

Table 6- Top 10 Critical Assets for Site 3

The relative frequency of total weighted scores is shown in Figure 5

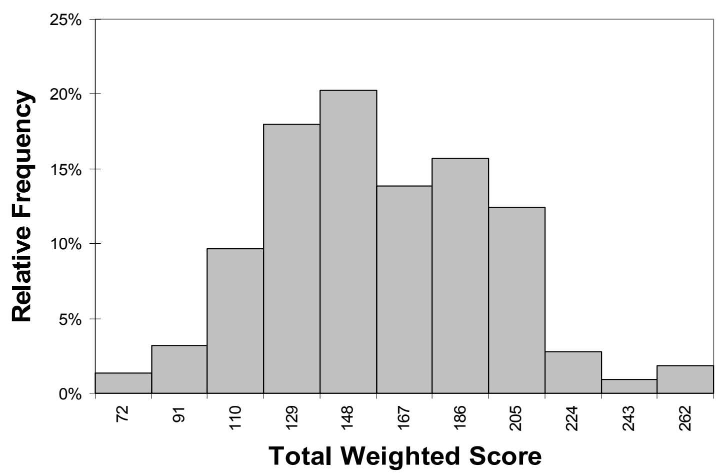

Figure 6- Relative Frequency of Total Weighted Scores for Site 3

The relative frequency of total output scores is shown in Figure 6

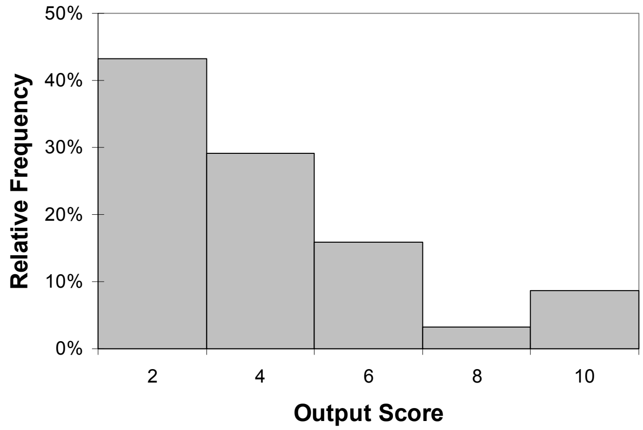

Figure 7 - Relative Frequency of Total Weighted Scores for Site 3

Discussion of Results

There are similarities between the results across the three sites studied. The following observations are made based on the results:

1. The results from the application of the methodology were well received by both the participants and other stakeholders. In the majority of cases, disagreements with the final ranking were not upheld after closer scrutiny of the criteria scoring.
2. There is variability in the Total Weighted Scores across the three sites supporting validity in the assumption of diversity of asset criticality across a facility.
3. The top ranked critical assets were dominated mainly by safety /environmental consequences. Although there were relatively high numbers of assets identified with safety / environmental consequences it was revealed that he number of maintainable items within the asset with a safety functionality were low.
4. Assets associated with the provision of facility services (air, water, steam etc.) featured prominently in the critical asset ranking. This was counter intuitive for many of the participants who expected the largest production assets to be the most critical.
5. There was a higher than expected percentage of assets assessed as having no measurable impact on the output of a facility. This was consistently demonstrated across all sites in the study series.

There were a number of lessons learned from the application of the methodology across the study series. This information was provided by participants in the application or subsequently by stakeholders or other observers. These lessons provided opportunities to modify the approach and apply additional work. These issues were:

1. Critical assets can disappear in the ranking. Assets with a high safety / environmental criticality with a low output criticality (or vice versa) could be significantly down the ranking. Separate lists should be maintained to segregate critical and non critical assets according to the ranking of the Total Weighted Score.
2. There is a need to improve the definition of an asset. Identification of assets is arbitrary and this method is not well described or defined.
3. Current criteria do not reflect the vulnerability of an asset to accidental damage or acts of vandalism. The criteria should be modified for subsequent applications.

4. There is an opportunity to document the methodology so that it can be successfully applied by others.
5. Computerisation of the data collection process greatly improved the efficiency and effectiveness of the application. Improvements to the current database would greatly enhance future applications.

Additional future work is warranted to satisfy these opportunities.

CONCLUSION

A systematic and standardized methodology was developed to identify critical assets. It was demonstrated in application that this methodology could be applied effectively and efficiently using the expert knowledge of those directly engaged in operations and maintenance functions. An assumption of diversity in asset criticality was supported by the application of this methodology. A variety in both ranking and relative criticality of assets was demonstrated consistently across the facilities included in the study series. The application of the developed methodology identified opportunities for future steps in the further development of expert knowledge based assessment tools of asset criticality.

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