RELIABILITY SYSTEM SETUP FOR MINE SITE INFRASTRUCTURE - PRIORITISATION AND REPORTING

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ABSTRACT

Deterioration due to corrosion of mine-site infrastructure is a fact of life for most mine sites, Australian and internationally. The presence of poor quality water, innately corrosive ores and harsh processing conditions all serve to increase the corrosion risk to infrastructure in mining, be it iron ore, coal, gold, copper and the like. West Australian mine sites are inherently corrosive as process/bore waters used for wash down purposes are notoriously high in dissolved chlorides (3-5 times that of seawater) and sulphates with strongly acidic pHs, some as low as 2.0-2.5. The mechanical maintenance divisions on mine sites generally have very good preventative maintenance regimes for mechanical plant, however the steel and concrete structures that support the mechanical plant are usually not included in any such maintenance regime and are repaired as required, often in an ad hoc manner.

In the interest of optimising the life of these structures on a mine site, a risk based, semi-quantitative approach to the reliability of structures needs to be set up, implemented and maintained. The reliability based approach to structural maintenance should effectively identify, prioritise and execute refurbishment activities in a time and cost effective manner. In addition to these characteristics the system should strive to be as simple and transparent as possible. This is due to the large turnover of personnel within mine sites over short periods of time, with often not enough time to train new personal adequately. This paper details a practical risk based approach to corrosion management based on the principals of ISO 31000 'Risk Management – Principals and Guidelines'.

The authors have recently worked with one such integrity reliability system at a mine site in Western Australia and this paper is an overview of a few of the main points of setting up such a reliability integrity system: issue identification and mathematical, semi-qualitative risk based prioritisation.

1. INTRODUCTION

More recently (2012/2013) as a direct effect of the global economic climate, mining companies are reducing unnecessary expenditure and unfortunately this traditionally means, that along with exploration and capital expenditure, maintenance budgets are reduced or severely slashed. This puts more pressure on the site maintenance planners to prioritise the repairs to ensure the maintenance budget is spent efficiently. In addition to this there is an increasing requirement to be able to effectively report on the effectiveness of the maintenance budget. Essentially this is about the 'Goldilocks principal': aim to spend the just the right amount of money in the right areas (high priority areas). This is in order to ensure assets are fit for service, from a safety and production point of view, until the day the plant closes.

Often one of the hardest budget requests to justify is for Integrity based items such as concrete repair, structural steel and coatings because it has always been hard to quantify the availability of an Integrity asset had it not been repaired. A figure of how much an item would cost to repair today in order for it to last the life of mine (LOM) versus if it were repaired in 5 years' time or to achieve 10 years would be required. For this quantification a measure or 'yard stick' is needed to show the reduction in corrosion risk on site to achieve this. This paper formalises an approach or model that was developed to quantify the existing corrosion risk on site using semi quantitative risk matrix models. These risk matrices determine a Risk Priority Number (RPN) for the issue which is then used to prioritise issues based on the associated likelihood and consequence of occurrence. Once the risk has been treated the Risk Priority Number is reduced and this can be measured to quantify a risk reduction regarding integrity items based on remedial activities across site.

The trend is that mining operations nearly always extend their working life past the original intended service life of a mine site, usually determined during the feasibility stage. This is due to a number of reasons, such as the discovery of more resources, improvements in technology allowing further processing of low grade ores and delayed processing of stock piles. As a consequence of this fact the mine site infrastructure is at a higher risk of premature failure as they are demanded to perform past their original intended service life.

The common scenario is that the plant reaches an age where Integrity assets show signs of deterioration; concrete assets start to disintegrate (due to corrosion), coatings start to fail and corrosion related maintenance is required. All too often these issues start to occur across the whole site and the question ultimately arises 'where do we start with the limited maintenance resources available?' The budget for integrity based works may not be allocated for a number of reasons including that it had not been a problem before and remnants of the archaic business cultural belief that coatings and concrete maintenance are not a high priority.

Since the mid 1980's, there has been a cultural change in the Mining industry which has moved away from a 'remove and replace' industry to that of a sustainable approach. There is a mentality developing that structural concrete and steel (collectively termed integrity items), if treated as maintainable items, can continue operation past their design life and remain available for the ever increasing mine life, often brought about by introduction of new technologies or other economic requirements.

1.1 DURABILITY DESIGN APPROACH

Concrete and structural steel assets are generally designed to last the proposed life of the mine. Economic design ensures that the structure is fit for its intended life plus a certain conservative number of years, however if a mine site stays open for longer than the original intended life, then there is demand for the materials to perform for longer than anticipated during the front-end engineering and design (FEED) stage. As per section 4.1 - Fundamental requirements of ISO2394:1998 (General Principals on reliability for structures); 'Structures and structural elements shall be designed, constructed and maintained in such a way that they are suited for their use during the design working life and in an economic way.' When considering design life and replacement interval projected cost, there has to be some understanding of the reliability of the design. As reliability increases, so the construction cost increases but the maintenance cost decreases.

As reported by the market analysts ARC Advisory Group, USA, even at the very early planning stage of an industrial plant project, some 80% of the total costs are defined in the FEED phase. Construction of the plant itself is rarely ever constructed to 100% as the tax benefits of completing a plant, say the last 10-15%, under a maintenance budget are appreciable. Items such as reinforced concrete structures and major structural steel members which cannot readily be refurbished (such as main vertical members in large structural steel structures and mill plinths) need to be designed for the full intended asset life, however, given the significant tax savings, some structural items that can be refurbished/replaced are designed to a perform for a lower asset service life. It should be noted that structures which are designed with a lower service life in mind than the life of mine the cost of replacement or refurbishment must be at a lower cost than the original increase in cost to ensure durability for the life of mine when first designing the structure.

To summarise; if mine site infrastructure is built with an intended life, which for a high percentage of these mines (≈95%+) is exceeded, reliability will decrease due to demands on infrastructure materials to perform past their original design life. Conversely decrease in reliability means an increase in maintenance. This correlates very strongly with experiences onsite at mine sites in Australia and around the world. If the structure is required to perform past its original designed life then integrity risk assessments should be carried out on a biennial basis so the risks can be defined and prioritised for maintenance budgets.

1.2 SUBJECTIVE NATURE OF RISK

No two people see the external world in exactly the same way. To every separate person a thing is what he thinks it is -- in other words, not a thing, but a think - Penelope Fitzgerald

Everyone has different perceptions of risk, based on their own life experiences, which include job experience and personal training. The sentiments above are interesting and apply to risk management. The identification of hazards can be undertaken by most, given they are adequately trained to identify them, however the allocation of severity and likelihood may be subject to interpretation based on one's own perception. Complex issues, especially those with high stakes, involving human perceptions and judgments, whose resolutions have long-term repercussions require a method or methods that remove the subjective nature of risk during assessment.

Sutton (2010) writes that the subjective components of risk become even more pronounced when the perceptions of non-specialists, particularly members of the public, are considered. He goes on to list the factors that affect risk perception:

- Degree of control; if one does not have control of a risk one may consider this a higher risk
- Familiarity with the hazard; one may become complacent when the hazard has been identified
- Direct benefit; willingness to accept a risk for a gain, such as higher production
- Personal impact; type/location of injury on a person leading to the person not carry out specific job tasks
- Natural versus man made; natural risks are considered more acceptable than man made risks
- Occurrence/Timing of events; the older the risk or event, the less concern
- Perception of consequence term; one large accident killing many people in a short amount of time (air crash) has a larger public outrage than the same number of people dying over a longer period (car crashes per year).
- Comprehension time; new risks take time to digest and be realised

The removal of ambiguity in the allocation of consequence and likelihood calls for a standardisation of the risk analysis matrices based on site figures and standards. The use of experienced personnel for the inspection and matrix development is crucial to more objective assessment of risk. The criticality matrix is designed to minimise the subjective 'human element' and provide a semi-quantitative measure of risk reduction.

1.3 OTHER RISK BASED SYSTEMS

The other risk assessment systems that we are familiar with can be improved upon to be used in site risk assessment of integrity assets. One of the main issues with the examples below is that they assume that the scale of risk is linear ie: that the difference in gravity between the individual consequences is uniform and thus the resulting relationships are linear also. This is generally not the case in terms of mine site infrastructure, for example the difference between deformation of a structural member (assigned consequence as say 4 – high) and failure of a structural member (assigned consequence 5 - highest) can be of a drastically greater magnitude than the magnitude between say perforation of a member due to corrosion (assigned consequence of 3) and deformation of a member.

In addition to this two inputs can render two of the same outcomes. A low likelihood coupled with the highest consequence, in both the multiplication model and the addition model, is the same figure as the highest likelihood and low consequence. The example systems shown in figure 1 and 2 below may be effective for other basic generic qualitative assessments of risk but require adjustment for semi-quantitative assessment techniques.

			Consequence				
			Lowest	Low	Medium	High	Highest
			1	2	3	4	5
Likelihood	Highest	5	5	10	15	20	25
	High	4	4	8	12	16	20
	Medium	3	3	6	9	12	15
	Low	2	2	4	6	8	10
	Lowest	1	1	2	3	4	5

			Consequence				
			Lowest	Low	Medium	High	Highest
			1	2	3	4	5
Likelihood	Highest	5	6	7	8	9	10
	High	4	5	6	7	8	9
	Medium	3	4	5	6	7	8
	Low	2	3	4	5	6	7
	Lowest	1	2	3	4	5	6

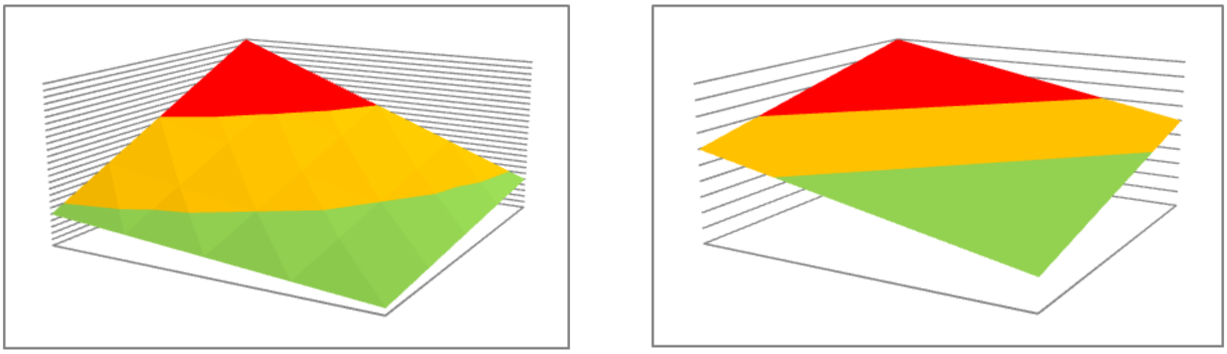


Figure 1 and 2: Examples of Risk Matrices, the left uses multiplication to formulate ratings, the right uses addition. Below are the surface graphs of both mechanisms.

2. RISK BASED INSPECTION PROCESS

The architecture of risk management needs to be set up including principals, framework and process which is discussed in ISO31000:2009 Risk management — Principles and guidelines. For the sake of this paper we will be using the risk management principles (in Figure 3 below) to outline the Risk Based Inspection (RBI) steps for a mine site. The diagram below shows the inter-relationships that each step has within this process.

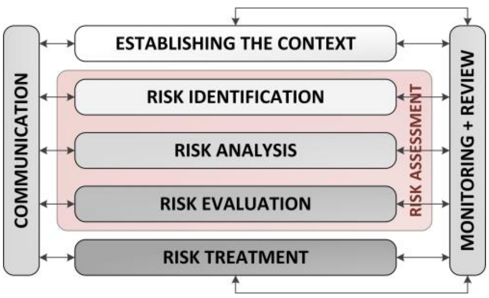


Figure 3 — Relationships between the risk management principles, framework and process (AS/NZS ISO 31000)

External third party inspections are undertaken on a schedule, based on pre-assessed structure risk. A new mine site may only require an inspection every 3 years, but for mine sites that are approaching, or that have exceeded, their design life this should be an biennial process.

2.1 ESTABLISHING THE CONTEXT

As with any inspection, homework needs to be undertaken to understand the background situation of the particular site that the inspection is going to be carried out on. The site cultures need to be understood as well as the area specific legal requirements, site contractor relationships and any previous data available will all be required to develop the risk assessment matrix.

The approach to corrosion management regarding integrity items should also be consistent with the risk management Standard AS/NZS ISO 31000:2009 Risk management—Principles and guidelines, and the organization's guidelines and procedures based on the standard.
Figure 4 is an example of the types of consequence categories that can be developed for the inspection of integrity based inspections. It is important to keep in mind that the scale increase between consequences needs to be of the same magnitude as the other categories. Using figure 4 as an example; the cost of repairing some slight spalling of concrete may be between $10,000 and $100,000 and also could prevent spillage of over 20 cubic meters of environmentally damaging materials; the consequences all have similar scales.

CATEGORY	CONSEQUENCE						
Economic Impact	$0 - $1k	$1 - 10K	$10k - $100k	$100k - $1M	$1M - $10M	$10M - $100M	$100M+
Environmental Impact	Minor Oil or reagent spillage of 1 Cubic Meters	Oil or reagent spillage of 20 Cubic Meters	Unplanned minor impact (< 1 months) to non-threatened species or their habitat.	Unplanned minor impact (< 1 months) to non-threatened species or their habitat.	Unplanned moderate impact (< 5 year) to ecosystem or non-threatened species.	Unplanned severe or extensive impact (<20 years) on ecosystem or Threatened Species.	Permanent loss of ecosystem or extinction of species. Permanent environmental impact over extensive area.
Safety Impact	First Aid Case - Small cut	Medical treatment injury	more than 2 people with medical treatment	Days lost due to injury	Moderate irreversible disability or impairment (<30% of body, 1 or more)	Very serious irreversible injury to >5 persons	Very serious irreversible injury to >20 persons
Corrosion Impact - CONCRETE	Hair Line Cracks	Crack >1mm	Slight Spalling Rust Staining	Large Scale Cracking and Spalling	Reinforcement bar corroding >20%	Possibility of falling sections. Deformation	Failure
Corrosion Impact - COATINGS	New or as-new Condition	Minor or general corrosion	Moderately affected, annual monitoring to occur	Some minor repairs or maintenance required (i.e. touch up)	Considerable repairs required (i.e. maintenance coat)	Major repairs/refurbishment or maintenance to rectify defects or current deteriorated condition	Severe state of deterioration/defective - disposal or replacement required
Corrosion Impact - STRUCTURAL STEEL	Coating pin hole failure	Minor Coating breakdown	Pitting and rust formation	Loss of steel section minor	Major Loss of Steel Section	Deformation	Major Failure

Figure 4: Examples of Consequence Criteria based on categories

The aim is for the scale of each increment to be similar within the matrix so that if the nature of the hazard is difficult to categorise then a number of categories can be used. Figure 5 is a basic worked example showing, in regards to health and safety, if a site has one fatality for every hundred thousand first aid cases with a five (5) section grid, a logarithmic curve can be derived. This curve can be applied to effectively scale the consequences in other categories.

Consequence	First Aid Case	Medically Treated Injury	Lost Time Injury	Permanent Disability	Fatality
Number Of Incidents	100,000	10,000	100	10	1
Cost Of Incident	1,000	10,000	100,000	1,000,000	10,000,000
Scale	1x	10x	100x	1000x	10,000x

Figure 5: Examples of Consequence Criteria based on categories

The same process as above can be applied once site data is obtained to provide a more accurate consequence magnitude calibration curve. It is often difficult to obtain sufficient data from companies in order to produce the calibration curves as this useful information is often considered as sensitive business information. A recent paper that covers the development of matrices further is paper 394; *The Role Of Durability In Risk-Based Asset Management Of Deteriorating Infrastructure* by P. Davis et. al. (18th International Corrosion Congress, 2011)

Once the matrix has been adequately calibrated a basic understanding of the way that the mine site operates is useful for the assessment. For ease of reporting, site area numbers and individual asset numbering system should be understood. The scope is thus defined and these areas are then further broken down into:

- Structural Steel - both structural capacity and coating condition;
- Concrete Assets - footings, bunds, walkways, slabs, etc;
- Material Handling - including supporting structure
- Static Equipment
- Rotary Equipment
- Electrical Equipment
- Ladders, Stairs, Walkways, including grid mesh and checker plate issues
- Classified Plant Equipment
- Piping and Pipe Supports
- Miscellaneous

2.2 RISK IDENTIFICATION

Risk identification is about issue capture. Generally mine sites have well developed systems that capture issues onsite. Figure 6 is an extract from 'maintenance and reliability best practices' which shows where a corrosion management system is applicable. These systems should be set up in a way that all personnel onsite, whether they are site employees, contractors, consultants or even visitors, can report corrosion related issues, however large or seemingly small. The system should allow the issues to be directed to the appropriate site contact. Each of these issues are then vetted or reallocated to the relevant department or asset owner for planning.

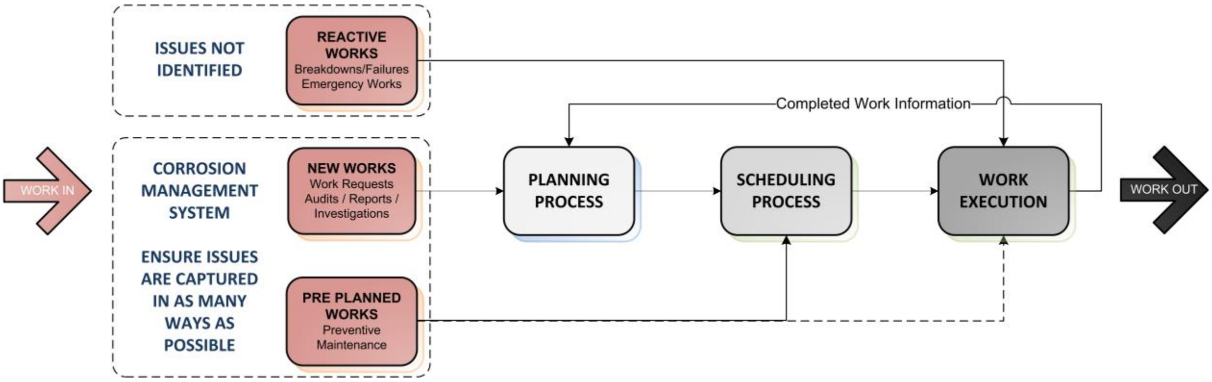


Figure 6: Identification of issues is the first hurdle to any corrosion management system. (Gulati, R. 'Maintenance and Reliability Best Practices' p77)

As part of this system external consultants and specialists can be used to identify corrosion related site issues through a Corrosion Management Audit or Condition Monitoring regime. The inspection covers all concrete and structural steel assets but can include equipment such as tanks, pumps, grid mesh etc. if required. The inspections use pre-determined standards and data to identify risks that require remediation throughout the plant and nominate a likelihood and consequence factor.

External expertise is advantageous in risk identification as a specialist view may identify additional issues which had failed to be previously noted/captured for a number of reasons. All too often site complacency or lack of relevant experience means that:

a) Issues are not identified which leads to failures and loss of production due to unavailability
b) Issues are not prioritised effectively which leads to budgets being spent in the wrong areas
c) Issues are not remediated in the best possible way which leads to premature failure of repairs

Once the issues have been identified it is important to capture the information and establish its priority. The priority can be based on the amount of risk that it poses the site. The risk of an issue can be determined by assigning a likelihood and consequence rating to obtain a Risk Priority Number (RPN) in a criticality matrix as discussed above. This can be achieved using a semi-quantitative approach similar to 'risk vs. residual risk table on a Job Hazard Analysis (JHA) and is explained further in section 2.3 – Risk Analysis.

2.3 RISK ANALYSIS

The risk analysis process provides a documented mechanism to assign a risk ranking to a hazard or issue. It is a relatively quick method to visualise risk and allow comparison between issues. Risk is defined as the chance of an occurrence that will have an impact upon objectives (AS/NZS 4360 Risk Management).

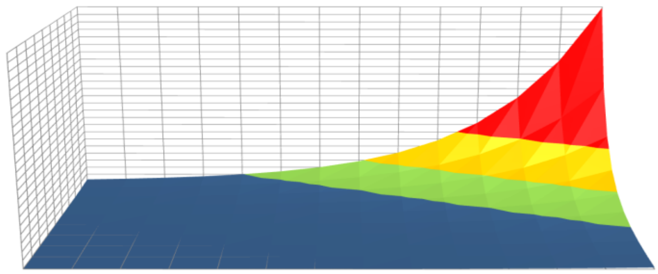
During the course of an inspection on a site a number of issues are collected and their risk needs to be assessed and prioritised. One way of achieving this is by using a consequence versus likelihood matrix which is formulated using existing site data and external standards and statistics relating to the context of the inspection (as discussed in section 2.2 – Establishing the context).

The **consequence** columns represent the different levels of detrimental affect that occurs if a hazard is realised. The **likelihood** rows indicate how likely it is that the hazard will be realised in a certain time frame.

Risk = Likelihood (Probability) of an occurrence x Consequences of the occurrence

By confirming the consequence and the likelihood on the matrix and finding the intersection of the two points it will identify the Risk Priority Number (RPN). The RPN is a calculated figure that indexes the consequence value (1-7) and the likelihood value (1-7) and provides an output based on the weighting factors discussed earlier in the paper. Figure 7 below is a basic example of a matrix with some of the basic consequence categories exhibited. The consequence descriptors need to be specific and concise with little ambiguity.

CATEGORY		CONSEQUENCE						
Corrosion Impact - CONCRETE		Hair line cracks	Crack <1mm	Slight spalling Rust staining	Large scale cracking and spalling	Reinforcement bar corroding >20%	Possibility of falling sections. Deformation	Major Failure
Corrosion Impact - COATINGS		New or as-new Condition	Minor or general corrosion	Moderately affected, annual monitoring to occur	Some minor repairs or maintenance required (i.e. touch up)	Considerable repairs required (i.e. maintenance coat)	Major repairs/refurbishment or maintenance to rectify defects or current deteriorated condition	Severe state of deterioration/defective - disposal or replacement required
Corrosion Impact - STRUCTURAL STEEL		Coating pin hole failure	Minor Coating breakdown	Pitting and rust formation	Loss of steel section minor	Major Loss of steel section	Deformation	Major Failure
		1	**2**	**3**	**4**	**5**	**6**	**7**
LIKELIHOOD Daily	**7**							10000
Fortnight event	**6**						1000	
One per quarter	**5**					100		
One per Year	**4**				10			
One in 5 years	**3**			1				
One in 20 years	**2**		0.1					
One in more than 100 years	**1**	0.01						



Priority 1	Urgent Attention required
Priority 2	Attention within 2 Years
Priority 3	Attention within 5 Years
Monitor	Continue to Monitor

Figure 7: An example of a criticality table (RPN partially completed) and associated logarithmic curve graph.

The criticality based inspection approach categorises risk in terms of corrosion impact to concrete, coatings or structural steel. As this is sometimes difficult to categorise, the operational, economic and environmental consequences are included to allow for comparison. The likelihood of an event occurring is also entered, based on known failure figures if available or estimated. The two figures (Consequence 1-7 and Likelihood 1-7) are fed into a criticality equation (developed from the curves discussed in section 2.1 Establishing the context) to produce a Risk Priority Number (RPN). This is covered further under risk evaluation.

Essentially the higher the RPN number the higher the assigned priority. This allows a pragmatic, systematic prioritisation regime to be assigned to all assets at the plant in question. Maintenance scheduling can then progress from this rating dependent upon determined urgency. Risk treatment of the Priority 1,2,3 and monitor categories are discussed below in 2.5 – Risk Treatment.

2.4 RISK EVALUATION

Once the risk analysis is complete risk evaluation can take place. A priority based schedule or risk treatment plan shall be constructed that enables assets to be scheduled for refurbishment works based on assessed condition and RPN.

The base report for each section allows the structural engineer and key stakeholders to risk assess each defect and further rank the issues. The intent is to provide a high level of confidence that the correct items are being addressed in the right priority. The quantified results are fed back into the overall results and a budget developed from the required works as dictated by the plant. Comments are provided on the performance to date of the assets and include recommendations for ensuring and extending service life of assets.

The repair strategy and required works are then planned for each line item individually and should identify:

- The extent of work (may not be clear until remediation commences)
- If engineering assistance may be required to assess repair methodology
- Timing (will be impacted by plant conditions and shutdown availability)

The work is then put into a plan based on risk, achievability, and budget. A 5 year corrosion remediation program can thus be formulated and should be reviewed on an annual basis (with inspections biennially).

2.5 RISK TREATMENT

A method of managing risk is to undertake remedial activities. In our case this is essentially about extending the life of an asset through repairs to concrete, structural steel and coatings. This risk management can either be achieved through eliminating the risk where possible, mitigating the risk, reducing the risk as low as reasonably possible (ALARP) or by transfer of the risk to someone else (such as insurance).

2.5.1 PRIORITY 1 AND 2

A common tool that is used is the ‘hierachy of hazard control’ triangle shown below in figure 8. This is used in the remediation process to best reduce the liklihood and consequence and thus the risk of a hazard.

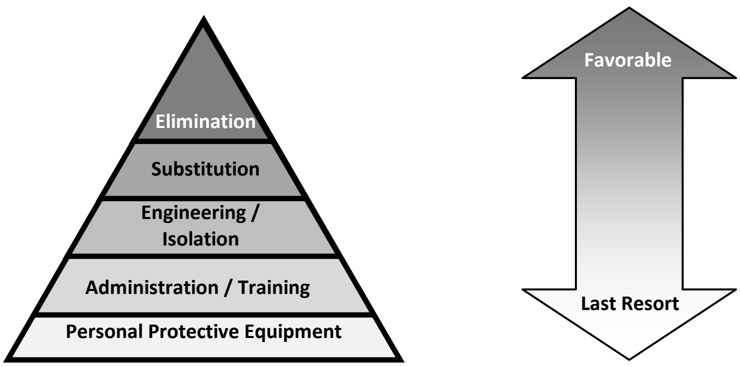


Figure 8: Risk Treatment options: ‘Hierarchy of hazard control’ triangle

2.5.2 PRIORITY 3

Good engineering design aims to ensure that reliability is at an optimum for the intended life which essentially means that the aim is to keep the likelihood and consequence low. It is important to note that because of this the majority of issues identified on an inspection will usually be low priorities. It is important to show these low priorities in any event for several reasons:

- Input data becomes a baseline for future comparison of an issue
- It shows that the item has been inspected and not forgotten
- Nominates a likelihood which might be very low
- Provides notes on why it is a low priority. Eg: Item is designed to be disposable/rotatable

2.5.3 MONITOR

In addition to the option for remediation is the option to monitor and study the hazards further. A number of methods are available and are backed by Australian Standards:

- Corrosion probes/ Coupons– Allows rates of corrosion to be quantified, repairs will be better planned, scheduled and costed;
- Crack gauges/tell tales – Obtain datum or bench line data as soon as possible to ascertain if there is a trend or not;
- Provide details of site data to allow better suited concrete mix design, type of rebar used, QA/QC for steel and concrete during installation, use ISO 9001 contractors;
- Consultants should ensure that joint design, reinforcement content are correct for crack control, good site practice for concreting and painting works;
- If cathodic protection is operating then there is the option to modify the outputs based on additional calculations and changes in the environment.
- Chloride and sulphate ingress can be monitored over subsequent years via the same sampling method discussed earlier.

2.6 CALCULATING THE RISK REDUCTION

After the detailed examination of the plant each issue is assigned a Risk Priority Number (RPN) based on consequence and likelihood of a hazard being realised. Risk priority numbers for all issues onsite can then be totalled to provide a Total RPN for that particular year. This figure can then be used to compare to subsequent years as a Key Performance Indicators (KPI) to show progress.

Essentially each year’s total RPN can be calculated as:

$$\sum \textbf{RPN (YEAR X)} = \sum \textbf{RECALCULATED REMEDIATED RPN'S} + \sum \textbf{NEW RPN'S}$$

The process of continuous risk based reporting using this method can be shown viewed as:

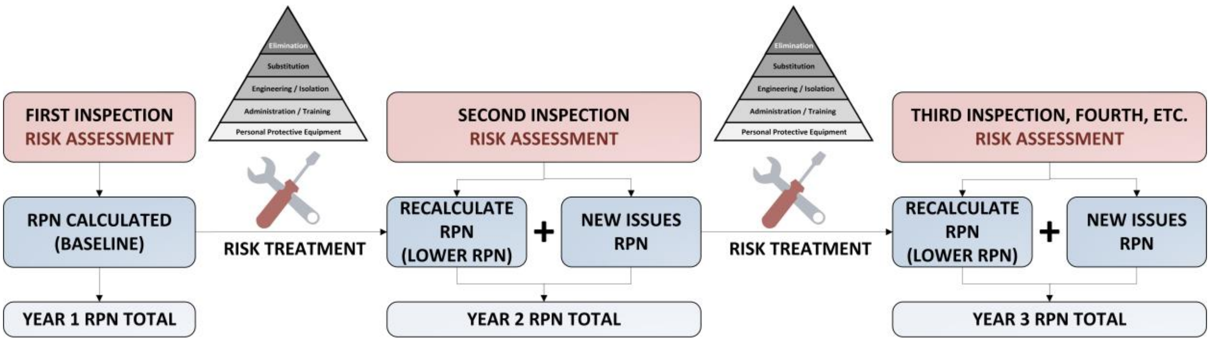


Figure 9: Flow diagram showing the RBI RPN method

As figure 9 shows, the RPN is recalculated after undergoing risk treatment. This RPN is lower than the original as the likelihood (and sometimes the consequence) has been reduced by the treatment. This recalculated RPN is known as residual RPN. Graphical reporting of the risk reduction on site can be then formulated to show progress as shown in example in figure 10:

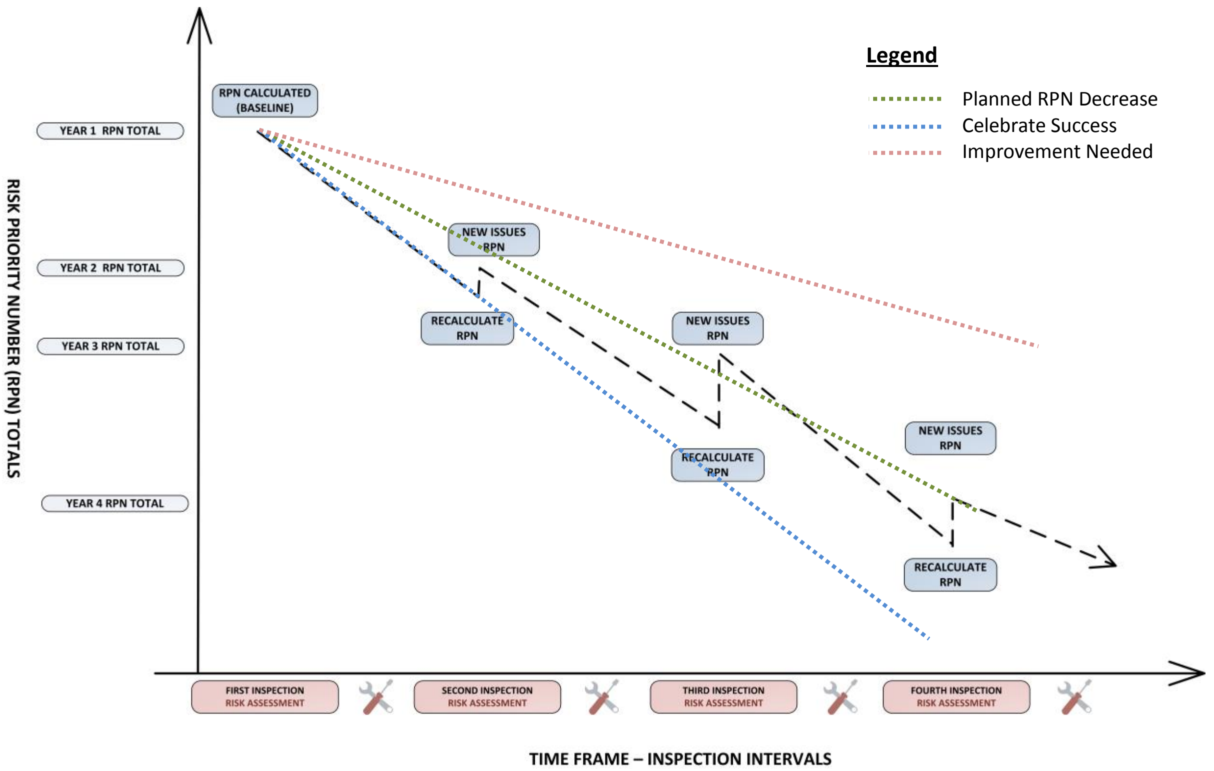


Figure 10: Graphical representation RBI RPN method

It is important to remember that although the RPN figure is quantifiable the inputs were a mix of semi-quantifiable and qualitative data inputs. These figures can be used to compare similar sites in order to get a feel for risk exposure. However this would have to be approached with some caution and information would be viewed indicative only and on a case by case basis.

By ensuring that the risk treatment is done adequately one can ensure that the RPN reduction is realised for the intended extended life of the mine. Remedial actions that are carried out with insufficient or ambiguous scoping/governing documentation may mean that the issue is not sufficiently addressed which can lead to subsequent time and money being spent revisiting the issue.

RPN realisation and even further RPN reduction can be achieved by ensuring that the implementation of a best practice Quality Control and Quality Assurance system is a requirement of the person(s) undertaking the remedial works. In addition to this, the use of ISO 9001 accredited contractors with experienced teams and whose core business is remediation generally achieves return on investment in a timely and practical manner.
The repairs should be carried out using adequate supervision, whether this is stakeholder personnel or competent third party supervision, this reduces the occurrence/impact of potential contractor issues and ensures a quality repair is achieved.

3. CONCLUSION

Implementing appropriate corrosion management systems, which result in the reduction/elimination of corrosion related deterioration of assets, not only assists in compliance with regulatory requirements but also has a direct effect on the assets overall economic performance.

The use of criticality matrices that are based on numerical site information, external statistics, standards and proven trials gives credibility to the risk assessment and gives the client and their stake-holders greater confidence in the results and recommendations.

Due to the size and complexity of a site, and constrained resources, it would be impracticable to measure and quantify every identified defect site wide. Using a semi quantitative method, which has a uniform contextualised approach, minimises the impact of the hazards that we have control over and allows us to forecast future issues.

In the interest of optimising the life of mine site assets; a risk based, semi-quantitative approach to the reliability of the assets needs to be established, implemented and maintained. The reliability based approach to structural maintenance should effectively identify, prioritise and execute refurbishment activities in the most time and cost efficient manner. In addition to these characteristics, the ranking system should strive to be as simple and transparent as possible. This is particularly relevant because of the high turnover of personnel within mine sites over short periods of time (2.0 – 2.5 years).

By understanding the exposure of a site, through the use of a system which is based on the relevant standards and governing documentation, a company can provide greater certainty and security for all its stakeholders. This is applicable whether a mine site has exceeded its original design life or not. The goal is to execute the corrosion risk management process through RBI in a stepped or staged approach to ensure mine site Integrity issues are identified, prioritised, planned and executed in a technically competent, safe and pragmatic manner.

With the global economic climate tightening budgets asset owners are realising the value of a reliability based approach to optimise structural maintenance, which ensures structures will last their required life, without unnecessary expenditure. Essentially this is about the ‘goldilocks principal’ which aims to spend the correct amount of money in the correct areas in order to ensure assets are fit for service (safety and production point of view) until the day the plant closes. Prioritisation through a RBI system using expert knowledge and resulting criticality table can achieve this.

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Giles' expertise lies in the refurbishment of existing concrete and steel structures. This spans from the initial investigation into the modes of corrosion through to devising the best method of repair, preparing documentation and then carrying out the project management of the refurbishment. Recently Giles has been involved with managing major civil repairs at various ore processing facilities as well as dealing with various corrosion issues at port authorities throughout Western Australia.

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As a specialist corrosion engineer, holding both a MSc and PhD in Corrosion Science & Engineering, Dr. Peter Farinha has been involved in identification and problem solving of corrosion related issues in steel corrosion and reinforced concrete including inspection, identification, failure analysis, materials selections, coatings, specification and repair methodology for over 30 years.