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Remote asset management for reducing life cycle costs (LCC), risks and enhancing asset performance

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ABSTRACT

Remote asset management are faced with additional challenges in monitoring conditions, coordinating logistics for maintenance crew, transport and spare parts for maintenance delivery and asset replacements. Recent trends in technologies, remote performance monitoring and risk-based decision making in Capital Expenditure (CAPEX) and Operations and Maintenance Expenditure (OPEX) decisions for asset management are being embraced by asset intensive industries around the world, where critical assets are located in geographically distributed remote areas or difficult to inspect and maintain locations. Industries are also pushing boundaries by reducing crew size, deferring capital expenditure and overhauling and decision making in inspection and in some cases relaxing Original Equipment Manufacturers (OEM) recommended maintenance schedules. This paper discusses some of the issues and challenges with remote asset management. Illustrative example from heavy haul rail is used to explain reduction in Life Cycle Costs (LCC) and further enhancing operational performance.

Keywords

Asset Management (AM), Remote Performance Monitoring (RPM), Risk Based Inspections (RBI), Capital Investments (CI).

1. INTRODUCTION

Risk management of assets in remote locations under the competitive global business scenario, looks into issues like; reducing costs, increasing realisation of value from assets and enhancing performance by failure free operating environment. Operation and maintenance cost can be up to 60 – 80 % of asset's life-cycle cost [1]. Stakeholders have been demanding more value from assets while regulatory requirements are putting greater emphasis on asset performance and safety.

Requirements of ISO 55001 is emerging as a central point for balancing costs, risk and desired performance for all major asset intensive industries [2]. Assets in 2008-09 were worth $63.9 trillion for the 500 top companies in the world and an estimated investment rate is $13 trillion per year. The total asset investment is expected to reach $101.7 trillion by 2020 and $*145.4* trillion by 2025 [3].

Tighter capital and harsher penalties for catastrophic consequences of failures are becoming predominate at an ever-increasing rate. Failure in Esso Longford Gas plant in Australia in 1998 caused two deaths and injured eight people. It led the state of Victoria without gas for 20 days. Main reason was the failure of a pressure vessel after a heat exchanger in the gas refining process broke down. Esso was fined $2 million (AUD) and forced to pay $32.5 million (AUD) in damages to affected parties. This incident caused an estimated loss of $1.3 billion (AUD) to the economy [4, 5]. A boiler explosion in 2017 at a coal-fired power plant in Uttar Pradesh, India killed at least 16 people and injured 80 [6]. The derailment of a fully-laden iron ore train has inflicted a heavy financial blow on BHP, with the incident contributing to a $US600 million hit to the miner's productivity [7]. There are thousands of similar cases around the world which emphasizes a need for risk-based approach to asset management decisions in general and continual monitoring using remote monitoring technologies for distributed assets and infrastructure located in remote places in particular. Failure to do so can lead to:

- downtime and disruption of services
- injury or death of personnel, users and wider communities
- production and service loss (revenue lost and compensation)
- equipment damage (not only the failed component, but other components in the systems which may be affected due to interrelated failures)
- damage to the environment (penalties, clean-ups and compensations)
- brand damage or loss of reputation (market share loss or class action); and
- cost of lost/ damaged or leaked material and contaminations (reduced yield and product recalls) and many others.

Railways, water, energy and mining sector have been addressing these issues in recent times for tackling the access problems and challenges of distance for inspection and maintenance, assuring reliability, availability, maintainability and safety of and services out of assets located and/ or operated in remote locations.

Transport Sector

Intelligent assets are expected to manage themselves with minimum human interaction in stations, rolling stock and infrastructure. Advanced monitoring technologies like SCADA, sensor. IR camera, eMaintenance including cloud computing, AI etc are being applied progressively.

Water Sector

Advance Metering Infrastructure (AMI), Supervisory Control and Data Acquisition (SCADA) and Meter Data Management (MDM) are being integrated using IoT for leakage and theft detection, environment and security, consumption and customer behaviour monitoring, compliance and regulatory requirements, operations and maintenance including intelligent asset management covering predictive maintenance.

Oil and Gas and Mining Sector

Autonomous vehicles, pressure sensing, vibration monitoring, temperature monitoring, hydrocarbon leak detection, wearable technologies in production, pipeline monitoring, video surveillance and detection of threat, asset condition tracking, motion status, sensor alarms and emission monitoring are being integrated to enterprise systems using IoT.

Energy Sector

Smart metering, distributed energy, micro grids, integrating renewables, smart communities, energy demand management, intelligent network, customer engagement and intelligent asset management for poles, wires and infrastructure.

Future direction of remote asset management is cognitive systems leading to new leverage models and unconstrained innovation in asset management for reducing cost, risks and enhancing performance in line with ISO55000 [2].

The online substation measurements supply now immediate information to identify a fault or potential faults while collating useful statistical information over time to trend breaker operations and duty in electrical substations in remote places [8].

Possessing Industry Sector

For a pressure vessel in process industries, model might need to consider several failure mechanisms including:

- creep
- fatigue (thermal and mechanical)
- corrosion
- erosion
- brittle fracture
- stress corrosion cracking
- hydrogen blistering
- overloading
- wind and earthquake loading and many others.

Cloud and IoT are being used for supporting Big data and Analytics for smarter enterprise in utilities, railways and telecommunications in Australia and many countries around the world. There are still barriers to overcome in this journey due to the security issues associated with technologies. Australian Cyber Security Centre (ASC) analysed threat and reported based on security incidents from various sectors. [9]

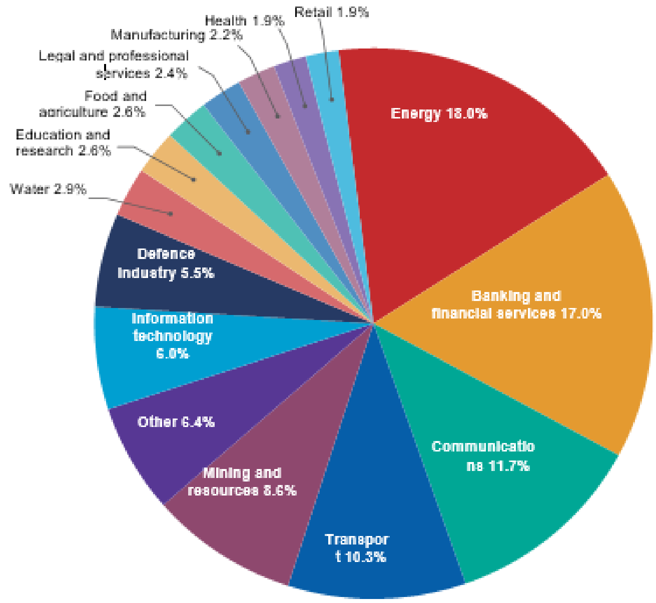

Figure 1. Australian Cyber Security Centre (ASC) threat report [9]

However, through the advancement of technologies and coordinated effort from industries, technology providers and government agencies this gap is being monitored and efforts being taken for further enhancing security. In this paper research conducted in wayside lubrication using way side assets is used for illustrative example. Major focus is on decision making from alternative solutions and how to rollout findings from pilot study.

2. METHODOLOGY

Reliability of assets is analysed using failure and condition data. Timely collection of condition data from remote assets in a cost effective manner and analysis for informed decision-making in interventions is becoming a norm with cost of censors and data transmission being reduced significantly with technological advancement.

2.1 Case study

Asset Management in Rail network is quite complex, especially for lager networks in Australia and India due to track and communication assets in remote places. For an example, Queensland Rail in Australia covers 2,670 kilometre of rail track with over 1200 curves where lubricators are placed for controlling wear and fatigues. Significant part of these asset portfolios are located in remote sites of the network connecting major coal mines and their distributions to ports. The operational risk of the network is severely influenced by a number of factors including track stability (very hot or cold weather), weather condition, wear limits (lubrications issues and rail- wheel wear), rolling contact initiated cracks (initiation, timely and accurately detection and mitigation using rail grinding), traction and condition of the breaking system and human factors including driver behaviour. This case study is focusing on way side lubricators located in remote parts of the network. First pilot study was near Mount Larcom close to Central Queensland port of Gladstone. Remote performance monitoring of rail curve lubrication was trialled for assessment of various technologies and effectiveness of various lubricators and lubricants. Significant capital injection was involved for resolving access and safety issues progressively over the network. Damage mechanism of components are modelled using age, usage, operating environment and condition data. Parameters for rail life is estimated using Million Gross Tonnes (MGT) of freight and remote performance monitoring data [10]. Figure 2 and 3 shows the narrow space and difficulties due to space restrictions and confined spaces for maintenance crew to safely conduct inspections and maintenance of track and any way side assets.

Figure 2. Safety issue in tight track access for maintenance crew [11]

Figure 3. Access and safety issues for maintenance in tunnels [11]

2.2 Research Theory

Asset management decisions are generally taken based on impact of those on the cost, risk and performance.

CAPEX= Cost of overhauls + Cost of replacements.

Capital investment options are ranked using various tools including

- Payback
- Net Present Worth (NPW)
- Net Future Worth (NFW)
- Annual Worth (AW)
- Internal Rate of Return (IRR)
- Benefit Cost Ratio (BCR)

Steps used are:

- Define the objective/s
- Define the alternative options
- Estimate the life time
- Estimate the benefits and costs
- Specify the time value for money (Discounting rates)
- Develop/ Define the performance measures for effectiveness
- Compare apple to apple for ranking the alternatives
- Analyse sensitivity using what if scenarios
- Recommend the option based on cost, risk and performance.

OPEX= Cost of operations + Cost of Inspection + Cost of Maintenance.

Recent trend is to take informed decision based on Life Cycle Costs (LCC) analysis based on the entire life of the asset and not just based on CAPEX or OPEX. It needs to include all costs over the entire life cycle considering:

- Service life, life cycle and design life
- Period of analysis
- Costs covering
  - Acquisition
  - Maintenance, operation and management
  - Residual values/disposal
  - Discounting
  - Inflation
  - Taxes
  - Utility costs including energy etc.
  - Risks

Life Cycle Costs (LCC) = Design and Procurement Cost (P) + Capital Cost (C) + Lifetime Operating Costs (O) + Lifetime Maintenance costs + Lifetime Maintenance Costs (M)+ Lifetime Plant Losses (L) + Plant Disposal Cost (D) [12, 13]

Even the measure of performance is sometimes tricky.
The performance of lubricators is assessed by visual checks. A portable Tribometer was used for measuring lubrication effectiveness by carry distance up to a set Coefficient of friction.

Finally, decisions on option can be different based on consideration of risk. For example lubricator without RPM capability can be cheaper. However, it can leave the track at risk in-between inspections and lead to significant consumption of asset life due to failure of lubrication in-between inspections.

Some organisations use weights for various damage mechanisms to come up with one number for ranking risks. However, it is proposed that risks be assessed for each category and the maximum risk be used in ranking for priority of resource allocation for mitigation of risks. Risk in majority of industries [14] around the world is assessed in industries in line with ISO 31000 which provides principles, framework and a process for managing risk. The risk can be ranked using a Risk Prioritization Number (RPN), given as:

RPN = Severity x Probability of Occurrence x probability of detection

Where the severity is ranked (commonly from 1-5) using metrics such as:

- Negligible: first aid treatment only (1).
- Marginal: injury requiring <10 days hospitalization or medical leave (2).
- Serious: injury requiring >10 days hospitalization or medical leave (3).
- Very Serious: injury requiring >30 days hospitalization or medical leave (4).

  Critical: fatality or permanent body injury (5).

The likelihood is similarly ranked (say 1-5), e.g.:

- Unlikely: might occur once in ten years (1).
- Remote: might occur once in five years (2).
- Occasional: might occur once in three years (3).
- Moderate: likely to occur once per year (4).
- Frequency: likely to occur many times per year (5).

Probability of detection is also ranked by easy to detect (1) to Unlikely to detect (5).

Consequence of failures, may exceed several million dollars of financial profitability/ liability, affecting the survival and/or continued viability for business continuity and/ or growth, long term operation outside performance standards or customer agreements and could lead to directed action for breaking promises to customers and for service delivery. Civil / criminal prosecution, unfavourable tariff outcomes might happen. It can lead to loss of operating licences and/ or possible closure of facility, significant fines and/or jail penalties of staff/ leaders due to legal outcomes. There might be continuous adverse national and/or international coverage, major regulatory restrictions, possible loss of licence including reputational damages and political consequences. Severe permanent damage to the environment outside operational areas with potential long-term consequences affecting the environmental integrity of the area, loss of important or listed environment / habitat and associated long-term impacts on the area of concern with environmental consequences including sustained community outrage might happen due to environmental damages. Finally, multiple death and/or large numbers hospitalised injuries leading to major health and safety issue of, staff, people and wider communities can impact safety requirements of the business. Justification of OPEX and CAPEX, therefore, need to consider:

- growth of demand
- renewal due to end of life
- improvements to address reliability, availability, maintainability, safety, performance and cost issue using remote performance monitoring and timely interventions using leading indicators and
- compliance/ regulatory requirement

Mitigation of risks are required to be taken in a consistent and informed manner across all areas and all levels of decision making in maintenance and asset management for entire portfolio of assets. Detailed risk-based analysis is needed for justification of capital investment in technologies and infrastructure.

Decision making process for maintenance and capital investment starts with knowing the asset, understanding the condition and remaining life and its capability and capacity to delivery what is needed by the business. This becomes complex for assets located in remote places. Options considered, generally, are:

(a) Do Nothing

(b) Upgrade with latest technologies including remote performance monitoring and IoT.

(c) Replace with technology based solutions

(d) Non asset solutions

"Do Nothing" has following risks:

- risk to health and safety of employees, contractor or member of the public
- regulatory breach of WH&S legislation and organisational WH&S procedures
- risk to damage to the environment
- increased costs associated with reactive shutdowns to bring in specialised equipment
- adverse public reaction and media attention
- inability to access for vital maintenance and repairs leading to failure
- potential risk of lawsuits and costs related to compensations and legal bills

Objectives and benefits for investments needs to be clear. The main objective associated with the feasible options in maintenance/ upgrade / modification/ replacements of the systems (e.g. a pump station in water utility or curve lubrication in rail network) is to mitigate the risks by reducing the likelihood of harmful incidents occurring on the site affecting the maintainability and operability [15. Benefits expected, generally, through the maintenance/ upgrade / modification/ replacements are:

- enhanced safety of employees, contractors and wider community
- reduced cost of compensations and legal bills
- reliable operation of the plant using accurate condition data and leading indicators.
- lower maintenance costs due to timely interventions
- mitigated risk of failures due to near real time data and reduced lead time for interventions
- minimised risk of regulatory breach of Environmental Licence conditions
- minimised damage to the reputation of the organisation
- increased employees and customers satisfaction

Decisions are taken based on total cost including risk cost over the life cycle of the asset [16]. Analysis needs to include procurement cost, operation and maintenance and replacement/ disposal costs along with training and technical services associated with technological solutions and any intervention option for mitigating risks.

"Do Nothing" option is, generally, unacceptable as the resulting residual risks are high. Other options are considered based on Net Present Worth (NPW) of investment and executive judgement based on risk appetite of the organisation, [17, 18].

Feasible time window is selected considering lean time and / or opportunistic maintenance/ upgrade/ replacement during major shutdowns/ closure/ planned outage. Residual risks of selected option is further assessed for better understanding of residual risk and validation of maintenance and asset management intervention actions.

The priority of progressive implementation in the entire network is proposed based on risk assessment for any particular locations. A risk-based allocation model is proposed using criteria for assessment of risk. They are:

- Criteria1: Safe access to sites such as trackside space, tunnels and narrow approaches
- Criteria2: Tightness of curves where rail wheel wearout rate is significantly high or relatively low in higher curve radius.
- Criteria3: Remoteness of the place which takes more time in providing service and definitive care for any accident recovery

All wayside assets are coded and pulled together for a common list. Each is given score of 1 (lowest) to 5 (highest) under risk criteria. Scores is calculated multiplying individual scores and are used for ranking for priority based on risk criteria and proposed for budgeting rollouts in annual budget cycle.

Table 1. Ranking for priority of asset replacement rollouts.

Asset Number	Criteria1	Criteria1	Criteria1	Score	Rank
XXX001	3	2	5	30	2
XXX002	1	5	2	10	3
XXX003	4	5	5	100	1
XXX004	1	2	3	6	4
- - - -					

Preferred option includes executive judgement in consultation with

- field Services staff
- asset Creation staff
- strategic Asset Management (SAM) staff for CAPEX/ OPEX decisions
- operations and maintenance planning/ Network Planning / Capital Work Planning Staff including project management.

3. FINDINGS FROM STUDY

Knowing the assets and residual life are the most important steps in taking informed decision in maintenance interventions and replacements. This becomes extremely challenging for assets located in remote areas due to distance and availability of competent technical people in assessments of condition. Additional cost of wheel wear was over $100 million (AUD) in one year due to lagging indicators and non-availability of track and wheel condition over a period of time. Moreover, there were several types of applicators and different types of lubricants in rail corridors in heavy haul Network in Queensland. In addition, common test was visual inspection and finger test where the carry of lubricant was measured and presence of lubrication was decided based on manual process and visual checking to see if lubricants are reasonably carried to the required distance in the rail curve and also at covering the gauge face of the rail or not. This was a subjective manual inspection at prescheduled time intervals and friction was not measured objectively with an alert for maintenance department when trackside lubricators were malfunctioning or failed to perform and detected only during next inspection cycle. This resulted in significant risk and cost to below rail and above rail assets including rail and wheel.

A solar operated pumping station with remote performance monitoring enhanced the reliability of the lubrication system and developed a risk-based maintenance practice for rail curve lubrication in heavy haul network. Carry distance of grease in gauge face was measured for all types of greases and various types of applicators. It was found that only 2 of the 11 lubricants and 2 of the all types of applicators were effective. It resulted significant increase of rail and wheel life and reduced operational and maintenance cost and cost of rail and wheel replacements.

Figure 4. Solar operated electrical lubricators [19]

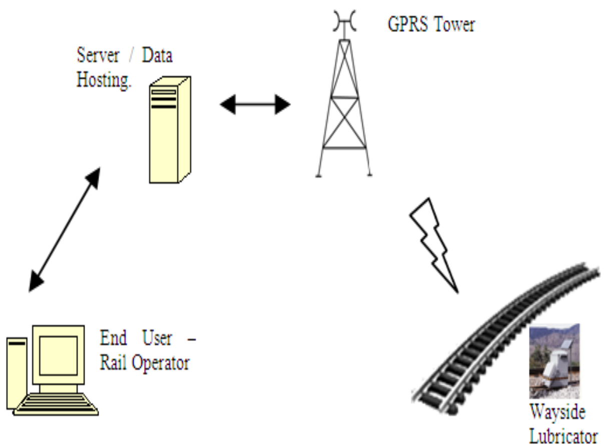

Figure 5. Mobile network in Remote Monitoring [11]

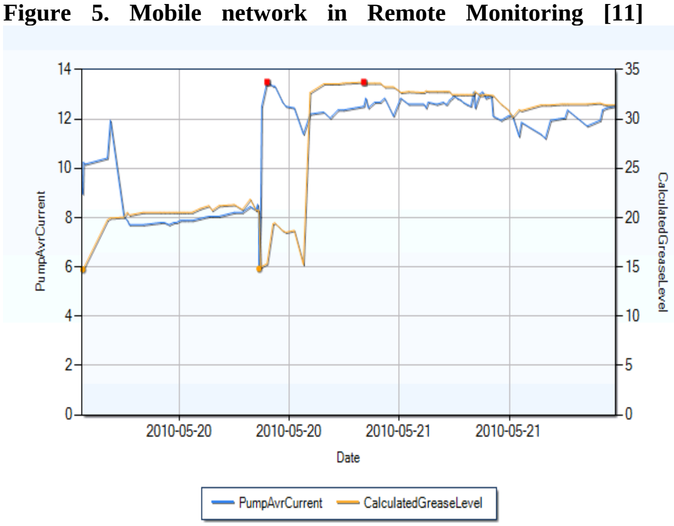

Figure 6. Performance of assets observed using RPM [11]

Risk based inspection methodology was developed to compare apple with apple. A portable Tribometer was used to measure the co-efficient of friction required for preventing any unreasonable wear. The cost of the capital expenditure was significance high. Electrical lubricators with remote performance monitoring (RPM) capability was in the range of $25000 (AUD) to $35000 (AUD) compared to $2500(AUD) to $4500 (AUD) of existing lubricators. Network had more than 1200 locations where this intervention is being rolled out after successful trial in Mount Larcom site in Central Queensland. Undetected breakdowns, manual inspections and track under risk for excessive rail and wheel wear were reduced drastically resulting in reduced track maintenance and track closures. This ultimately enhanced rail and wheel life due to controlled lubrication where it is needed (in gauge face) instead of contaminating ballast and/ or top of rail surface.

4. CONCLUSIONS

Assets in remote places are faced with additional challenges in condition assessment, maintenance delivery and asset replacements. Recent trends in industries are use of technologies, remote performance monitoring and risk-based decision making. This paper discusses issues and challenges with remote asset management in heavy haul network and how technology plays a big role for addressing those challenges. Illustrative example is used to explain how decisions in heavy haul is taken for remote performance monitoring for wear and fatigue management considering risks and not just based on costs. There is significant opportunity for future work. Some of those are listed below:

- Currently safe speed of the rolling stock is determined based on analysis of risks based on limited data and therefore, same speed is enforced along the whole corridor (blanket speed restriction). Current practice causes reduction of operational efficiency and/ or missed detection of potential risks of derailments and accidents. With the advent of low-cost sensors and easier deployment, the risks in various corridors of the track can be monitored at critical points of rail network using IoT based rail monitoring system, enabling operators and maintainers to gather more accurate and precise condition data in real time.
- There is opportunity for future work, using data through IoT-based system in the entire network as well as weather forecasting data from Bureau of Metrology (BOM). A predictive risk model can be developed based on machine learning technique and artificial intelligence that will allow forecasting of the operating risks in a more realistic and accurate manner. This will allow different operating safe speeds at different sections of the network resulting in increased operational efficiency and safety.
- Dynamic maintenance schedule covering remote locations using real-time data collected automatically from the sensors fitted with track side and rolling stock assets by updating pending lubrication or maintenance job list along with sending SMS to the personnel in the field.

5. ACKNOWLEDGMENTS

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