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ASSET MANAGEMENT COUNCIL

CRITICAL SUPPORT SYSTEMS FOR ASSET MANAGEMENT – M&R

Proactive Asset Management Through Maintenance Condition Data

Optimizing a Groundline Corrosion Management Program for Steel Transmission Towers

Embedding Spatial Dimension in Asset Risk Profiling towards a better management of community assets in Auckland Council

Includes **State of the Asset Management Sector 2020** Report

ERNST KRAUSS

EDITOR IN CHIEF

You have succeeded in developing the Asset Management Framework, defined the Strategic objectives for the Assets and the way they are to be managed. What are your next steps? How will the Organisation know about their responsibilities? The Operators, Maintainers and their Managers are all on board with the new system. Some Engineers are supportive. Will this Asset Management System be successful? Critical questions, as there are other disciplines and teams involved in the management of Assets. What about the alignment of risk expectations, finance and accounting, the inclusion of information, document and data management to support the Asset Management Framework? Have the Projects teams be appraised and embrace the requirements of the new Framework and how aligned and committed are the supply Chain teams? Are Contracts appropriately structured and refreshed?

These and many more questions arise when we are talking about the successful implementation of an Asset Management System. It is often understood by Senior Management that an Asset Management Framework is all that is required to make an Organisation effective as an Asset Management Organisation. That would be like going to a fine dining restaurant and only being served the meat without all other ingredients to the dish presented and without condiments, those only being listed on the menu.

Asset Life Cycle Management in line with the ISO 55000 series Standards requires the whole Organisation to be in tune with the Asset Management requirements that are defined at the Strategic and Operational levels. One personal Observation, confirmed by other Practitioners, is that among the most critical support functions for success are the Senior Managers, or "C" level if you wish. Without their active understanding of the support required by them it will be difficult to make a lasting change in line with the desired status to be an Asset Management Organisation.

Organisations that have successfully transitioned to an asset Management Organisation have embraced the holistic view that an Asset Management System requires personnel trained and informed at all levels of the Organisation in the new way of working. The Asset Management Council's Asset Management Delivery Model and the Asset Management Systems Model are helpful devices to reiterate the significance of all main and support functions that make up the complete Asset Management System and should support the Asset Management Framework. The current issue of "The Asset" provides some thoughts and experiences successful integration of support functions and the kernel of an Asset Management System. And that integration also requires us to understand the whole breadth and depth of managing Asset over their Life Cycle and the realisation that it is not only Maintainers and Maintenance that are responsible for managing Assets.

We trust you enjoy the articles provided and welcome, as always, your feedback.

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FROM MY DESK: CHAIRMAN'S LETTER

CHAIRMAN, DAVE DAINES

The introduction of the Asset Management System Standard (ISO 55001) in 2014 has seen an increased focus on asset management in a wide range of businesses.

For many organisations since, the motivation has been solely on achieving certification. However, managing assets within the context of asset management involves a wide range of support systems to achieve the objectives of the organisation. The most significant of these support systems lie within the framework of maintenance and reliability.

Maintenance and reliability focuses on the asset, ensuring it is fit-for-purpose. A regular maintenance schedule enhances the reliability of the asset throughout its lifecycle, and actually extends the life of the asset. Maintenance is a critical business function that impacts on plant output, product quality, production cost, and safety and environmental performance, and ultimately builds value for the business.

There are numerous strategies which assist in the maintenance and reliability of assets. Both preventative maintenance and corrective maintenance procedures are two systems which are necessary to determine the capability of an asset within a known and measurable level of assurance. Leveraging data to maintain assets by implementing a predictive analytics system is an increasingly successful and valuable tool for many businesses, especially given the rise of Big Data.

In this issue of The Asset Journal, you will discover varied examples of critical support systems for maintenance and reliability of assets that have proved successful for many organisations. We hope you find value in reading the information curated herein and, of course, we welcome your feedback

David Daines
National Chairman, Asset Management Council.

ARTICLE 1 – Proactive Asset Management through Maintenance Condition Data

Bob Teunisse, Air Domain Centre Capability,
Acquisition & Sustainment Group, Department of Defence

In an increasingly cost-conscious environment, it is essential to be able to realise the inherent reliability of an asset through optimising the maintenance conducted on that asset. Maintenance Condition Data (MCD) plays a vital role in optimising maintenance to ensure safety, increasing availability and minimising operating costs – all of which are hallmarks of a robust asset management framework.

Over the past seven years the Aerospace Maintenance Policy Review Team (AMPRT), and now the Reliability & Aircraft Maintenance Programme (RAMP) Team, has led a variety of maintenance policy optimisation initiatives for fixed wing aircraft within the Australian Defence Force (ADF). Based on these initiatives and a wealth of additional related experience, this paper will outline the importance of MCD and its role in establishing a proactive asset management framework; identify current challenges within the ADF Air Domain related to capturing meaningful MCD; and provide strategies that can be employed to improve the quality of MCD collected and how it is used.

Keywords: maintenance condition data, performance evaluation, performance monitoring, condition monitoring, optimised maintenance

1. INTRODUCTION

The ISO 5500X International Standards provide an overview of asset management and asset management systems; and define requirements for an asset management system to enable the effective and efficient management of assets. A key element of the ISO 5500X asset management framework is 'performance evaluation' , which is reliant on 'performance monitoring' or 'condition monitoring'.

Within the ADF, it is a regulatory requirement to record defects on aircraft when discovered. As such, when an item is unacceptable for in-service use due to its condition, an 'unserviceability' (U/S) is raised, which will prevent the item from being fitted to an aircraft. Further investigations resulting from a U/S can identify the type and level of degradation and the root cause of the U/S at the time it was identified/reported.

However, for most ADF aircraft there is minimal information recorded against a U/S item regarding the rectification to get a 'servicable' item back in-service; the format for a significant amount of the U/S-related data is paper-based; and there is no requirement to record the condition of a maintained item during scheduled maintenance inspections prior to the U/S being identified/reported. All of which limits the proactive asset management of ADF aircraft as promoted by the ISO5500X framework.

In 2011 the then Head of Aerospace Systems Division within the Defence Materiel Organisation formed the AMPRT, a 'tiger-team' specifically established to aid in-service aircraft platform managers to optimise the extant maintenance policies for their respective platforms.

As a result of the First Principles Review in 2016, the RAMP Team was formed within the Air Domain of the Capability, Acquisition & Sustainment Group, which subsumed the AMPRT. The charter for the RAMP Team is to support Acquisition Projects Offices and System Program Offices with:

- Reliability, Availability and Maintainability (RAM) analysis to support informed decision making across procurement, logistic and engineering activities;
- Develop and review RAM requirements and specifications to support tender evaluation; and contractual negotiations; and
- Conduct/Support maintenance optimisation initiatives across the Capability Life Cycle of ADF aerospace platforms.

Based on the maintenance optimisation projects undertaken by the former AMPRT and current initiatives being led by the RAMP Team, the need has been identified for a robust condition monitoring system to collect MCD prior to and once a U/S occurs. As a result, the RAMP Team is currently pursuing a number of Maintenance Data Improvement Initiatives (MDIIs) to ensure relevant data is collected to support engineering decisions for the optimisation of ADF aircraft maintenance programs. This paper presents key aspects of MDIIs and how these initiatives can support a robust closed-loop asset management framework.

2. DISCUSSION

2.1 Importance of Maintenance Condition Data

Boito et al (2015) estimate that maintenance costs for military aircraft can range between 33% - 40% of the overall Operating and Support (O&S) costs for a given platform. Since this is a significant portion of the overall O&S budget, great saving can be realised through optimising the Maintenance Program (MP) delivered by the Original Engineering Manufacturer (OEM).

Typically when an aircraft is acquired for in-service use, the OEM will provide a MP based on predetermined Configuration, Role and Environment (CRE) assumptions. However, within the ADF, experience has shown that the in-service CRE can vary from the assumed CRE that the OEM MP is tailored for. Therefore, to ensure the right maintenance is done at the right time for the right reasons, periodic reviews of the MP should be undertaken to verify the MP is optimised for any changes in CRE, and this requires relevant and accurate MCD.

Mathew et al (2006) indicate that the use of MCD will enable optimise maintenance, which can lead to potential reductions in maintenance and material costs. However, the value of MCD also ensures that the aircraft remains safe to use in its intended roles because the intent of Preventative Maintenance (PM) tasks is to ensure the function of an item within a system is available when the system is in use. If the failure of an item has safety-related consequences, the effectiveness of the PM tasks performed on that item may determine if an

unsafe circumstance could occur. Therefore, accurate and relevant MCD for an asset can affect the safety, the cost of ownership and the availability of an asset.

2.2 Current Challenges with Maintenance Condition Data

Flintsch et al (2009) identify that data collection is an integral aspect of Asset Management and further state that data collection for asset management are often not designed to support the decision processes associated with specific assets. This situation has slowly evolved within certain areas of the ADF Air Domain, i.e. volumes of data have been (and continue to be) collected, yet often this data is not utilised to support proactive asset management.

For example, from 2012 – 2015 the AMPRT conducted a detailed analysis of the major servicings associated with the Royal Australian Air Force (RAAF) PC-9/A aircraft. To access relevant data to support the optimisation of the servicings reviewed, the AMPRT requested access to servicing records for 15 aircraft over a five year period. As a result of this request the AMPRT received 15 boxes of paper based servicing records (one per aircraft) that had to be retrieved from a remote storage facility. Within these boxes were approximately 15 servicing packs, each of which contained up to 100 pages. To extract the relevant data from these data packs, four AMPRT members spent over a month extracting more than 5,000 U/S details. The effort to retrieve the data from storage, then extract the useful data into an electronic format indicates that although large amounts of data had been collected, it was not being actively reviewed to support proactive asset management.

This highlights two significant challenges with the collection of MCD, namely: MCD is not being collected to support a closed-loop asset management system; and the format of the MCD (i.e. paper-based reports opposed to electronic data) is not conducive for analysis, trending or interrogating.

Another challenge with the ADF Air Domain is that much of the data that is being collected lacks the level of detail required for asset managers to truly understand the nature of the U/S and how the U/S was rectified. This was noted during the conduct of the MP review projects conducted by the AMPRT on the RAAF P-3C and PC-9/A fleets. Table I provides examples of U/S entries that lack sufficient detail to support asset management decision; and comments indicating why the provided information is not adequate. Table II provides examples of U/S entries that would provide asset managers a better understanding of the nature of failure or degradation and the root cause. With a better understanding of the failures, degradation and root causes, asset managers are better equipped to proactively manage those assets.

The final MCD challenge to be addressed by this paper pertains to the collection of degradation data prior to a U/S being identified/recorded. Currently within the ADF there is no need to record the condition of an item being

Table 1 - Examples of Vague Unserviceability Records[9]

Unserviceability	Comment
RH aileron trim tab to be replaced.	Reasons why the component requires replacement should be described, i.e. the mode of failure or external symptoms of failure, e.g. 'shaft bent', 'shaft seized', etc.
Port outboard leading edge drop down access panel cracked as marked.	When this type of entry is reviewed away from the actual maintenance environment there is no way of knowing in what physical area 'as marked' is describing. Where possible the actual location of the crack and its dimensions should be described.
Corrosion inside of nose wheel well lip.	Where possible the degree of degradation should be described along with the size and type of corrosion evident, e.g. 'exfoliation corrosion evident on the inside of nose wheel well forward lip, approx. 2cm in size'.
Centre bottle & flex line found U/S.	Specific failure mode or symptoms should be described, e.g. cracked line, corroded line, leaking etc.

Table 2 - Examples of Detailed Unserviceability Records

Unserviceability	Comment
With ground power applied #3 engine flight idle stop fails to disengage.	Clearly identifies the context and the problem.
Pilot side windshield has delamination evident at the LH bottom edge approximately 2" wide and "5" vertical.	Clearly identifies the area of concern and the extent of degradation.
Flight station aircon unable to get temp below 19 degrees Celsius in auto or manual.	Clearly identifies the functional failure.
Wing flap control handle friction lock slips at 26lbs force.	Provides quantitative measurements of degradation.

maintained unless a U/S is identified. So, regardless of the number of times an item may be inspected or examined during maintenance, no data is collected on the condition of that item unless a U/S is identified. This creates a 'digital' data point for a MP analyst (i.e. the item is either serviceable or U/S). If MCD is collected when PM tasks are performed on items, the analysts will have a more robust set of data to characterise the degradation of the items, thereby enabling improved maintenance optimisation opportunities for those items.

2.3 Maintenance Data Improvement Initiatives

To improve the ADF aircraft asset management framework and to enable the optimization of ADF aircraft MPs, the RAMP Team has established MDIIs to improve the collection of MCD at the coalface. The MDIIs will address the MCD challenges outlined about, namely:

- MCD collection does not support proactive asset management
  - o maintenance data is collected to comply with regulations (opposed to supporting asset management objectives);
  - o maintenance data is paper-based (opposed to electronic)
- MCD lacks quality and sufficient detail to support asset management decisions
- no progressive degradation data is being collected prior to a U/S being identified/reported.

To address the above MCD challenges, the MDIIs being pursued by the RAMP Team include the following:

1. providing Continuation Training (CT) for maintainers for the collection of appropriately detailed MCD;
2. establishing MCD reviews at maintainer facilities;
3. encouraging the collection of electronic MCD; and
4. collecting progressive degradation maintenance data prior to an item becoming U/S.

Maintainer CT

Maintainers of ADF aircraft are very professional and take great care to perform their duties to the highest standards. Instead of telling them how to maintain aircraft, the proposed CT is intended to provide the context of why MCD is important; and to educate maintainers in how their recorded maintenance data is utilised in decision making to ensure ongoing safety and airworthiness, cost of ownership optimisation and improved aircraft availability.

Often maintainers are pressured to get an aircraft serviceable as soon as possible. The propose CT will ensure maintainers continue to develop their skillsets and enable professionalism in what they do and support the aircraft for the duration of its service life; and the proposed CT can inform maintainers of the type of data that will support long-term proactive asset management of the aircraft.

CT was provided to maintainers of the RAAF PC-9/A fleet in support of the MP review project conducted by the AMPRT. Subsequent to the training, the AMPRT team observed a positive change in the detail provided in MCD. This enabled engineering decisions related to optimising maintenance tasks to be better substantiated. As a result of the PC-9/A MP conducted and the MCD collected, the RAAF PC-9/A fleet had approximately 800 hours of additional aircraft availability within the first year of implementing the revised MP.

Reviewing Maintenance Condition Data

The old adage "rubbish in; rubbish out" comes to mind when considering the need to review maintenance data for accuracy and vagueness. Aljumaili (2016) states that poor quality leads to poor decision-making. Within the ADF, often the asset management analyst is not collocated in the same facility as the people who conduct maintenance and record maintenance data. As such, reviewing MCD at the maintenance facility will improve data quality; and clarify vague descriptions. This will ensure the data received by the asset management analyst is relevant and accurate. Although reviewing the data at the maintainer facilities may impose the need for additional personnel, the asset management benefits gained through improved data quality will support decisions related to aircraft safety, costs of ownership and aircraft availability.

Electronic MCD

As the PC-9/A MP review project illustrated, paper-based MCD significantly limits the ability of an analyst to manipulate data. The manipulation of data can enable trends to be observed and to identify anomalies that warrant further investigations.

Due to various contractual and security issues, a significant amount of MCD collected on ADF aircraft is paper-based. Although the more modern platforms utilise electronic maintenance management systems, a number of legacy platforms (such as the P-3C and PC-9/A fleets) rely on paper-based maintenance records. For legacy ADF platforms reliant on paper-based maintenance records, the RAMP Team encourages the transcription of particular maintenance records into an electronic MCD database. With electronic MCD the asset managers for legacy platforms will be able to observe trends and anomalies that affect aircraft safety, costs of ownership and aircraft availability.

Progressive Degradation Maintenance Data

ADF aircraft began utilising hand written maintenance condition code-type functionality in the early1990s to record the level of degradation observed during the performance of specific maintenance tasks. The collection of this type of data was specified for the conduct of 'age explorations' into the performance of a specific item over a specified interval. With the introduction of DEF(AUST) 5692 compliant Weapon System Databases (WSDB) in the late 1990s, the Failure Reporting Requirement (FRR) data field allowed the capture of a condition code information against a specific maintenance task. Although this functionality has existed for several years, it has not been typically exploited to proactively manage the platform assets because the condition code definitions set in the 1990s were limited to describe the degradation observed.

In 2012 the AMPRT revised the FRR Condition Codes to allow a more quantitative rating of degradation to be recorded. Previously, the original hand written codes required recording the form of degradation (e.g. wear, delamination, etc.) and if the degradation was within accepted limits or not. The revised FRR codes enable the recording of the form of degradation, as well as a qualitative assessment of the degree of degradation (e.g. no detected degradation; 25% of allowable limit; 50% of allowable limit; 75% of allowable limit; or U/S).

With this additional information degradation trends for a particular maintenance task can be mapped for a given aircraft on successive servicing, as well as across the fleet. These trends help enable the asset managers to make more informed decisions regarding maintenance optimisation options. However, for this approach to be effective it is essential to have this data in electronic form and candidate PM tasks must be selected for recording FRR codes.

Through applying the various MDIIs presented in this paper, significant benefits have been realised by the ADF, which include:

- increased aircraft availability through extended intervals for major servicings;
- reduced cost of ownership through reduce material and manpower costs from:
    - o extended major servicing interval;
    - o streamlined/standardised servicing tasks; and
    - o the removal of superfluous maintenance activities from the MP;
- increased fleet planning flexibility due to reduced frequency of major servicings; and
- assured continued safety through identifying potential safety-related issues.

3 CONCLUSION

Through conducting a variety of maintenance policy optimisation projects, the AMPRT and RAMP Teams identified the value of collecting relevant MCD with appropriate levels of detail in an electronic format. This type of MCD has been demonstrated to enable asset managers to proactively manage their assets through:

1. trending/monitoring maintenance-related issues; and
2. determining the effectiveness and applicability of the existing maintenance policy.

Within the ADF Air Domain the RAMP Team is actively encouraging asset managers and maintainers to adopt the recommended MDIIs, which includes:

1. providing Continuation Training (CT) for maintainers for the collection of appropriately detailed MCD;
2. establishing MCD reviews at maintainer facilities;
3. encouraging the collection of electronic MCD; and
4. collecting progressive degradation maintenance data prior to an item becoming U/S.

It is acknowledged that for the above initiatives to be effective, there will be an impost on the asset management organisations with respect to providing personnel to action the above activities; providing training to personnel to ensure the activities are performed as required; and ensuring that processes are in place for the collection, storage and review of MCD in support of a proactive asset management framework. However, the benefits the ADF has already realised from employing these initiatives demonstrates a significant return on investment.

The ISO 5500X asset management framework identifies the need for performance monitoring and condition monitoring for a robust closed-loop asset management system. The MDIIs presented in this paper will aid proactive asset management practices as promoted by ISO 5500X.

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ARTICLE 2 – Optimizing a Groundline Corrosion Management Program for Steel Transmission Towers

John Kile1 & Nate Cecil[2], [1]General Manager, Steel Infrastructure Solutions[2],Senior Director, Steel Infrastructure Solutions, Logsys Power Services an Osmose Company

The vast majority of steel transmission towers in the United States were erected from the early 1950s to the late 1970s. The most common transmission tower type installed during this period was a stand-alone four leg lattice tower with direct buried steel grillage foundations. Most current upper level utility managers rose through industry ranks beginning their careers from the mid-1970s through the 1980s. When these individuals, who are now the decision makers for their respective utilities, were hands-on daily asset managers, the aforementioned steel transmission towers had been in service for an average of between 15 to 35 years. During the period when current utility decision makers honed their trade and grew professionally, they came to believe that corrosion was not a concern for steel transmission towers. At the time, they were correct.

Fast forward 35 years to 2019. These once young utility professionals have evolved and matured into executive level utility managers making critical system reliability decisions daily. These utility executive managers are the stewards of tens, if not hundreds, of millions of operational budgetary dollars annually. It is imperative that these executives target capital and operations and maintenance (O&M) dollars at the projects and programs

that mitigate risk, increase reliability, provide the most economy, generate the most revenue, benefit the rate payer and benefit the shareholder. Unfortunately, for many of these decision makers, their frame of reference regarding the corrosion risk for their steel transmission towers is based on their experience decades ago when they had little to no corrosion deterioration on their transmission towers.

The facts illustrate a different story. True – thirty or so years ago, many of these steel transmission towers were not exhibiting outward signs of corrosion deterioration. Decades ago, the standard practice was to use a hot dip galvanizing sacrificial coating on the steel to protect against corrosion of the underlying structural steel supporting the tower. As its name implies, a sacrificial coating is designed to deteriorate over time to protect what the coating covers. It has been demonstrated through years of field inspections of thousands of steel structures that a galvanized zinc coating in direct contact with soil will be partially to fully depleted approximately forty (40) years after it is placed in the direct buried environment. Once the sacrificial zinc coating is depleted, the underlying ferrous steel begins corroding exponentially in the absence of the sacrificial coating.

How is this corrosion risk message conveyed to the utility industry to protect the public, the rate payers and the investors who entrust their safety and resources to the utility? The message must be demonstrably proven to the decision makers at the utility. The following case study may be used toward that end.

1. STEEL TRANSMISSION CIRCUIT LIFE EXTENSION

The subject utility located in the southern United States has nearly 16,000 transmission circuit miles and over 40,000 steel lattice towers. For eleven years from 2006 to 2016, the subject utility's transmission asset management consultant/ contractor performed extensive steel tower inspections, corrosion mitigation and structural restorations to extend the life of the utility's steel tower assets as part of an asset management program. During the transmission asset life extension program for this 11-year period, 11,797 towers were evaluated with a full corrosion zone excavation (45 to 60 cm below grade) to identify structural reject foundations and to apply corrosion mitigating coatings to non-reject foundations. A total of 36,807 non-reject leg foundations were mitigated with coatings during the first full excavate first pass. During this same period, 10,381 reject leg foundations were structurally restored as a part of a second restoration pass. The life of all assets was extended approximately 20+ years because of these management processes.

The original program through 2016 was robust and significantly hardened the utility's steel tower grid, improving system safety and reliability, and extending the service life of the towers. However, the program was also indiscriminate in identifying actual risk and slow in progressing through the system. At the current pace and utility budget availability, it would take approximately 25 years to advance through the balance of the entire steel lattice tower transmission plant.

The utility requested a faster, more economical way to identify and harden the areas in the steel tower grid where corrosion was adversely affecting the structures at the groundline. Basically, the utility needed to determine the health of their remaining 25,418 uninspected steel transmission towers in a period of not greater than 3 years.

2. SOLUTION

Create an all capital asset life extension program to ensure attainable and reliable year over year funding.

Use data science to create an algorithm that incorporates tens of thousands of actual tower inspections, tower age, tower location, climatological and soil data, and machine learning to predict circuits where corrosion is most likely to be an issue.

Prioritize the remaining circuits for a field engineering study to capture the requirements for asset life extension based on the results of the predictive analytics.

Perform an accelerated in the field engineering study of the towers on the prioritized circuits that collects environmental readings and groundline steel section loss. The partial foundation excavation determines if groundline corrosion exists. The environmental readings will determine the structure's potential for corrosion, while the steel thinning measurements will reveal the actual structural condition of the tower.

Develop prescriptive individual tower solutions that will restore the original design strength and extend the life of the tower. In a turnkey all capital program, this process is the stage where concepts and designs

are finalized. Individual tower solutions may include one or more life extension requirements such as coating, restoration, cathodic protection, etc.

Execute the work to extend the life of the towers.

Generate increased rate of return, decrease present value revenue requirements and decrease total cost of ownership via new transmission system capital infusion.

Use follow on full excavate and coat pass on a 20-year cyclical basis to restore mitigation protection and to monitor the steel transmission asset health.

Result is a 40-year life extension of all circuits with a savings to the utility approaching $900 Million over the next 40 years by implementing an asset management program in lieu of asset replacement.

3. PROCESS

1. The utility provides all steel transmission asset data to include:
   a. Asset ages
   b. Latitude and Longitude coordinates
   c. Circuit ID
   d. Structure ID
   e. Structure Type
   f. Foundation Type
   g. Circuit Voltage Class
2. The contractor/consultant runs the source data through their proprietary predictive analytics algorithm.
3. Structural conditions for each asset and circuit are predicted.
4. Circuits are ranked in a risk priority from most severe risk exposure to least severe risk exposure.
5. The engineering study is performed. The engineering study includes:
   a. Inspect structure for mechanical damage and other overhead issues
   b. Partial excavation of each foundation to 20 cm
   c. Visual assessment to determine is significant corrosion is present
   d. Thinning measurements to determine section loss of steel
   e. Environmental reading to determine potential for corrosion
   f. Redox
   g. pH
   h. Structure to soil potential (VDC)
   i. Soil resistivity
   j. No coatings are applied during the engineering study
6. The predicted circuit risk rankings are adjusted based on the field findings and data collection from the engineering study
7. A restoration backlog is developed for all reject foundations
8. Restoration and mitigation designs are developed by the consultant/contractor's in-house staff of Professional Engineers
9. All restorations and mitigation on reject towers are completed in the next 10 years. This process restores the foundations to their original condition, extending the life of the system by 20 years minimum.
10. A second mitigation replenishment pass is scheduled and budgeted for 20 years after the commencement of the life extension program. This second pass extends the life of the transmission system an additional 20 years, for a total of 40 years of system life extension.

4. ENGINEERING STUDY RESULTS

- Towers having a minimum of 3 Priority Condition (greater than 50% structural thinning) reject foundations and towers with 4 Condition D (25% to 50% structural thinning) reject foundations were classified as requiring emergency attention. The engineering study discover 219 such towers.
- Priority reject towers had a least one foundation that was Priority Condition (greater than 50% structural thinning). The engineering study discover 393 such towers.
- Condition D reject towers had a least one foundation that was Condition D (25% to 50% structural thinning). The engineering study discover 2,468 such towers.
- Condition C reject towers had a least one foundation that was Condition D (10% to 25% structural thinning). The engineering study discover 2,015 such towers.

- Condition B towers were not rejects, and required no additional action during the first cycle of the asset life extension program. The engineering study discover 20,323 such towers.

5.LIFE EXTENSION REMEDIES AND COSTS

5.1 Basis for Run to Failure Model vs. Programmatic Asset Management Approach

- All Condition D, Priority and Emergency Reject towers were considered failed in place, as their current condition would no longer sustain the original design loads.
- Emergency Reject towers were deemed to require immediate restoration or replacement.
- Structural Priority Condition towers were deemed to require restoration or replacement within 6 months.
- Structural Condition D and more deteriorated were deemed to require restoration or replacement within 12 months.
- The model considered that 5% of structural Condition C reject structures would trend to Condition D each year.
- The restoration and mitigation costs were based on the currents rates in the consultant/ contractor's master service agreement with the utility.
- A tower replacement rate of $200,000 was assumed.

5.2 COST COMPARISON

- The cost to replace all Emergency Reject towers in Year 1 is $43,800,000 – run to failure option. Note replacement of these structures the current year is virtually impossible because of the time required for design, permits, procurement, etc.
- The cost to replace all Priority Condition towers in Year 1 is $78,600,00 – run to failure option. Same impediments to such an expedited start exist.
- The cost to replace all Condition D towers from Year 2 through Year 6 is $98,740,000 per year, or
- $493,700,000 total – run to failure option. Similar, but less severe, impediments to such an expedited start exist.
- The effect on replacement costs of Condition C structures trending to Condition D structural reject adds cost to the run to failure model beginning in Year 7 – annual cost of $17,810,000 for 20 years at a total cost of
- $356,200,000.
- The total cost over 40 years for the run to failure model is approximately $972 million.
- The cost to restore and mitigate all Emergency Reject towers in Year 1 for 20-year life extension is
- $5,700,000 – managed life extension option.
- The cost to restore and mitigate all Priority Condition towers in Year 1 for 20-year life extension is $2,750,000 – managed life extension option.
- The cost to restore and mitigate all Condition D towers in Year 2 through 6 for 20-year life extension is
- $20,000,000 – managed life extension option.
- The cost to restore and mitigate all Condition C towers in Year 7 through 11 for 20-year life extension is
- $2,700,000 – managed life extension option.
- The total cost for a 20-year life extension of reject structures is $41,950,00, or 4.3% of the replacement cost.
- At program Year 21, a 20-year mitigation replenishment cycle is commenced to remove and replace all below grade tower coatings as a part of the managed life extension option. The total annual present value cost for the coating cycle is $3,200,000. Thus, for an additional $64 million, the life of the transmission tower plant can be extended to 40 years.

The decision point for the customer is – Do you want to replace failing transmission towers with new towers with a design life of 60 years for $972 million, or do you want to extend the life of existing structures for 40 years for $106 million, a cost savings of 89%? The utility wisely allocated approximately $8 million of capital budget to fund the asset life extension program for fiscal year 2019.

ARTICLE 3 – Embedding Spatial Dimension in Asset Risk Profiling: Towards A Better Management of Community Assets in Auckland Council

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ABSTRACT:

Risk-based approach to asset management has increasingly becoming significant in asset-intensive industries in light of financial constraints and aging assets. Auckland Council with over $8.6 billion of community assets face similar constraints and are also exposed to a wide array of risk including significant flood risks. Despite the unknown probability of events, we believe a better understanding of the nature of the flooding risks is critical to recommending the appropriate asset management strategies. A flood risk analysis can be used to identify where flooding could most likely occur and its magnitude and the vulnerability of these assets and the treatments required to reduce or eliminate risk. . A range of geographical variables are analysed using the capacity of LIDAR data with 3D hydrological analysis, combined with a range of geographic variables and asset variables. The flooding risk variables identified from the spatial process

are analysed by the statistical procedure, Principal Component Analysis. A new principal component dataset was created to extract important variables and used to develop a regress tree model. The possibility score of the flooding risk are classified based on the building locations. The results of the analysis can be used to support asset management decisions such as the appropriate building design, construction methods, materials used and flood defence devices deployed. This study addresses the sufficiency of indicating variables and their suitability for flooding risk modelling and how it could be used for making longer term asset investment or divestment decisions such as relocating to another site or reconfiguring the facility for different usage.

Keywords: Provide keywords to assist with searchability of paper

1. INTRODUCTION

Risk-based approach to asset management has emerged in the discipline over last decade particularly in asset-intensive sectors. Sophisticated methodologies have been designed to identify asset risks in various industries, but not with the intention of necessarily reducing risk but in using it to balance asset performance against its life cycle cost. By having an acceptable asset risk exposure, asset expenditures are justified to maximise scarce and competing organisational resources. In this regard, risk management has become integrated into the industry's best practice in asset management such as in the ISO55000 (2014). Risk has been defined in the literature in many ways. It is normally associated with danger, loss, harm, damage (OxfordDictionaries.com, 2019). ISO31000 (2009) defined risk as a "chance or probability of loss". But this definition has recently been revised. Risk is now defined in ISO31000 (2018) as "the effect of uncertainty of objectives". This suggests that risk refers to both positive and negative consequences of uncertainty. It is usually expressed "in terms of risk sources, potential events, their consequences and their likelihood".

An increasing number of literature incorporates the spatial dimension in understanding and managing risk in the capital-intensive sectors, particularly in utility, transportation and energy. In fact, a number of studies have been conducted demonstrating how Geographic Information System (GIS) as a tool can be used for asset risk assessment. For instance, Baah et al. (2015) determined the risks of wastewater pipe failures of a mid-size city in Ontario, Canada by applying a risk matrix system and weighted scoring summation methodology. They calculated consequence of failure of sewage pipes by including spatial aspects such as proximity to hospital, school, building, river, parks, and downtown location. A GIS-based risk assessment and vulnerability analysis was developed by Inanloo and his colleagues ((2016) for transportation and pipeline infrastructure in downtown Miami, Florida. Spatial analyses were performed to estimate the affected population, area, and traffic flows. Lyu et al. (2018) conducted a flood risk assessment of the Guanzhou railway metro system using a GIS-based modelling approach. Hazard, exposure and vulnerability indexes were calculated based from various spatial variables such as rainfall, elevation, slope, land use, proximity to river, train line and road network. Furthermore, more sophisticated models have been developed for risk- based asset management in the utility and transport sectors which draw concepts and techniques from engineering, statistics, data science and artificial intelligence, amongst others. Christodoulou and his team (2009), for instance, presented a neurofuzzy decision support system for carrying out a risk-of-failure analysis to urban water pipe assets using data from New York City and city of Limassol in Cyprus. Catrinu and Nordgard (2011) discussed various methods for integrating risk analysis and multi-criteria decision support under uncertainty in the context of electricity distribution system. Spielhofer et al. (2016) proposed a comprehensive risk assessment framework including a decision support software tool for network level assessment of asset risk and impacts specifically for road asset management in Europe.

With the advent of extreme events including climate change, a growing body of literature in asset management have also attempted to incorporate these variables in risk assessment. For instance, Orcesi et al. (2016) proposed an optimisation framework for asset management for highway infrastructures which combines a degradation model with risk analysis for bridge components, retaining walls and steep embankments. His framework also accounts for challenges posed by climate change to determine optimal asset management strategies. In the energy sector, Komljenovic et al. (2016) proposed a high level risk-informed decision-making framework in asset management, which incorporates the risk of extreme and rare events as part

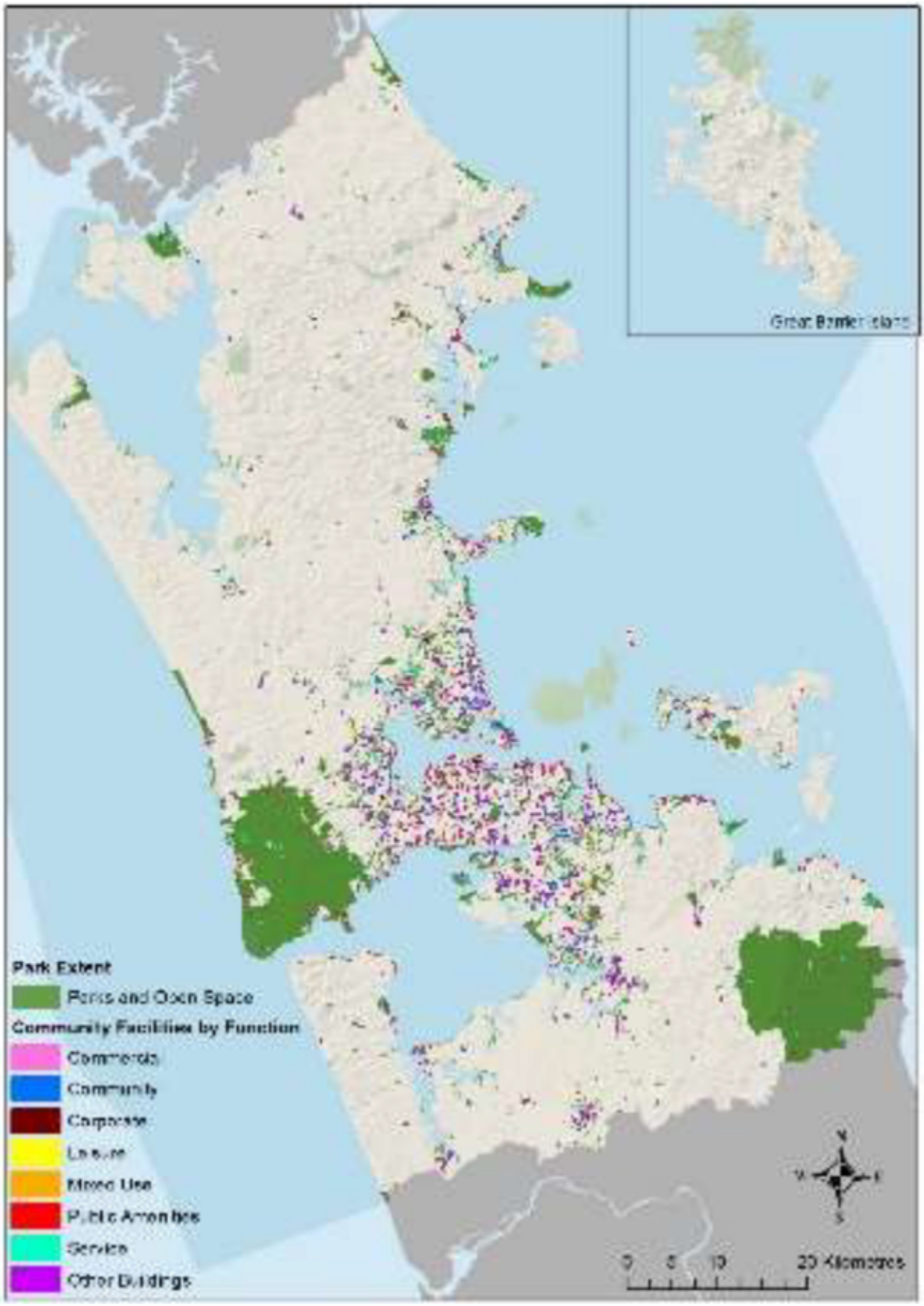


Figure 1 – Map of study area: Community assets in the Auckland region

of the overall risk assessment. Abkowitz et al. (2017) conducted an assessment of critical transportation assets in the State of Tennessee that are mostly vulnerable to extreme weather events, such as tornado, lightning, heavy snow, heavy rain and flooding, amongst others. Despite the advancement in knowledge and techniques in asset management through the inclusion of spatial dimensions in risks assessment, the majority of the work on risk-based asset management appears to have been focussed on network infrastructure, i.e. utilities, road and transport, and electricity. It seems to be that not much work has been done in looking at the spatial dimension of asset risk in community-based assets, such as parks and open spaces and community facilities.

In this context, the Community Facilities (CF) department attempts to explore how spatial dimension can be embedded in asset risk profiling of community-based assets using the Auckland region as a case study. CF considers community assets such as community buildings, parks and open spaces are of equal importance to utilities and transport assets. These assets deliver public goods to the community in terms of providing active recreation, passive recreation, social spaces and cultural spaces, all of which contributes towards better quality of living. In this study, flood risk has been identified as a form of extreme weather event given the fact that Auckland had experienced heavy rainfall and rare stormy weather patterns in recent years which caused flooding as well as coastal slips to many parts of the region. This study will address the sufficiency of indicating variables and their suitability for flooding risk modelling and how it could be used by CF to make longer term asset investment or divestment decisions such as relocating to another site or reconfiguring the facility for different usage.

2.THE CASE STUDY AREA: AUCKLAND REGION

In 2011, Auckland Council was formed with the amalgamation of eight legacy councils, which is by far the largest territorial local authority in Australasia. Its land area covers approximately 49,000 square kilometres (Auckland Council, 2015) with over $56 billion of infrastructure. The Community Facilities department is responsible for over

$8.6 billion worth of community assets (Auckland Council, 2018) that comprised of approximately 4,000 parks and open spaces (e.g. 32 regional parks, 190 sports parks, and 54 cemeteries); and over 3,000 buildings, (e.g. 55 libraries, 42 pool and leisure facilities, 40 art facilities, 191 community halls/ centres, and over 700 public toilets and changing rooms, amongst others. In addition, there are over 400 council buildings are on lease with various community groups and organisations and another 800 on ground leases (see Figure 1).

Occurrence of flooding is not uncommon to Aucklanders. A research of historic weather events compiled by NIWA (2018) revealed that the various parts of the region experienced flooding over the past century. Heavy rain in Auckland (10.90 cm in 48 hours) occurred from 22 -23 July 1928 which caused flooding in low lying areas. In 21 July 1935, heavy rain brought significant flooding in north Auckland, particularly in Wellsford and Warkworth, including the Auckland City's central suburbs. Due to heavy rainfalls and storm event from 28 February to 01 March 1966, the southern and eastern districts of Franklin, Manukau, Howick and Papakura, were severely flooded, which resulted to an estimated damaged cost of NZD 34 million. This event was repeated again in 16-17 February 1985 where many houses and properties were flooded in the south and east of the region, including Waiheke Island. In 25 May 1997, heavy rain (70 – 100 cm in five hours) in the Auckland metropolitan area caused flooding in the southern and western suburbs. In more recent years, the region experienced extreme flooding on 11-12 March 2017 caused by very heavy rain. In west Auckland alone, 65mm of rain fell in one hour. Floodwater swept over 300 homes, with waist- deep in some places. A number of regional parks in east of Auckland were closed and campers were evacuated to higher grounds. The most recent flood event in the region occurred on 03 February and 28 April 2018, which affected the west coastal town of Piha (Auckland Council, 2018). A number of residential properties, infrastructure, including community facility buildings, i.e. Piha Mill Camp, were inundated. The incidence of flooding in various parts of Auckland demands more investigation about flood risk associated with community facilities considering Council's significant asset portfolio on community buildings across the region.

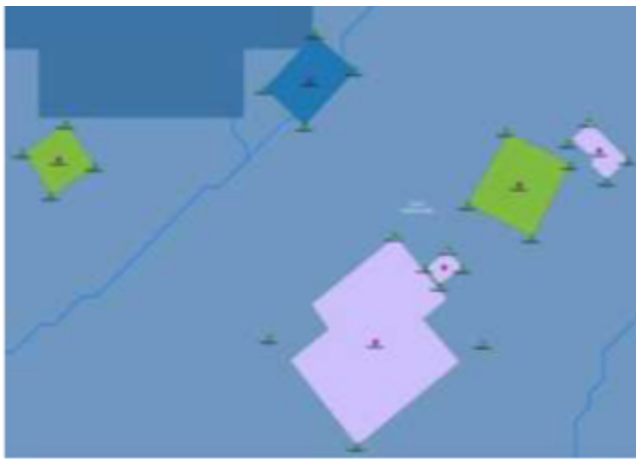
3. DATA AND METHODOLOGY

3.1 Spatial Data

This study used the following geospatial dataset from Auckland Council to undertake flood risk analysis of community assets, particularly council's building portfolio(see Table 1):

Dataset	Format/Description	Source
Community facility building	vector, polygon	Community Facilities Dept
Flood plain	vector, polygon	Healthy Waters Department
Flood prone area	vector, polygon	Healthy Waters Department
Overland flow paths	vector, polyline	Healthy Waters Department
Coastal inundation	raster	Infrastructure and Environmental Services
Digital elevation model	raster, from LIDAR regional scale, 2013	Geospatial Unit
Digital surface model	raster, urban only, 2013	Geospatial Unit
Slope	raster, regional scale, 2010	Geospatial Unit

A multi-method approach was employed in this study to undertake flood risk analysis of community buildings. This comprised of: (i) a spatial analysis; (ii) principal component analysis; and (ii) decision tree analysis.



3.2 Spatial Analysis

Figure 2 – Building corners and centroid generation in GIS

A total of 3,521 community buildings were subjected to this flood risk analysis. Corners and centroid of each buildings were identified based from its building footprint (see Figure 2). For each point location, GIS was used to extract multiple variables from vector and raster datasets. These include elevation, slope, building ground level, flood plain level, overland flow path, coastal inundation and stormwater catchment. Depression within the flood prone area were also identified by calculating the minimum level, spill level and depth of the flood prone. For each point location, the affected area and property values were divided by building area and building valuation. When all point locations are within any of above variables, then the entire building is considered as exposed to flood risk. Otherwise, if only some of the point locations are affected, only part of the building is exposed to flood risk. The results of this initial analysis show that there are 984 buildings exposed to one or more flooding risk factors. Of these, 409 buildings are entirely affected whilst 575 are partly affected. However, the above spatial analysis is just an initial high-level flood risk assessment. Following the initial spatial process, R based statistical procedures have been applied to the flooding factor analysis, and subsequently develop a tree-based model to classify flooding susceptibility.

3.3 Principal Component Analysis (PCA)

PCA is one of the most important algorithms in the field Data Science and is by far the most popular dimensionality reduction method currently used in data analysis (Lopes, 2017). PCA's objective is simple, i.e. identify a hyperplane that lies closest to the data points, and project the data onto it. In most cases, the hyperplane is determined by the axis through the dataset, which preserves the maximum amount of variance. In this case, the axis is referred to as Principal Components, also known as PC1 as it captures the maximum amount of variance within the dataset. The second principal component denoted as PC2 and is

orthogonal to the first, accounts for the largest remaining variance in the dataset. By formula, if there are a set of predictors V1, V1, …, Vp, the principal component can be expressed as (Analytics Vidhya, 2016):

PC1 = Φ1V1 + Φ2V2 + Φ3V3 + …. + ΦpVp Equation 1

where,

1 PC1 is the first principal component;

- p1 is the loading vector comprising of Φ, Φ2…for the first principal component; and
- V1… Vp are normalised predictors.

Therefore, the second principal component can be expressed as:

PC2 = Φ12V1 + Φ22V2 + Φ32V3 + …. + Φp2Vp Equation 2

If the first and second principal components are not correlated, their directions will be orthogonal. Consequently, the third, fourth, fifth, to the nth component that follows captures the remaining variation without being correlated with the previous components. As a rule, for n x p dimensional data, minimum (n-1, p) principal component can be constructed (Analytics Vidhya, 2016).

In the context of this study, a matrix of over 3,428 (n) observations of 14 different numeric variables (V) were identified (in red) based from the spatial analysis conducted above that are related to flood risks in community buildings (see Table 2).

As listed in the above table, the flooding risk variables derived from spatial analytical process includes the factors, numeric and asset information. To analyse the correlation between the topographic and hydrological variables and flood susceptibility, PCA was applied as dimension reduction procedure for pre-processing stage to develop the decision tree classification model.

Since there is a large p = 14, there can be p(p-1)2 scatter plots. That is to say, nearly 200 plots are possible for analysing this variable relationship. PCA was adopted in this study to remove the redundancies in the data by choosing the most important features that will still represent the entire dataset. By applying PCA to the flood risk dataset, the principal factors could be revealed. These principal factors best describe variations in the data by finding and clustering variables that measure the same theme. PCA computes for a new set of variables ("principal components") (see Table 3 - PCD Data Frame for Flood Risk) and expresses the data in terms of these new variables. Generally, the first principal components, PC1, PC2, PC3, and so on explain the most variance against the rest of the variables whilst the last component explains the least variance (Cheplyaka, 2017).

The PCA results in five (5) useful measures as above. Each column of rotation matrix contains the principal component loading vector.

Dataset	Type	Variables	Type
SAPID	Factor	Prone spill level	Hydrological - Continuous
Risk category	Factor	Prone depth	Hydrological - Continuous
Stormwater catchment	Factor	Overland flow catch area	Hydrological - Continuous
TYPE	Factor	Located building area	Financial - Continuous
Building point type	Factor	Affected building value	Financial - Continuous
Distance to building footprint	Topographic - Continuous	DESCRIPTION	Asset Information
Building centre ground level	Topographic - Continuous	AssetType	Asset Information
Elev diff to bldg. ground level	Topographic - Continuous	AssetGroup	Asset Information
IDAR DEM 2013	Topographic - Continuous	AssetGroup	Asset Information
LIDAR DEM 2013	Topographic - Continuous	Streetnumber	Asset Information
Urban DSM_2013	Topographic - Continuous	Streetname	Asset Information
LIDAR slope all	Topographic - Continuous	Site	Asset Information
Coastal inundation SLR0Depth	Hydrological - Continuous	Sitedescription	Asset Information
Floodplain level	Hydrological - Continuous	Localboard	Asset Information
Prone minimum level	Hydrological - Continuous	Plannergroupid	Asset Information

Table 3– PCD Data Frame for Flood Risk

1	10002-B002	Rec Corner Points	-1.14463196	-0.798028196	0.4535105518	0.398764301	-6.365852e-02
2	10002-B002	Rec Corner Points	-1.14520694	-0.726831294	0.3737788058	-0.088282659	-3.573940e-02
3	10011-B001	Centroid	2.10627050	-7.635911390	-2.1232152411	-0.552805222	-5.982695e-01
4	10018-L001-102	Rec Corner Points	0.46153190	-0.821827158	1.7054278681	0.143232651	1.239880e-01
5	10018-L001-102	Rec Corner Points	0.44105550	-0.827399191	1.6539150946	-0.088747419	2.581679e-01
6	10019-B001	Centroid	9.27937211	-1.680423616	3.4246070616	-0.771561067	7.928238e-02
7	10019-B001	Rec Corner Points	9.14289965	-2.401251926	4.0522320949	3.164382095	2.351308e-01
8	10019-B001	Rec Corner Points	7.92473406	-2.272791721	4.2129904377	-1.179477317	1.379910e-02
9	10019-B001	Rec Corner Points	7.94897571	-2.163263270	4.2226774377	-1.356240704	-2.514357e-01
10	10019-B001	Rec Corner Points	9.20870598	-2.019040667	3.6154428164	0.639814508	3.934834e-01
11	10019-B002	Centroid	9.12719585	-1.361719319	3.6536549789	-0.881957016	1.263070e-01
12	10019-B002	Rec Corner Points	9.13985514	-1.465783413	3.7607464532	-0.187177113	1.052806e-01
13	10019-B002	Rec Corner Points	9.30132501	-1.307251539	3.6495649019	-0.702659590	-1.331471e-02
14	10019-B002	Rec Corner Points	9.01752408	-1.384204175	3.6776114068	-0.933995109	1.390232e-01

Table 4 shows the proportion of variance explained by each principal component. The first principal component explains 38.673% of variance. The second component explains 14.8% of variance whilst the third component explains 12.4% of variance, and so on. The higher the variance, the higher will be the information contained in those components.

For the purpose of retaining as much information as possible using these components, it is important to find out how many components should be selected for decision tree analysis. On this regard, the summary of the PCA results revealed that the first five (5) principal components have covered 82.6% of the information identified from spatial flooding risk analysis (see Table 5, Figure 4 and Figure 3).

Table 4 – Proportion of variance explained

[1]	3.866048e-01	1.480361e-01	1.241556e-01	9.479745e-02	7.257731e-02	5.811796e-02
[7]	5.451651e-02	3.342442e-02	1.470894e-02	8.943835e-03	3.812528e-03	3.045195e-04
[13]	1.448585e-09					
[19]						

Table 5 – Summary of importance of components

Importance of components:									
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Standard deviation	2.3265	1.4396	1.3184	1.1520	1.00801	0.90203	0.87363	0.68406	0.45379
Proportion of Variance	0.3866	0.1480	0.1242	0.0948	0.07258	0.05812	0.05452	0.03342	0.01471
Cumulative Proportion	0.3866	0.5346	0.6588	0.7536	0.82617	0.88429	0.93881	0.97223	0.98694

Figure 3 – Percentage of explained

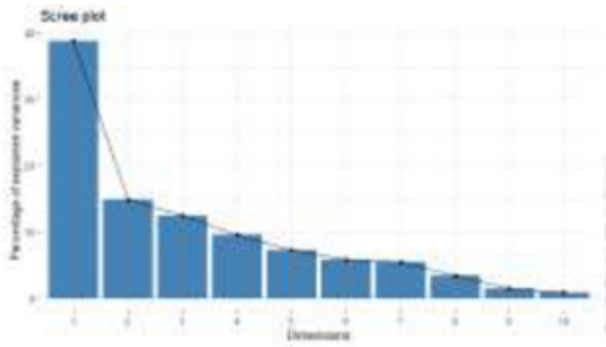


Figure 4 – Cumulative proportion of variance variables explained

Figure 5 – Factor map of contributing

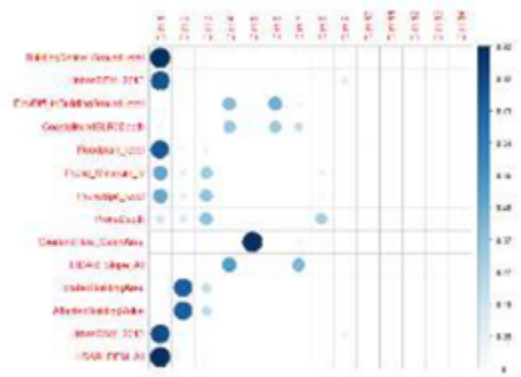
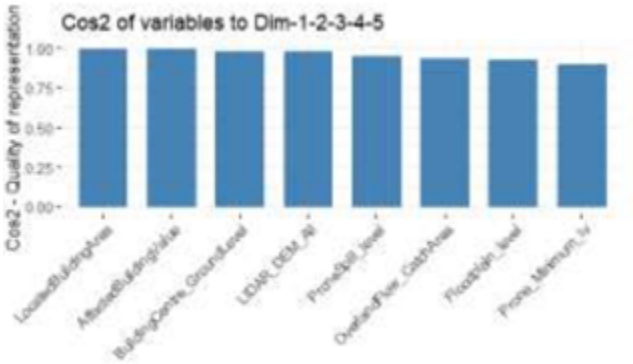


Figure 6 – Quality of representation (Cos2) for principal components



The next phase is to understand which variables contributed to the principal components. The variables correlated with PC1 to PC5 will significantly explain the variability in the dataset. Variables that do not correlate with any PC or correlated with the last dimensions are variables with low contribution and have been removed to simplify the overall analysis. The contribution of each variable to the PCs was mapped on a factor map (see Figure 5).

Before mapping, below is a summary of the first four (4) variables that contributed to the principal components (see Table 6 - Summary for first four contributing variables):

The quality of representation (Cos2) from the results of the PCA can also be shown using a bar plot of variables (see Figure 6).

From the above plot, high Cos2 indicates a good representation of the variable on the principal component. In this case the variable is positioned close to the circumference of the correlation circle. A low Cos2 indicates that the

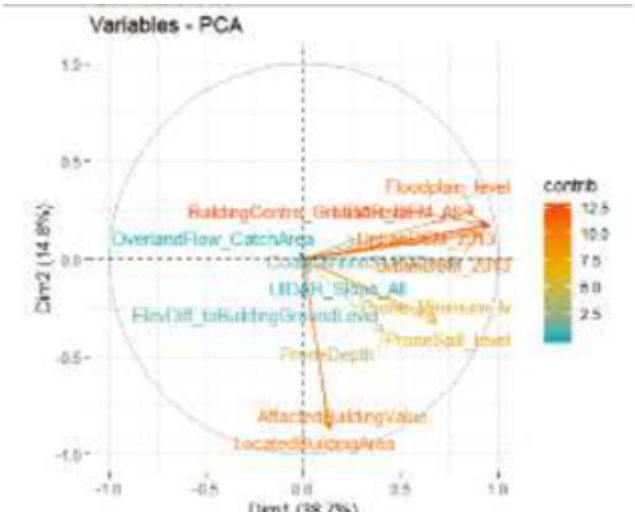
variable is not perfectly represented by the principal components. In this case, the variable is close to the center of the circle (see Figure 7).

Table 6 – Summary for first four contributing variables

	Dim.1	Dim.2	Dim.3	Dim.4	Dim.5
BuildingCentre_GroundLevel	9.103239e-01	0.02925864	0.034911223	0.006813075	1.826738e-04
UnbanDEM_2013	7.957177e-01	0.02019069	0.030618728	0.005137834	1.357984e-05
ElevDiff_toBuildingGroundLevel	1.272755e-05	0.04428808	0.003924881	0.400113303	4.438542e-02
CoastalInundSLR0Depth	6.812092e-02	0.01042674	0.005432006	0.339661094	2.775883e-02

By looking at the plotted high Cos2 values in the dimension 1 - 5 (see Figure 5 and Figure 6), most correlated variables for the decision tree modelling can be identified in the following order: (i) building area location; (ii) affected building value; (iii) building centre ground level; (iv) LiDAR DEM; (v) prone spill level; (vi) overland flow catchment area; (vii) flood plain level; and (viii) flood prone area minimum level. Based from the plots above the first two variables - building area and affected property values – have higher values, whilst other variables contribute almost evenly to the next modelling process. In summary, through PCA, five principal components which contributes from seven (7) flood risk variables have been identified. The new PCA data frame will be used as a basis to develop the decision tree model as the next step

Figure 7 – Bi-plot diagram for principal components



3.4 Decision Tree Analysis

One of the most important technique in machine learning and data mining application is tree-based modelling. Decision tree modelling can be used both in regression and classification problems. It works for both categorical and continuous input and output variables. It requires derived data into training and test dataset. There are various approaches to construct decision tree, the most common method is called classification and regression tree (CART) approach developed by Breiman et al (1984). As described in the previous section, PCA was carried out as a pre- processing stage for the decision tree learning algorithm. A new data frame comprised by the principal components for the decision tree model is now available to classify flood susceptibility of community building locations. Since all six (6) principal components are numeric and continues, a regression tree algorithm is appropriate for the classification (see Figure 8).

In this study, a regression tree has been developed by calculating the principal components on the training data set. A regression tree was then fitted by the statistical method of "anova" in the tree model in R. When the model was fitted, a summary below explains the steps of the splits (see Table 7).

The tree started with 3,438 observations at the root node and the first variable split on is PC1. It covered 44% of the most important variables. As you may recall, the PCA Cos2 results on the factor map (Figure 5), there are seven (7) variables that contributed to PC1. The are 659 observations that directly ended up to the leftmost terminal node with a variance score of 299. The rest go to second branch of the regression tree and subsequently split further into seven (7) terminal nodes, altogether indicating predicted importance value (seeFigure 9).

By visualising the developed full tree as above (refer to Figure 9), the percentage of data that falls to the node and the average PC values are displayed for the branch. Basically, the tree has six (6) internal nodes resulting to seven

(7) terminal nodes. Although this model used the five (5) principal components to develop the model, this visual diagram of the tree is partitioned to the first

Figure 8 – Principal components data frame for regression tree

```
> str(Regtrain.data)
'data.frame':   3438 obs. of  8 variables:
 $ SAPID                    : Factor w/ 941 levels "10002-B002","10011-B001",..: 1 1 2 3 3 4 4 4 4 4 ...
 $ Reg_train.BuildingPoint_Type: Factor w/ 2 levels "Centroid","Rec Corner Points": 2 2 1 2 2 1 2 2 2 2 ...
 $ PC1                      : num  -1.145 -1.145 2.106 0.462 0.441 ...
 $ PC2                      : num  -0.798 -0.727 -7.636 -0.822 -0.827 ...
 $ PC3                      : num  0.454 0.374 -2.123 1.705 1.654 ...
 $ PC4                      : num  0.3988 -0.0883 -0.5528 0.1432 -0.0887 ...
 $ PC5                      : num  -0.0637 -0.0357 -0.5983 0.124 0.2582 ...
 $ PC6                      : num  0.572 0.457 -0.61 0.815 1.07 ...
```

three principal components only. This is because, behind the scenes the model is automatically applying a range of cost complexity to prune the tree. In actual practice, an original tree can be pruned to a smaller size to experience similar results within a small margin of error (University of Cincinnati, 2018). The plot below (see Error! Reference source not found.) provides a cross-validation error for each split which can be used to prune the tree. The one with the least cross-validated error is the optional value of control function (CP) given by the function. After pruning, the internal nodes reduced to four (4) and the terminal nodes reduced to six (6). After completing the tree model from the training data, the model was applied to the test data and the original training data to predict the index value to represent flood risk to community building locations (see Figure 10)

Table 7-Summary of regression model for flood risk classification

```
      CP nsplit rel error    xerror       xstd
08439431      0 1.0000000 1.0004901 0.01461473
03325998      1 0.9156057 0.9271855 0.01579324
02295409      2 0.8823457 0.8946634 0.01626919
02039204      3 0.8593916 0.8780049 0.01673146
01393806      5 0.8186075 0.8315045 0.01652309
01321547      6 0.8046695 0.8235783 0.01660692
01000000      7 0.7914540 0.8209061 0.01686906

able importance
PC2 PC3 PC5 PC6 PC4
 25  17   6   4   4

 number 1: 3438 observations,    complexity param=0.08439431
an=464.3583, MSE=76519.58
ft son=2 (659 obs) right son=3 (2779 obs)
imary splits:
  PC1 < 1.349798     to the right, improve=0.08439431, (0 missing)
  PC2 < 0.5858627    to the right, improve=0.03322042, (0 missing)
  PC6 < -0.5225018   to the right, improve=0.02240253, (0 missing)
  PC3 < -1.618262    to the left,  improve=0.01956980, (0 missing)
  PC4 < 1.448618     to the left,  improve=0.01558671, (0 missing)
rrogate splits:
  PC2 < 1.277535     to the right, agree=0.866, adj=0.303, (0 split)
  PC3 < 1.824528     to the right, agree=0.857, adj=0.255, (0 split)

 number 2: 659 observations
an=299.3354, MSE=66021.15
```

Figure 9 – Regression tree for training data

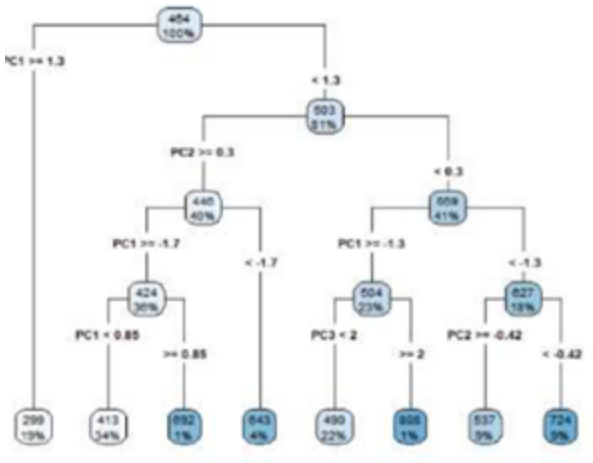


Figure 10 – Pruned Tree for flood risk training data

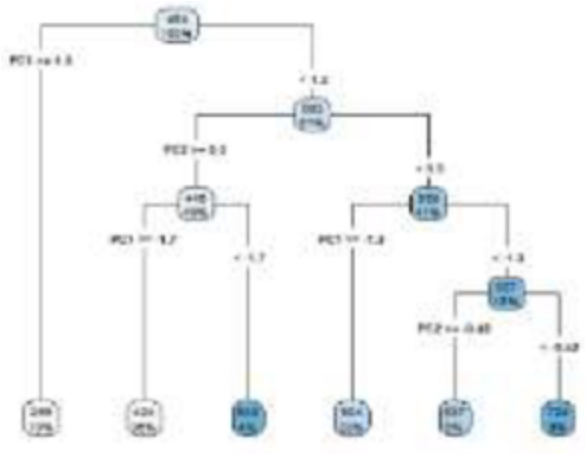


Figure 10 – Cross Validated Error

RESULTS AND DISCUSSIONS

The decision tree model was used for mapping the predicted score for flood risk index based from the results of the principal component analysis and spatial analysis of various geographical variables. Table 8 shows a summary of the 984 buildings by function and that are exposed to one or more of flood risk factors together with the average flood risk score. There are total of 706 CF buildings are identified under the flooding risk. 324 of them are whole buildings within one or more flooding risk. The others are part of building affected by the flooding risks. The table also shows the average index of the flooding risk predicted by the regression model based on the building functions. Except of the buildings which are not classified by the function, the commercial buildings have relative high index of the flooding risks.

The Table 9 shows the predictor values of each predictor variable from the decision tree. The buildings exposed to the coastal inundation areas have highest index for the flooding risks. For the buildings where the ground level is lower than the spill level of the flood prone area, they have the second highest average index of the flooding risks.

This prediction indicates the physical location and the ground height of the of the buildings are very important factors to decide if the buildings are exposed to the flooding risks.

For visual and easy interpretation, the predicted index was mapped in GIS (see Figure 12). To make a visual representation, the index was based on the six (6) terminal nodes of the decision tree. The map shows the spatial distribution of flood risk index based from the number of observations, i.e. 3,428 building point locations taken from 984 buildings exposed to one or more flooding risk factors. The lower the score, the lower the risk of flooding. The higher to the index, the higher the risk of flooding. The spatial distribution of the flooding risk index is correlated with the table 9, the high flooding risk areas are close or along coastal areas. When we zoom in the exam the flooding risk index by the building locations, we can see the difference of the building external ground level and building ground level is also important factor for the flooding risk. If the building ground level is higher than the external ground level, the buildings have lower flooding risk or won't be exposed to the flooding risk.

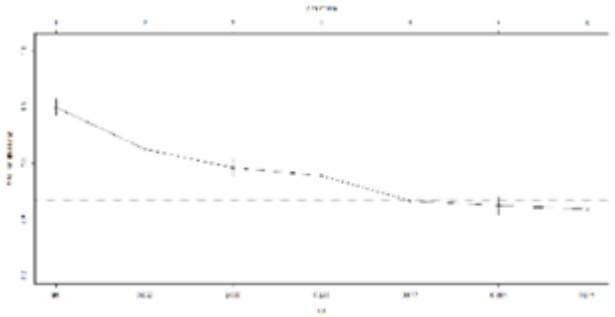


Figure 11 – Cross validated error

Table 8 – Summarry of community buildings with flood risk

Table 9 – Predictor importance

Predictor Variables	Minimum Predictor Value	Maximum Predictor Value	Minimum Predicted Flooding Risk Scores	Max Predictor Flooding Risk Scores	Mean Predictor Flooding Risk Scores
Costal Inundation (Depth, m)	-2	2	413	724	579
DEM Lower Spill Level (m)	0	18	490	537	496
Flood Plan Level (m)	0	249	299	808	445
Spill Level - Flood Prone Area (m)	0	76	299	808	425
Minimum Level - Flood Prone Area (m)	0	3074	299	808	464
Main Overflow Path (m2)	3000	25748964	299	692	419
AffactedBuildingValue ($)	168	9220621	299	808	464
Building Ground Level (M)	-1	248	299	808	464
Difference Betn Extennal conner to Building ground centrial H (m)	-6	5	299	808	464
Located Building Area (m2)	0	3074	299	808	464
Affacted Building Value ($)	169	3074	299	808	464
LIDAR DEM (M)	-2	3074	299	808	464

Figure 12 – Decision tree predicted scores of flood

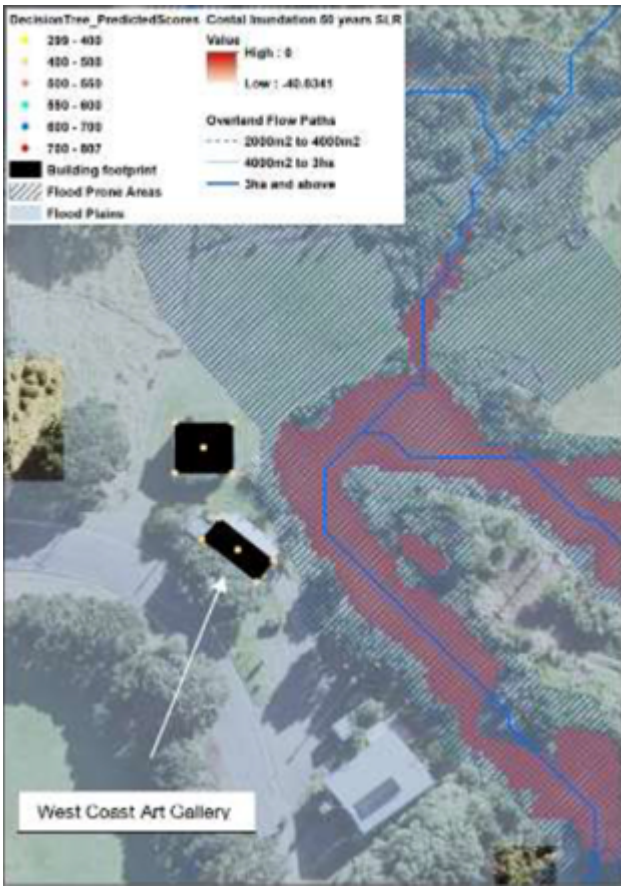


Figure 13 – West Coast Art Gallery Location Map

Figure 13 – West Coast Gallery in Piha

To further validate the results, a specific example of a building that is known for flooding has been examined. In this case, the West Coast Art Gallery in the coastal town of Piha has been selected (see Figure 13). This building is owned by the Council and used to be the old volunteer fire station. A group of local artists saw the possibility of converting this building into an art centre for the local and wider community. The building is currently under community lease. It was affected during the April 2018 local flood incident.

The map above shows the location of art gallery (see Error! Reference source not found.. It is situated within the flood plain, and is closed to the flood prone area, coastal inundation zone and overland flow paths. Its predicted score is 489.61 and is true for all corners including the centre and whole building is under the flooding risks.

3.5 Conclusions and Implications

This study attempted to explore how spatial dimension can be used in asset risk profiling of community assets in Auckland, particularly council's building portfolio. The use of GIS combined with machine learning approaches, principal component analysis and decision tree analysis. The study has investigated a wide range of spatial factors associated the flooding risks by the spatial analysis. The identified variables are evaluated by Principal Component Analysis. Through the pre-process analysis for the decision tree, the principal components PC1 to 5 are identified. The 8 variables correlated with PC1 to PC5 significantly explain the variability in the dataset. The simplified dataset by the PCA were used as input to develop the classification tree. The regression tree predicted the importance of the variables for the flooding risks. The spatial distribution of the predicted values has revealed the areas and factors which exposed to the high risk of the flooding. This study has proved that combination of the spatial process with machine leaning have advanced the analytics in flooding risk management. However, to achieve accurate modelling, we need to investigate more related factors to be added into this process.

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STAR PROFILE – Subhadip Sengupta CPAM

1. Why asset management?

Cost optimisation is key to any business, and for asset intensive industries like, oil & gas, petrochemicals or transportation, it is important that we optimise costs with as low as reasonably practical risks for the benefit of all stakeholders including our communities. As an engineering professional working in maintenance, turnaround execution, troubleshooting, equipment condition monitoring, plant commissioning, RCM, RBI, root cause analysis, RAM analysis for last 18 years, asset management becomes a default option as it encompasses all of them.

2. How long have you been working in the asset management sector?

I have been working for past 18 years, primarily in petrochemicals and natural gas processing companies in India, Saudi Arabia and UAE. I have also worked in consulting firm for roughly for a year as a senior consultant.

3. What is your speciality?

My speciality areas are rotating equipment, vibration analysis, and reliability engineering. I am a Certified Reliability Engineer by ASQ (American Society of Quality) since 2013 apart from being CPAM recently. Some of key skills include, Asset optimization, Maintenance & Reliability practices, Reliability Cantered Maintenance (RCM), FMEA/ FMECA, Risk Based Inspection (RBI), Reliability, Availability and Maintainability studies.**4.**

4. What drew you to explore more about this Reliability Engineering?

'Reliability' is a very common term used in personal life as well as working life. Many people and have different perceptions about 'reliability', and the term is being tied up with many things. However, the fact is it is a technical domain with a heavy reliance on statistical concepts. Reliability engineering concepts explore the power of data and helps in taking decisions related to assets. This analytical aspect of reliability engineering drew me towards it.

5. What is the best career advice you have ever received and who gave it to you?

The best career advice I received, was during my initial years from one of my managers. It was, "Take charge of your own learning and development". When we are in school or University, there is a curriculum for our learning which we need to complete in certain number of years, but that is not the case when you are in your professional life. You can learn many things in less amount of time, if you take a little more initiative and plan your professional development plan accordingly.

6. What makes a great asset manager?

I n my opinion, you have to have analytical skills, leadership skills if you want to be a successful asset manager. A strategic view of the business and ability to take data driven decisions are essential skills for a great asset manager.

7. What is the most exciting trend that you have noticed in asset management today?

The most exciting trend in asset management is 'digital transformation' like many other fields or businesses. 'Big Data' and 'analytics on edge' are here to make our life easier. However, fundamentally it may not change the asset management concepts, but shall facilitate data contextualization, data mining, data cleaning, statistical inference and predictive analytics. Also, we would be able to process huge amount of data and generate a dynamic, holistic and overarching view of our assets with much less efforts.

8. What is the biggest challenge facing the asset management sector today/your particular field of asset management today?

Drive to optimise costs while maintaining the safety and reliability of our assets. Also, we need to align ourselves with the financial functions in order to avoid ambiguities. The latest AM standard (ISO 55010) published last year, provides now a guideline to achieve this alignment. However, we as asset management professionals should take a proactive effort to eliminate any misalignment.

9. What is your proudest career achievement?

I think my proudest moment is yet to come. However, I cherish one of my achievements which happened in Saudi Arabia, when I had played a key role in ensuring an engineering modification in two most critical equipment of a polymer plant, before commissioning, which significantly reduced the high vibration issues.

10. What's next for you?

I would like to contribute in AM by establishing a living process to improve reliability of assets through the development, enhancement and ensuring the implementation of effective asset management systems in industries like oil & gas Energy, manufacturing, transport. Lead initiatives related to the digitalisation and predictive maintenance through machine learning. Advice and support stakeholder group and implementing reliability related activities by mentoring, facilitation and coaching cross functional teams. I am also looking forward to work in asset management roles in Australia or engineering consultancies operating out of Australia.

11. When you're not busy at work, what do you enjoying doing to unwind/relax/explore?

I enjoy being with my family and friends when I am not busy at work. I enjoy playing cricket with my friends during weekends here in UAE. I also love photography and like to travel in different places to explore different cultures.

Mr. Subhadip Sengupta is working as Senior Engineer, Reliability, in Operations Excellence Division of ADNOC Gas Processing. He supports the establishment of structured Reliability Management processes across the organisation to improve business results. He has more than 18 years of experience, spaning in three countries, in Condition Monitoring, Reliability Centered Maintenance, Root Cause Analysis, Reliability Modelling with Petrochemical and Oil and Gas Industry. He is a certified reliability engineer (CRE) by American Society of Quality apart from being a RPEQ and MIEAust and CPAM.

Subhadip recently achieved his Certified Practitioner of Asset Management (CPAM). To find out more about our internationally recognised certification scheme, visit www.amcouncil.com.au/certification

STAR PROFILE – Gilbert Moore CAAM

1. **Why asset management?**

   It became a natural progression from my technical trade foundations and working in maintenance management for many years. I became further enlightened to asset management through my postgraduate studies and utilisation of my membership with the AM council. By attending events, and interacting with others, I continue to learn about how asset management is being applied in ways I did not appreciate previously.

2. **How long have you been working in the asset management sector?**

   Can I say that from the time of working in my dad's bike shop at 11? After I finished school, I enlisted in the Australian army and completed a Fitter Trade in the Army apprentice school in 1994. Then through various roles of Fitter Supervisor, Planner, Technical Integrity and others, I was exposed to a wide variety assets and asset management systems and processes. I did not realise it at the time, but these foundations have served me very well over the last 35 years.

3. **What is your speciality?**

   Maintenance planning, process and budgeting. Numbers are my thing, I work to help others around me with business cases or improvement opportunities, through the use of company data. I am able to link basic work order tasking all the way through to strategic level asset management documentation.

4. **What's the best career advice you've ever received and who gave it to you?**

   I'm not sure where I heard it – but the "Culture eats strategy for breakfast". I know it's not quite that black and white – you need both to succeed. When I apply it on a personal level, each time I focus on this phrase, I have had successful outcomes.

5. **What makes a great asset manager?**

   In recent times I fellas thought asset management has moved away from simply data and processes to people engagement. I think that a great asset manager, amongst other skills, needs to be able to read people, workplace culture AND data in order to clearly communicate the asset strategy. They must also be able to talk to the "techs" as well as the Senior leaders. The Asset management framework touches (or at least should) every person in the organisation and ,therefore, the good asset manager needs to be able to engage at all levels.

6. **What is the most exciting trend that you've noticed in asset management today?**

   The use of real time company data and where that data can be applied to the decisions being made around asset performance. In particular I'm interested in how maintenance and operations are being integrated into "one team, one dream". Most organisation have an operations planning department SEPERATE to the maintenance planning department. It creates a challenge for the Operator and Technician, to make the "correct operational choices" whilst protecting the asset for the life of the asset.

7. **What is the biggest challenge facing up-and-coming asset managers today?**

   The complexity of the modern working life combined with the breadth of the asset management portfolio. Trying to remain focused with so many projects, both minor and major in nature, required to meet business operational needs as well as managing the asset life cycle plan appropriately.

8. What advice would you give to an up-and-coming asset manager today?

One of my references for my recent CAAM certification speaks about "people, process and systems" as being the foundation in this area. If any one area is weak then this "tripod" of success will be uneven. A new manager in this space needs to be able to determine if it is people, system or process issues that is limiting the company achieve the required asset performance. Only then can they help close the gap by addressing the individual training required, or process and system improvements that maybe required to support the other two legs of the tripod.

9. What is the biggest challenge facing the asset management sector today/your particular field of asset management today?

Integration of the maintenance planning and operations planning teams. There are a number of companies working on this and I look forward to exploring this area on a personal level, I will watch with interest how they tackle this issue.

10. What is your proudest career achievement?

Working in high performance teams. I was able to work within those teams and contribute towards a common goal. On one occasion the operations staff recognised these efforts and presented me with a small token of appreciation for my (and my teams) efforts, being recognised by them was indeed a proud moment.

11. What's next for you?

Soon I will be transitioning into a new role, I hope to continue to share my experience in blending the maintenance and operations scheduling in the rail environment. In the near future I'd like to explore more opportunities around becoming an Asset management auditor, this was something I have had previous exposure to that I really enjoyed..

12. When you're not busy at work, what do you enjoying doing to unwind/relax/explore?

I like spending time out doors with friends and family. When not doing that, I am trying to beat my uncle's at golf, I am living proof that accuracy (them) beats distance (me) every time.

Gilbert recently achieved his Certified Associate of Asset Management (CAAM). To find out more about our internationally recognised certification scheme, visit www.amcouncil.com.au/certification

Babushka Dolls and Asset Management

by Linda Kemp, Communications Specialist, Asset Management Council

At the Asset Management Council's recent Asset Management in Government Symposium, one of our presenters, Deanne Leaver, gave the delegates an inspiring visual hook to highlight the complexities of asset management: Babushka dolls.

As soon as the PowerPoint slide was displayed, along with Deanne's linking phrases, everyone in the room sat a bit higher in their seats, their interest well and truly awakened. In every break following her presentation, Deanne was constantly surrounded by attendees; her popularity further cementing my view that her analogy was a winner. I was delighted to finally get my turn to sit alongside Deanne, and I jumped straight into my proposal: an interview where I could find out more about her role and her amazing analogy. It was my real pleasure to spend thirty minutes with Deanne, and our time together forms the basis of this article.

Deanne is the Director for Asset Strategy at Victorian Health and Human Services Building Authority (VHHSBA—pronounced vezba). She manages a massive portfolio of $23billion assets , including a multi-disciplinary team of professionals focussed around the technical areas of, community building, environmental sustainability, property, medical equipment, engineering services and of course, asset management.

Deanne humbly states, 'my role is to lead the leaders.'

Her team works in and out of all stages of both asset and project life-cycles, including front-end planning, ideation of business cases, and securing funding. In the mid-section of the project the team works alongside the designers, and finally, moving into the acquisition stage, there is involvement with back-end design and construction and then into the operations phase by providing advice to health services who operate the assets and deliver the day-to-day services. To sum, her team identifies the opportunities that will build value in the highly complex system known as public health.

As you can likely imagine, no two days look the same. Deanne is part of the 5AM club; an early riser, she heads to the office gym to set the tone of her day. By 8AM, she is at her desk, but that is often where the similarities end. Some days, she can be in work boots, hard-hat and jeans on a construction site; other days she'll be in the office, dressed in corporate attire, going from meeting to meeting. VHHSBA offers flexible working arrangements, and through this arrangement, Deanne has Strategic Wednesdays: a day where she works from home, catching up on the vast quantities of reading materials, and an opportunity to plough through the paperwork that can easily mount up on her desk.

Early in her career, Deanne was given a golden nugget of advice. Called the 1-3-5 rule, she attempts to work by this rule each day by aiming to tackle one big task, three medium-sized ones, and five little jobs. This rule gives her a sense of accomplishment and control of her days. I interrupt Deanne to ask how she determines a task's size.

Deanne responds, 'In terms of a big task, I don't consider it has to be really big, like writing a policy. It could be tackling a difficult conversation with a stakeholder. It's not time-driven, nor about the size of the task, but more about how it adds value to the business.'

Anyone working in asset management knows the underpinning element of any asset management strategy is to build value for the business, which gives me a perfect segue to Deanne's well-lauded analogy of the babushka dolls. For Deanne and her team at VHHSBA, the analogy of the babushka dolls came about through meeting the obligations of the Victorian government's asset management policy, the Asset Management Accountability Framework (AMAF).

As those reading in Victoria will know, the AMAF is broad, with a wide scope for meeting requirements according to the assets operated within a particular department. Newly into her role, Deanne discovered the AMAF was about to go into implementation yet there had been very little done towards preparation. Deanne and her team established VHHSBA's Asset Management Establishment Project using four

key work streams to fit within: Data, Strategy, Business processes and Competency. However, it soon became clear that the complexities of the AMAF and the layering aspects of an asset framework were not gelling with partnering executives. Until in one meeting, quite organically, Deanne mentioned, 'It's like a babushka doll. It all fits inside.'

It was a lightbulb moment. Everyone hooked onto the visual. Deanne turned to her project director and said, 'Right, that's how we're explaining it from now on.'

Since then, Deanne has used the visuals of babushka dolls as a way to explain a clear line of sight from the organisation's strategic directives down through its plans and policies. Within a set of five dolls, VHHSBA starts with the organisations strategic plan, the Statewide Design Services and Infrastructure Plan, the Asset Management Policy to the Asset Management Objectives and KPIs embedded within the Strategic Asset Management Plan completing the set. Deanne famously says, 'a babushka of asset management'. When I ask if the AMAF is a helpful policy or one that hinders her workload, she responds with, 'The AMAF is really helping us in our area. I was told as a new executive there are three things that you don't want to do. You don't want to break the law, you don't want to break the bank, and you don't want to break your trust to the public. And the AMAF really gives us the prescription to build and optimise our asset management practices. It gives us that authorising environment to shift to a proactive state.'

Deanne proudly notes that within the health system, Victoria delivers the some of the highest standard of care and outcomes, particularly when compared with similar systems globally. However, it is also under increasing pressure with unprecedented population growth. In the health sector, other pressures include chronic disease, higher community expectations for more convenient services, all coupled with the fact that Victoria's asset base is aging. Deanne believes that the AMAF is most definitely helping her team to work with agencies to collectively think different and to shift the dial from a reactive to a more proactive asset management space.

It's interesting to note that VHHSBA is a very new business, only operational since 2017. But within the Department of Health and Human Services and VHHSBA, there is great support for asset management strategies and practices. When AMAF was introduced, Deanne's CEO provided a gateway for an executive steering committee. Support was also cross-governmental with Victoria's Department of Transport getting on the journey to provide assistance with foundational structures. The challenge for VHHSBA lies in bringing asset management in everyone's day-to-day tasks. Given that Deanne's team do not operate and maintain the assets, control is relinquished past the policies themselves; the adoption of those lies with the health services and agencies.

To bring our conversation to a close, I ask Deanne to provide me with a glimpse into her life outside VHHSBA.

I am not surprised when she reveals her favourite season to be summer, as her warm personality has radiated throughout our chat. For Deanne, there is an increase to her quality of life on a balmy evening, being able dine outdoors and spend time with her children as the sun sets late on a busy day.

Of course, summer in Australia includes Christmas and I'm again unsurprised when Deanne tells me she lives in a community where everyone decorates their homes with Christmas lights. Many people come to meander and enjoy the display. Simultaneously showing her sense of humour and concern for reducing carbon emissions, Deanne says, 'I ask people to start at my home, as it has the solar lights on it, and then as you move up the street the lights get brighter, whereas if you start the opposite way where it's all really bright, you can be a bit disappointed by the time you get to my dully lit house.'

It has been a treat to spend time with Deanne, unpacking the AMAF, hearing about women in asset management, and of course gaining a wider understanding of her glorious analogy of babushka dolls. Thank you, Deanne, for your generosity in sharing knowledge and time.

Linda Kemp, Communications Specialist, recently spent time with Deanne Leaver, Director for Asset Strategy at VHHSBA. Deanne was a speaker at AM Council's recent Asset Management in Government Symposium and she wowed the crowd with her visual representation of babushka dolls.

Smart Sensors, Smart Collaboration, Smart Asset Management

by Linda Kemp, Communications Specialist, AM Council

At Asset Management Council, our Strategy '23 is made up of three strategic goals: Strengthen our Asset Management Community; Share Information and Knowledge; and Build Capacity and Capability.

Imagine how my interest soared, then, when I stumbled across information regarding the smart network sensors created and operated by SA Water, being deployed within Sydney Water's pipe networks. How collaborative, I thought! Two of AM Council's member corporations proactively sharing knowledge dovetailed into our strategic goals and I therefore immediately arranged an interview with Peter Seltsikas from SA Water. During our chat, I discovered more about the smart sensor's role at SA Water in terms of maintenance and reliability, as well as the partnership with Sydney Water.

Peter's role at SA Water is Senior Manager, Asset Management. He is responsible for the strategic development of asset management across the corporation. With a team of people, Peter also looks after asset and capital investment planning in line with the business's $14 billion asset base. As the custodian of asset information, Peter ensures appropriate structure around asset information and the systems that capture data to allow the business to make decisions that enable value. Peter spends his days balancing between critical projects and connecting with people: stakeholders and customers, regulators and staff. During his spare time, he is a non-executive director of the Australian Dance Theatre Company in Adelaide, a role he thoroughly enjoys as a way of supporting the community and providing assistance to the arts sector.

SA Water's smart network was deployed midway through 2017 with the installation of 350 sensors and loggers, as well as 100 smart meters for 70 businesses in the CBD of Adelaide. This critical maintenance asset was born in partnership with the University of Adelaide, from a drive within SA Water's asset management team to reduce the impact and frequency of water main leaks and breaks, provide a more detailed view of the water network and enable customers to gain more understanding of their water use, and deliver service expectations. The implementation of the smart sensors into the water pipes within the CBD's system minimises interruptions and disruptions to service, while also providing SA Water with precise evidence about how the pipes are performing.

The smart network functions by listening for leaks via acoustic sensors placed on the outside of the pipes. The acoustics pick up base noise level; a world-leading analytics platform enables the system to identify the specific noise of a leak. Since deployment, SA Water has used the technology to identify and then proactively repair around forty potential main breaks in the CBD, and thereby reducing the impact on customers and commuters. Following the success in the CBD, SA Water has now rolled out variations of its smart network to four additional

targeted locations in metropolitan and regional South Australia.

This is a highly positive result for SA Water.

Given the success of the smart network, it comes as no surprise that Sydney Water reached out to SA Water. The utilities sector is one where traditionally collaboration is sought and valued, both domestically and on a global front; partnerships are viewed as a path to advance opportunities and science at a much greater rate. SA Water joined forces as part of a research project between Sydney Water and numerous other water utilities and leading research universities, as part of a $3 million project coordinated by a NSW State Government initiative, the NSW Smart Sensing Network. The network in Sydney deploys forty acoustic sensors across an area of around thirteen kilometres in the CBD, using SA Water's analytical tools and data systems, reviewed in Adelaide on a daily basis. The CBD in Sydney is vastly different to Adelaide's; the size of the two cities alone brings about a highly disparate base noise level. The smart system therefore needs to learn again in a different environment which noises to block

and which specific noise presents a leak in the pipes.

The collaboration proves symbiotic for all parties. Sydney Water is trialling the smart network on a temporary basis as part of the research project to discover the validity of such technology in its own pipe network. For SA Water, however, the company is able to understand the data systems and techniques from a different perspective, as well as additional ways to add value for their own customers and stakeholders.

From a maintenance and reliability perspective, the operational lifecycle of the asset is reasonably short, given the technology that underpins the smart network, and the need to replace it as new and more advanced technologies become available. However, SA Water is looking to use smart technology as an enduring capability at an operational level, working on new ways to apply infrastructure that disrupts traditional asset management practices. The technology behind the smart network system has flow-on benefits for SA Water in terms of providing a data-centric focus that offers good quality data, enabling the company to move from asset management justifications based on limited information to reliable and trustworthy information that proves valuable in the long-term.

The smart network technology is powered by batteries. SA Water runs a regulated maintenance and reliability program of battery replacement. Part of the maintenance program for the smart network seeks to identify where sensors go offline, and the reasons why they do so.

In their revolutionary smart sensor network, SA Water has provided a positive example of critical support systems for asset management.

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ASSET MANAGEMENT COUNCIL

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18 JUNE 2020 | SYDNEY

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*The Asset Management Council is delighted to announce the launch of its **2020 Data Symposium**, taking place **18 June 2020** in **Sydney**, bringing together a plethora of industry thought leaders and asset managers committed to the development of Asset Data Management best practice.*

Through a combination of keynote presentations, round-table discussions and operational case studies, this packed one-day event will examine how to:

- *Keep control of increasing volumes of data*
- *Be able to highlight the value of data driven techniques in asset management to other stakeholders*
- *Decide which models and technologies are best to implement for your business*
- *Hear the latest 'tips and tricks' to achieve success from your peers*

*With export speakers taking to the stage from groups such as; **KPMG, Broadspectrum, Western Water, SAP Australia, Transport for NSW, GS1 and Jacobs**, this is a must attend event for anyone looking to improve alignment of data strategy, asset management and overall business objectives.*

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MAINTENANCE & RELIABILITY SUMMIT 2020

22 JULY 2020 | PERTH

Can zero service disruption be a reality?
Why put maintenance and reliability higher up the business agenda?
Effective maintenance and reliability is just good business!

*The Asset Management Council's **Maintenance & Reliability Summit 2020** is the ideal opportunity to meet with **over 100 other like-minded industry professionals** and expert thought leaders for a day of sharing & learning designed to tackle the challenges of:*

- *Raising maintenance & reliability's visibility at a corporate level*
- *Achieving best practice in reliability information management*
- *Working with the supply chain to achieve zero-breakdowns*
- *Understanding how IoT & intelligent assets can support maintenance teams of the future*

*Don't miss **Felicia Tristanto,** the AMCouncil National Chair of the Maintenance & Reliability special interest group, lead a fantastic line-up of expert speakers for a day that is solely aimed at assisting you with achieving your business goals through the effective alignment of asset maintenance strategy and company objectives.*

*Other speaker groups confirmed already include: **Wood PLC, Austal Ships, Bentley Systems, KPMG, Rio Tinto, Fremantle Ports, Strukton Rail Australia, AECOM & Water Corporation WA.***

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CHAPTER **NEWS**

WHAT'S HAPPENING IN THE CANBERRA CHAPTER?

The Canberra chapter began the year with a case study presentation by Wayne Francisco from GHD, and the AGM. Wayne had the challenging project of introducing asset management to MTA Bridges and Tunnels in New York City.

This journey began in 2007 and is still ongoing, but Wayne highlighted a number of hurdles and traps that organisations can encounter on the way to achieving a mature asset management system, not the least of these is what to do when the company has a change of management and the inevitable restructure. Also of great interest was Wayne's description of New York's corporate culture and how he handled it. Interest was high and we ran out of time well before comments, questions and conversation around his titled presentation:

Starting from Scratch - Getting Started on an Asset Management Journey

The evening was rounded off with a report on the activities of 2019, and the election of the incoming committee. We are pleased to announce the 2020 incoming committee:

- Chair: Ryan Chenery
- Assistant Chair: Mike Schulzer
- General Committee members:
    - Alex Wilson
    - Wayne Francisco
    - Solomon Ecundayo

Unfortunately Brett Morrison couldn't serve again this year due to work commitments, however we would like to thank him for his service in previous years, and look forward to his return. Mike Schulzers wishes to thank the previous committee for their support, as do we thank Mike for his effort in chairing the chapter. Welcome back Alex for another season on the committee, and welcome to new committee members, Wayne and Solomon. Finally, we would like to congratulate the new chair, Ryan, who has our full support and confidence.

WHAT'S HAPPENING IN THE SYDNEY CHAPTER?

Sydney gets an overview of ISO55010

Sydney Chapter kicked off 2020 with its Annual General Meeting at Ausgrid 24-28 Campbell St, Sydney, followed by a presentation from Martin Kerr on ISO 55010: Asset Management – Guidance on the Alignment of Financial and Non-Financial Functions in Asset Management.

It was a well-attended event, 36 members registered which resulted in 29 attending members participating and supporting the evenings AGM proceedings. There were some changes to the Sydney Chapter Committee with the following committee members being selected:

- David Wilkinson (elected as continuing Chapter Chair for 2020)
- Samiha Najem (elected as Secretary for 2020)
- Myles Gatherer (elected as committee member)
- Klaus Herrmann (elected as committee member)
- Bhagya Shankar (elected as committee member)

Richard Arthur will continue as Deputy Chair. Stephen Poropat and Imtiaz Chowdhury will continue as Committee Members.

The Sydney Chapter Committee thanks outgoing committee members – Glenn Hopkins, Mark Ragusa and Lucio Favotto for their time and commitment to the chapter!

Please note: Sydney Chapter is seeking a representative for the NSW WiAM special interest group. If you are interested please contact David Wilkinson via 'chapsyd@amcouncil.com.au' and he will put you in contact with Lucie Mitchell our WiAM lead.

Martin provided an energised discussion on the role of ISO 55010 and how it provides benefits of alignment between the financial and technical aspects of Asset Management. Clarity was provided to the attending members of how this specification assists to help for process, leadership and governance, policy and strategy, data and information, understanding around Financial and Asset registers as well as key decision making for insourcing, outsourcing and asset vs non-asset solution improvements.

Martin was peppered with many questions to assist members in their understanding on the topic and a practical path to consider the ISO specification in their respective businesses and change management processes.

We thankyou Martin for an engaging and informative presentation! **– ISO55010: Asset Management - Guidance on the Alignment of Financial and Non-Financial Functions in Asset Management**

CHAPTER **NEWS**

WHAT'S HAPPENING IN THE MELBOURNE CHAPTER?

Melbourne explores a Yarra Trams' Experience

Melbourne started it's 2020 technical session programme by delving into the design, implementation and certification of engineering and asset management systems to ISO55001 and ISO15288, particularly for the case of Yarra Trams over their 2-year management systems journey and the next steps for them. The interactive session was presented by Dr Allen Tam, currently the Manager of Strategic Asset Management at Yarra Trams who is leading the ISO55001 certification and reliability engineering journey.

We thankyou, Allen, for an engaging and informative presentation **– The Design, Implementation and Certification of Engineering and Asset Management Systems to ISO55001 and ISO15288**

WHAT'S HAPPENING IN THE BRISBANE CHAPTER?

Brisbane goes back to asset management basics

Thursday 20th February saw our Brisbane chapter present their first live webinar broadcast from the new EA office location in Brisbane CBD. This was aimed at non-engineers and those new to the concept of asset management.

The session was jointly presented by local chapter chair, Keith Paintin, and committee member, Stephen Walker.

The purpose of this event was to bring asset management back to basics and provide the audience with an overall taster for what asset management is and how it can support informed decision making in an organisation, by working through a series of key concepts and real world examples of improvement opportunities.

– Asset Management 101 Getting the Basics Right- Asset Management 101 Getting the Basics Right

WORLD ASSET MANAGEMENT DAY

Tuesday, 21 April 2020

Celebrating and supporting the growing international focus of the value of Asset Management

O CANADA! ASSET MANAGEMENT IN YOUR HOME AND NATIVE LAND

This month for the article on World Asset Management Day, we go across the Pacific Ocean to Canada, in Toronto.

The Regional Municipality of York is made up of nine local municipalities, all of which aim to build strong and safe communities for its residents and businesses. The population is expected to swell to close to 2 million people by 2041[1]. The York region is investing in infrastructure to accommodate this growth in population.

One such investment is the Major Mackenzie Drive project that includes building four new bridges and replacing the fifty-year-old culvert at McNaughton and Arvo roads[2]. The deteriorated culvert was replaced with a larger, more durable concrete culvert, with underground infrastructure reinforced[3].

The surrounding environment and riverbed was improved.

Asset management for culverts begins at installation: they must be properly sized and protected from erosion and scour, with consideration given to load, hydraulic flow, surrounding soil analysis and erosion protection. Failures to culverts can occur for a variety of reasons, and if the failure is sudden, it can cause catastrophic outcomes, often resulting in loss of life.

Don't forget to register for AMPEAK20, held in Melbourne from 19-22 April and during which World Asset Management Day will be celebrated on 21st April 2020. The conference looks to be our best yet, with a record number of abstracts received and numerous presentations already being prepped on asset management strategies, all of which will share knowledge that ultimately benefits us all…so don't miss out!

1. Sourced: https://www.york.ca/wps/portal/yorkhome/yorkregion/yr/plansreportsandstrategies/transportationmasterplan/transportationmasterplan

2. Sourced: https://www.york.ca/wps/wcm/connect/yorkpublic/46887e73-d2d9-4e4e-bcfa-7a3224d78e61/YRMatters_FALL_Winter_19_InteractiveWeb.pdf?MOD=AJPERES&CVID=m-GDiEkp.2

3. Sourced: https://www.youtube.com/watch?v=YGeJ1O656Cc

ICMIAM – 2020 Communique

The International Conference on Maintenance and Intelligent Asset Management (ICMIAM-2020) was jointly organized by the Department of Mechanical and Manufacturing Engineering, Manipal Institute of Technology (MAHE) Manipal, Federation University, Australia and Asset Management Council, Australia on the 17th and 18th January 2020 at the Manipal Academy of Banking, Bengaluru. The conference had a number of keynote addresses by Dr. Anne Gibbs, CEO, Asset Management Council, Australia, Dr. Gopinath Chattopadhyay, Post Graduate Program Coordinator, Federation University, Australia, , Dr. Alok Verma, Ray Ferrari Professor, Old Dominion University, U.S.A., Dr. John Hardwick, Executive

Director Sydney, Roads and Maritime Services, NSW, Australia, Mr. M.N. Thippeswamy, Chief Engineer (Retired), Bangalore Water Supply and Sewerage Board, Bengaluru, Prof. Khanindra Pathak, Indian Institute of Technology, Kharagpur. There were invited lectures by Dr. Syed Islam, Dean, School of Science, Engineering and IT, Federation University, Australia, Ms. Shilpi Chattopadhyay, UX Designer, VAE Group, Australia, Dr. Venkat Reddy, EAMS Team Leader - ALM & SD, Queensland Rail, Australia, Dr. Sanjay Mishra, Head, INSPIRE MANAK Programme, Department of Science and Technology, New Delhi, Dr. Nalinaksh S. Vyas, Indian Institute of Technology, Kanpur, & Chairman of the Technology Mission for Indian Railways, Dr S. Gopalakrishnan, KSIIDC Chair Professor, IISc, Bangalore. In addition presentations were made by industry leaders

: Mr. Pratik Muley, Product Manager, Forbes Marshall Pvt. Ltd. Pune, Ms. Arioli Arumugam, GE Aviation, Bangalore, Dr. Debdutt Patro, Product Specialist, Ducom Instruments Pvt Ltd, Bangalore, Mr. Alex Mathew, IoT - Digital Enterprise Assets, SAP, and Dr.Ashwin Kadkol, GE Global Research, Bengaluru.

There were 50 papers and 8 posters in Asset Management, Data Science, Asset Life Cycle Management, Water Audit and Analysis, Tribology and Maintenance from participants from across the world. The papers and posters have been selected based on a review process that was established in the previous conferences organized by the Department of Mechanical and Manufacturing Engineering. The present venue Manipal Academy of Banking, Bengaluru is sister concern of Manipal Academy of Higher Education (MAHE-Manipal).

Asset Management & Maintenance have become essential areas of concern for many of industries and infrastructure owners, operators and maintainers.

Aiming to meet the demand for access to knowledge in asset management and its link with systems, standards and technology and the desire to extend the collective efforts of Universities, Peak Bodies and Industry to others in the wider asia- pacific, this event is held for the first time outside of Australia. This event was possible due to joint collaboration with the Federation University and expertise from Asset Management Council, Australia, especially Dr. Gopinath Chatopadhaya, Joint Chair and Dave Daines, Joint Chair Asset Management Council, Australia. Dr. Raghuvir Pai Professor of Mechanical Engineering at MIT was the Chairperson of the conference.

An important feature of the conference was the blessings by Revered Swamiji Muktidanandaji, President, Shri Ramakrishan Ashrama, Mysuru. He gave a very important insight on the spiritual aspects and linked it with technology and asset Management and life management, especially with regard to nature

and environment which are an integral part of the materialistic aspects of technology.

This conference focused on the overview of the benefits of working within an asset management framework, as well as insights into implementing, improving and enhancing asset management through systems and standards, and technologies for balancing costs, risk and performance. This Conference had the strong support of industries, universities, professional bodies and wider communities. It was a large gathering of academicians, industry personnel across the globe which was useful in fostering the interdisciplinary collaborations. A decision to form an Asset Management Society, India was taken during the conference.

Automating The Samp through an IMS online: A Tool for Inspiring Change and Collaboration

Dr Nazrul Islam 1, Julian Watts[2]
1. Gippsland Water, Traralgon, VIC, Australia
2. KPMG, Melbourne, VIC, Australia

ABSTRACT

When encouraging sustained business change, leadership and early engagement is key. The online and 'living' version of Gippsland Water's Strategic Asset Management Plan (SAMP) project demonstrated exemplar buy-in from an early stage and sought to trigger a step change in innovation and collaboration of business decision making. Initially piloted for the investment decision making process, the Integrated Management System (IMS) Online captured the imaginations of staff and allowed a clean slate for surfacing the right information to the right people at the right time to make better decisions in an increasingly complex operating environment.

This case study is designed to demonstrate the process for engaging a wide cross-section of a water business resources. It seeks to utilise senior management to empower teams in making a sustained change in the way information is utilised for decision making and maintained using strong governance.

INTRODUCTION

Gippsland Water has experienced a significant reduction in their business customer demand whist realising continued growth of residential customers. These changes triggered the senior leadership team to embark on a change program to create collaboration and alignment in the way infrastructure was invested in.

Due to the reduction in revenue from Gippsland Water's business customers, the economic model for reinvestment in assets needed to be redesigned. To do this in a sustainable manner, all parts of the organisation needed to be involved and engaged to drive all possible innovation and non-asset solutions.

It was decided that the update of the 2012 Asset Management Strategy would embrace new concepts present in ISO55001 and the Department for Treasury and Finance, Asset Management Accountability Framework. These changes would be realised as an online and 'living' version of a Strategic Asset Management Plan (SAMP), known as the SAMP Online. These concepts would to better integrate leadership, stakeholders and customers, finance and IT alongside asset planning and operations.

METHODOLOGY

The methodology included using first principles to define the critical decision points within cyclical business operations and capturing what information inputs supported those decisions. This was an opportunity to leave behind the reams of data traditionally collected for regulatory and reporting purposes and focus purely on information that supported business decisions.

THE EVOLVING INNOVATION

With the approach to move the SAMP to an online platform, there was also the opportunity structure the information using the core sections of the 'Management Systems' international standards ISO9001 , ISO14001 , ISO18001 and ISO55001 for asset management (see Figure 1). This effectively creates a flexile platform to build an Integrated Management System (IMS) on. This structure was created on the Gippsland Water Intranet and enabled a multi-layered approach to storing and governing level of detail.

This meant that whilst capturing the information needed in a SAMP, the actually SAMP artefact could be automated directly from the IMS.

Better Practice SAMP and IMS Structure

Gippsland Water has access to delivery team members who supported inputs into the 2018 update of ISO55002, the guidance for implementing the ISO55001 Asset Management System.

Specifically, there is a new section on SAMP development. This ensures GW SAMPs will be current and aligns to current and upcoming standards.

The team were also international reviewers of the Institute of Asset Management guidance on developing and maintaining Asset Management Plans. The objective of the guide is to provide practical advice and how this applies to: the assets and their optimal, whole life cycle management and Improvements in the asset management capabilities of the organisation.

Stakeholder inputs to the SAMP and IMS Structure through stakeholder engagement workshops, the delivery team captured the core business requirements as:

- Keep the SAMP simple, make it stick
- Keep the SAMP off the bookshelf
- Focus SAMP content on the right information that drives decisions
- Integrate with existing processes wherever possible (IMS, EPM)
- Utilise the Efficiency, Optimisation and Innovation business teams
- Be realistic about level of effort
- Be clear about timescales and communicate widely

The delivery team used this guidance to innovate a process to make the updated Asset Management Strategy (SAMP) no longer a periodically updated document (last updated 2012). It can be generated from a selection of pages across the IMS Online in one click.

The web based IMS Online solution (see Figure 2) provides the ability of all stakeholders to work concurrently and enables distributed ownership of content and provides time savings in SAMP generation (see Figure 3).

The IMS Online also enabled a structured workflow to capture projects and enable an investment prioritisation process. This was initially a pilot subject topic was introduced to cover the Asset Investment Value Alignment decision making process, or AIVA for short.

Engagement

Gaining buy-in from different business units was critical to success. Early engagement was sought after to capture ideas and dispel potential blockers. By engaging with representatives from across Asset Strategy, Asset Planning, Asset Delivery, Operations, Customer, Finance and IT, the project Working Group (see Figure 4) was able to gain useful insight to challenges faced when it came to accessing the right information to make the right decisions at the right time.

Continued Awareness

To maintain project momentum, periodic communications were distributed to staff via the Intranet homepage and newsletters, This was coupled with common branding of the SAMP Online to retain project identity and recognition (see Figure 5). Once the pilot for AIVA was launched, further communications were made to encourage staff to 'browse' the information published and provide feedback on accuracy and relevance.

Soft Launch and Roadmap

The platform was launched to all user groups in April 2018, in-line with the collaborative nature. Although it had a limited scope of content, the pilot areas were functioning and able to be updated. The Gippsland Water formal launch session is planned in June 2018, where MD will provide an all-hands briefing to launch the IMS Online and further raise the awareness.

RESULTS & CONCLUSION

Leadership

The Senior Leadership Team (SLT) was instrumental in empowering managers and team leaders to encourage resources in the collation of relevant information and the adoption of the SAMP Online. The SLT could recognise the value in a common approach to decision support that utilised a simple platform, that was accessible on multiple devices and provided remote access to field staff.

Data Amnesty

An important aspect of the project was that no data was bad data. The ability to link to source documents regardless of where they were kept was a guiding principle. This was also coupled with a data governance structure to document who the SAMP Online page owner was and who the content owner was. This enabled appropriate support in maintaining and renewing the data – in the same way we do for physical assets.

Sustaining Outcomes

As with any change initiative, sustaining the change and realising the benefits was at the centre of the project. The approach of engaging with a wide selection of internal stakeholders was a defining moment in maintaining project engagement and leading the business with something that was owned by many and valued by all. One method of engagement was using a survey to capture what difference people considered was important when assessing 'value' of investments (see Figure 6).

Benefits

The benefits of the Automated SAMP include:

- Collaborative – the online nature makes accessing each other's content and providing feedback easier and faster
- Distributed – content ownership is managed by the right individuals in the right department with delegated authorities to update as required
- Transparent – all relevant content is shared, reducing the change of siloed data sources so all information is taken into account for decision making
- Governed – clear content and page owners with change control built in with a steering committee to manage scope
- Accurate – all information should be the most current and relevant with data-as-an-asset principles enabled
- Automated – Key reports can be generated by merging selected pages into one file for point-in-time distribution. No more onerous periodic updates.

Lessons Learnt

Beyond engaging the SLT and various business units, an important lesson was to set the vision and the overarching structure of the SAMP Online. This meant that the approach to implement the AIVA pilot fit within a wider framework and was able to be built on in a way that managed potential scope creep and falling prey to collecting information of limited value.

The delivery team were the driving force and thought leaders behind the project. They not only designed the IMS Online but also managed the communication, collaboration and delivery of the platform.

Whilst the project have been rewarding, it was also challenging to manage the expectations of multiple stakeholders. The project team needed to provide strong guidance however allowed others to lead and inspire.

This paper was presented at the International Conference Maintenance and Intelligent Asset Management , Bangalore, India Jan 2020

Figure 1 – Aop Levels of the IMS Online Structure

Figure 2 – Value propositions of the Integrated Management System Online

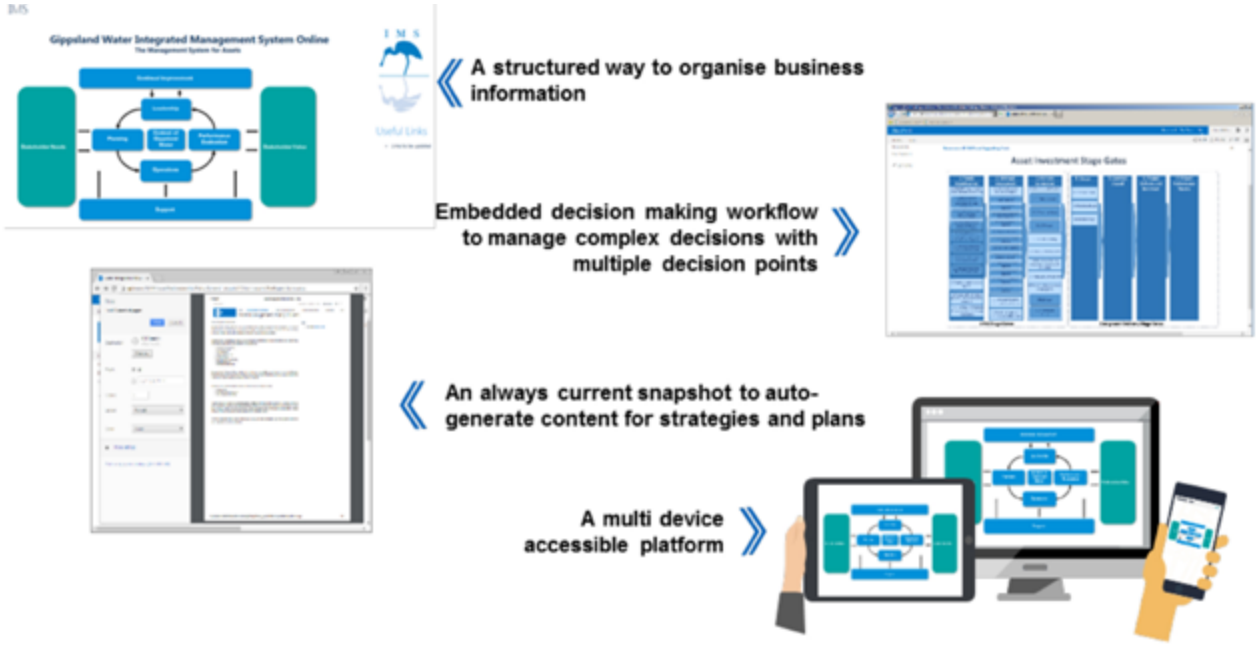


Figure 3 – The Automated Strategic Asset Management Plan

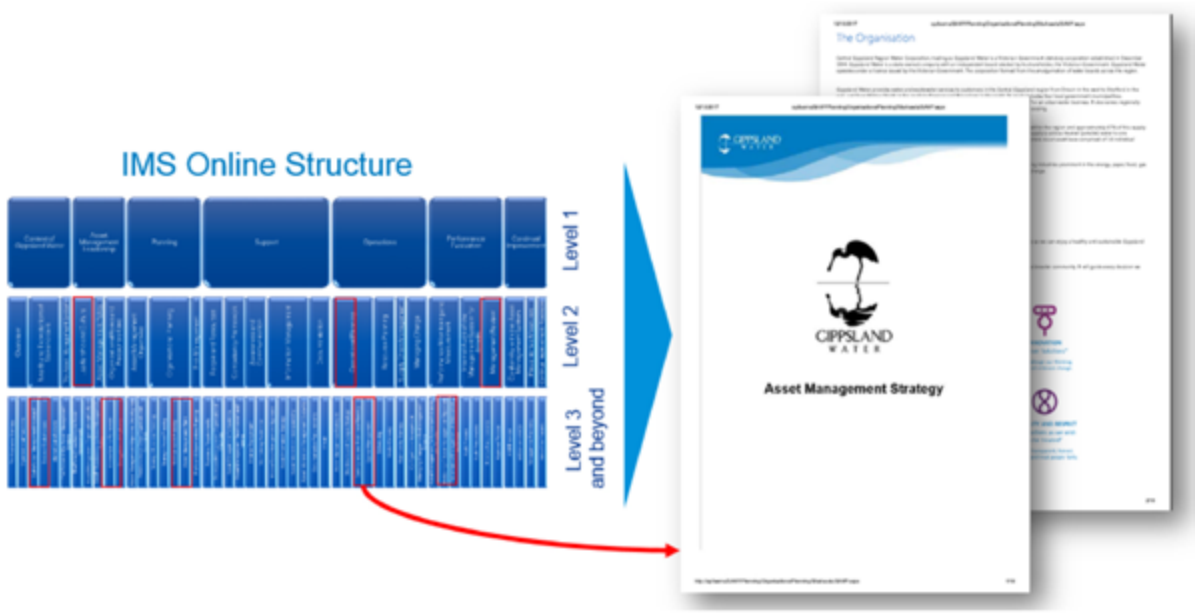


Figure 4 – Governance Structure of Project Teams

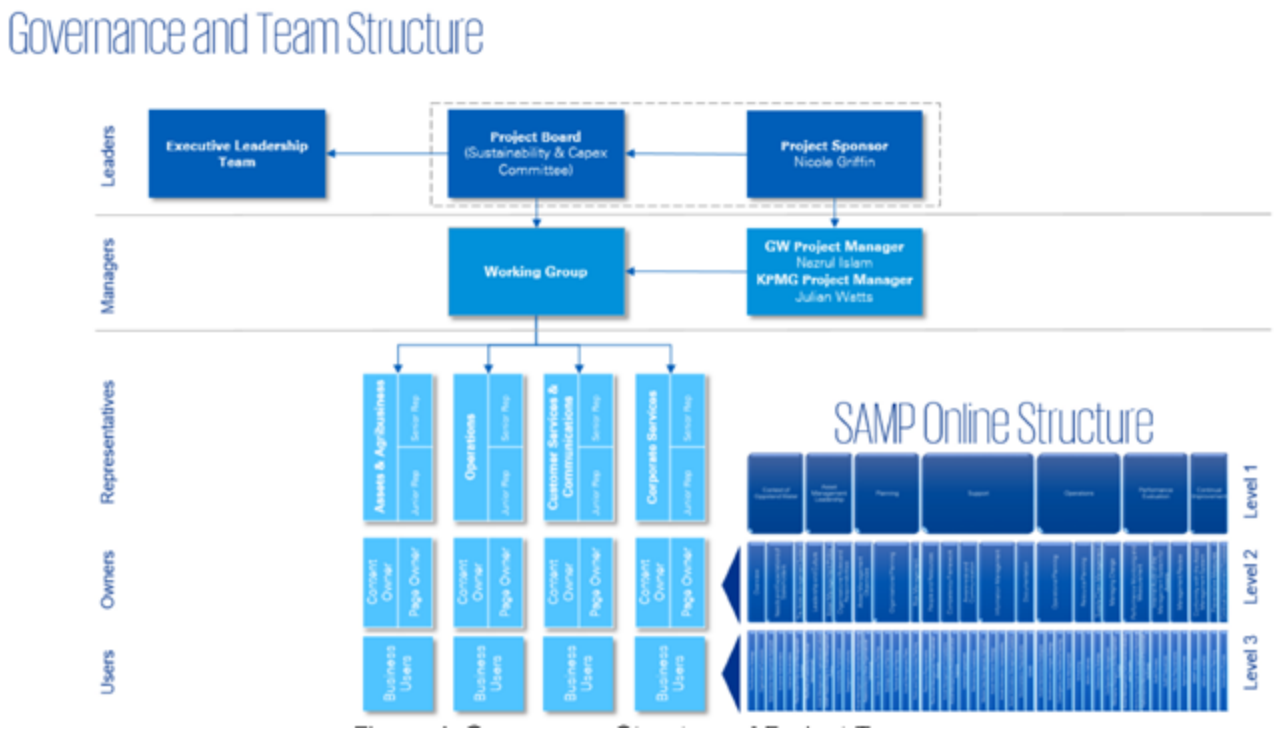


Figure 5 – SAMP Online Development Roadmap and Communication Tool

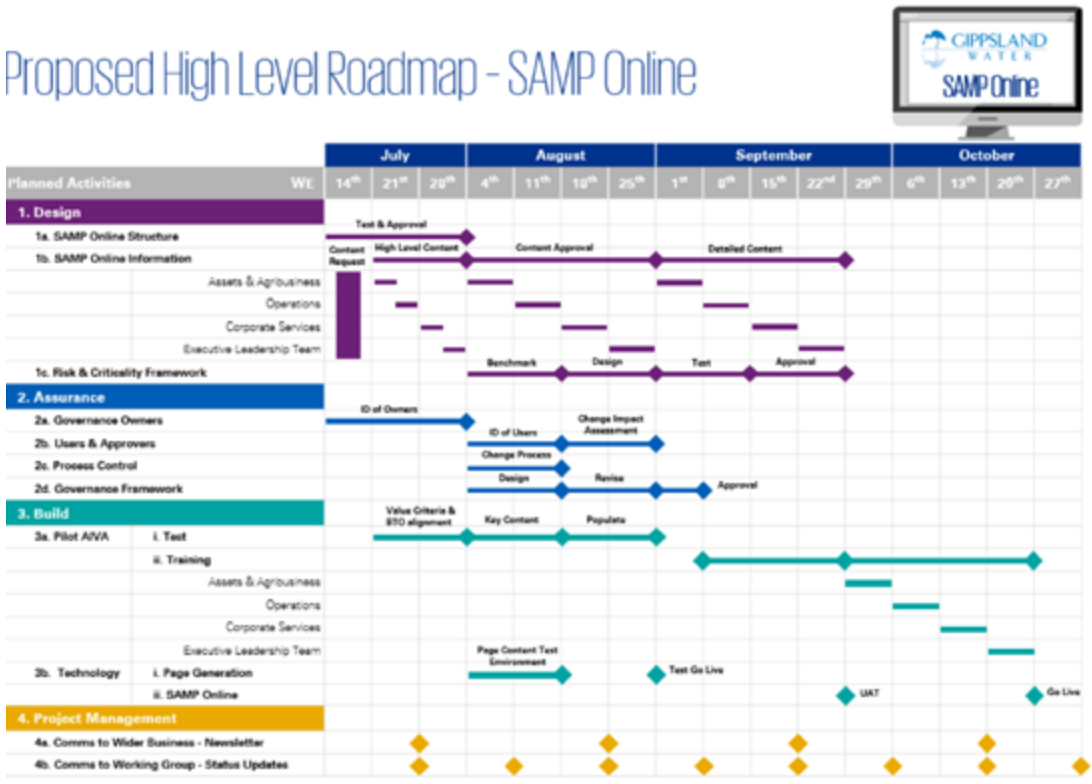
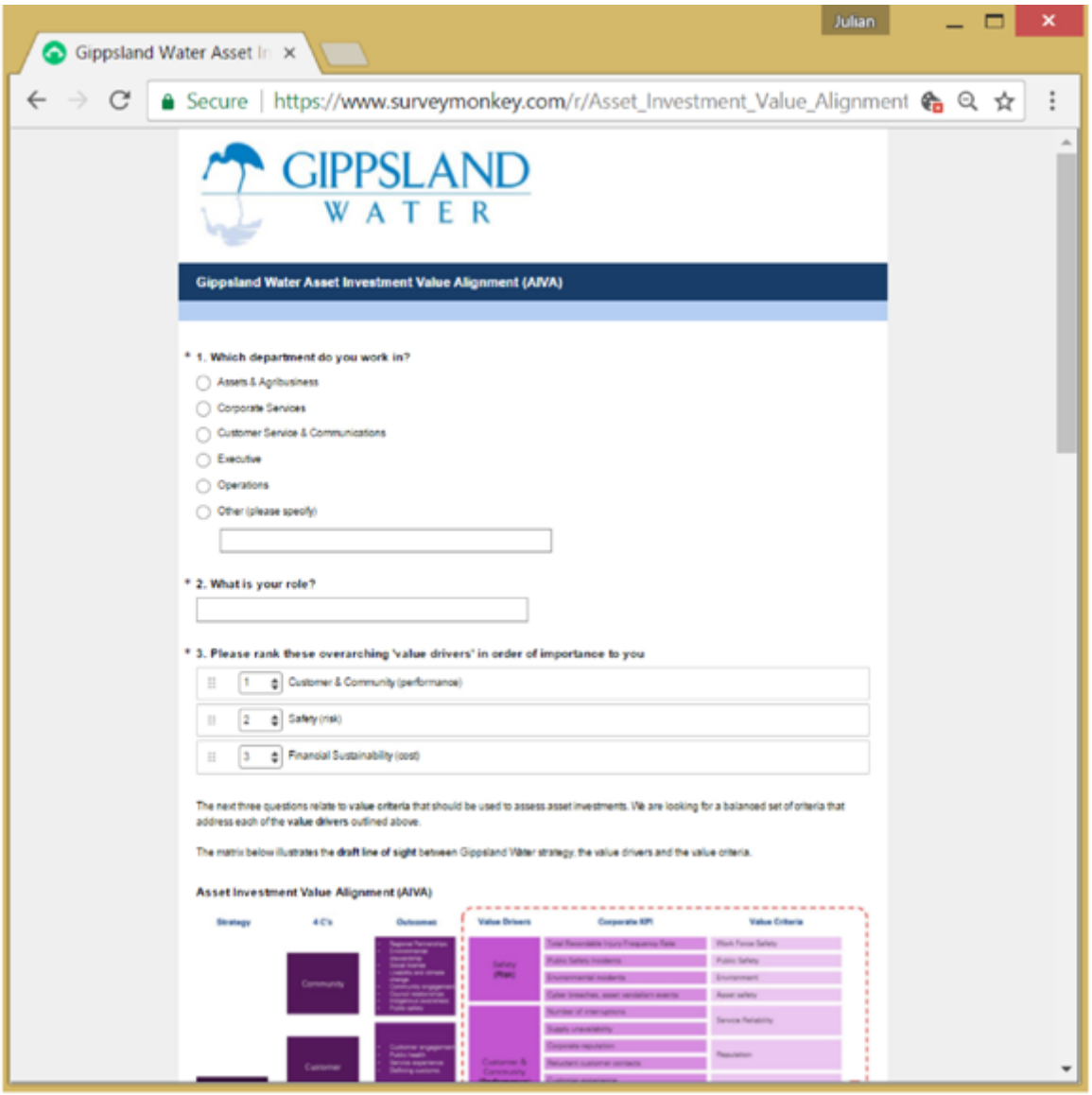


Figure 6 – Online Survey Utilised to Engage a Wide Selection of Business Units



Geotechnical Asset Management in Road Infrastructure under a Changing Climate

Susanga Costa, Harpreet S. Kandra

Abstract—Geotechnical assets are important elements of infrastructure systems of a country. Management and maintenance of geotechnical assets are crucial for uninterrupted operation of infrastructure systems. This paper highlights the need for geotechnical asset management and discusses the key challenges to deal with in the context of road infrastructure system in Australia. Primary consideration is given to discuss the impact of climate change on geo-infrastructure and associated problems. Key challenges identified are reliability of climate change predictions, impact of extreme events and the difficulty of present performance monitoring and future performance prediction. Other common problems related to geotechnical asset management have also been briefly discussed. The biggest concern is to gain the attention of asset managers towards geotechnical assets.

Keywords: geotechnical asset management, soil, climate change.

I. INTRODUCTION

A HEALTHY infrastructure network is crucial for maintaining good living standards and economic prosperity in any country [1]. Basic infrastructure systems include transportation facilities, telecommunication networks, electrical grids and water supplies. The assets in these infrastructure are worth billions of dollars and hold the basis for smooth functioning of the society and economy. Therefore, the maintenance and management of infrastructure assets are vital to any country. One of the biggest problems for developed countries in the 21st century is the ageing of existing infrastructure whereas developing countries struggle to build adequate infrastructure to keep up with the increasing population. Common to all countries are the budget constraints, material shortage, decreasing efficiency and reduced capacity, increasing needs and expectations of diverse user groups. In addition to these inherent problems, every country has to deal with the new challenges imposed by climate change and urbanisation.

Although asset management has gained increased attention of both public and private sector in the recent past, new problems created by changing climates across the world have not yet been adequately identified and/or addressed. One reason for this is the reluctance and indifference of governments of some countries to take mitigation and adaptation measures against climate change. Another reason is, while climate change is certain, there are considerable uncertainties in predictions of future climate conditions and political decision making around these matters.

Road transportation systems occupy a large amount of geotechnical infrastructure (geo-infrastructure). The most common of those assets are embankments, slopes, subgrades (stabilized or non-stabilized), unsealed pavements, tunnels, foundations, retaining walls and drainage systems. Assets in other infrastructure include earth dams, buried pipes and catchments. Traditionally, asset managers in road transportation infrastructure have focused more on pavements, bridges and track structures than the geotechnical assets [2].

A typical deterioration of road side slopes due to erosion and tension cracks are shown in Fig. 1. The effects of climate change are strongly felt in geo-infrastructure as they are more sensitive to natural climatic events. Changes in precipitation and temperature patterns can cause unprecedented soil moisture and pore pressure variations inside soil mass causing distress in geo-infrastructure.

Fig. 1 – An example of road side slope deterioration due to erosion and tension cracks (M1 Freeway near Geelong, Australia)

Unlike other engineering materials (e.g. steel, concrete), soils are extremely sensitive to atmospheric conditions and exhibit complex behaviour under changing weather conditions. Soil is a particulate material which is comprised of three phases in most situations: solids, water and air. Under extreme conditions, consequent to changing climate, the number of phases could however be reduced to two: 1. fully saturated (solids and water) 2. fully dried (solids and air). In the field, the state of the soil varies between these two extremes in response to local weather conditions. Thus, the amount of precipitation and temperature have a significant influence on the performance of geotechnical assets. Relative humidity and wind speed can also influence soil, but to a lesser degree.

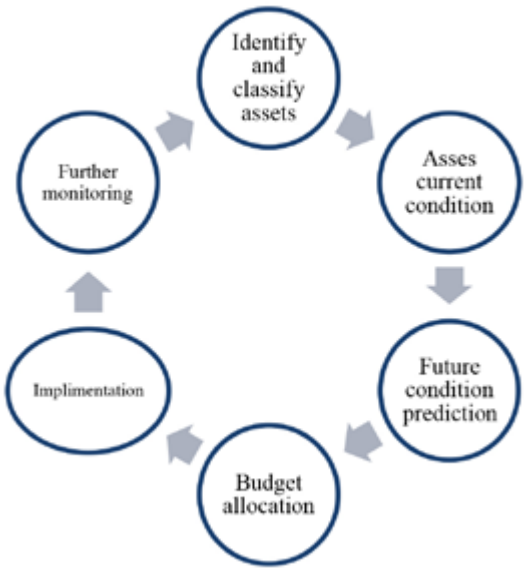
Rocks are less sensitive than soils to frequent weather changes. However, fractured rocks are vulnerable to the impact of weather conditions and changing weather cycles. Rock fractures can store soil and water. Changes in water pressure inside the fractures is critical to the stability of the rock. Temperature changes, on the other hand, cause thermal expansions and contractions in the rock widening/narrowing the fractures.

This paper reviews the current practices and challenges related to geotechnical asset management (GAM) in road transportation systems. Common problems pertaining to transport related geotechnical asset management are discussed with special attention to new challenges arising due to climate change. Conditions in Australia have been used as the context for discussion.

II. COMMON CHALLENGES

The biggest problem for geotechnical assets is to be recognized by their owners as valuable assets that need to be managed. Geotechnical assets, in general, are considered unpredictable hazard sites [3]. Thus, they are often ignored until a failure is imminent or actual failure occurs. A typical geotechnical asset management plan applicable to transport agencies is shown in Fig. 2.

Fig. 2 – Typical geotechnical asset management plan for road agencies



Once the necessity for geotechnical asset management (GAM) has been recognized, there exist other problems with asset management plans and implementation shortcoming. Wolf et al. [4] identified following limitations based on transportation research records [5].

1) Massive inventories – Collecting state-wide inventory information on different types of assets require substantial effort. Moreover, there are uncertainties whether the investment will be paid off

2) Incomplete inventories – Most transport agencies do not have completed inventories with initial condition ratings for the geotechnical assets.

3) Varying methods for condition measurements – Each asset type requires a different method to measure current condition. For example, assessing

shrinkage cracking of an embankment needs a different method than long-term settlement of a bridge pier.

4) Difficulty to predict transient condition variation – as mentioned in the introduction, performance of geotechnical assets fluctuates with seasonal weather patterns. Predicting these fluctuations is a challenge since many uncertainties prevail.

5) No reliable methods to predict catastrophic failures from deteriorations detected through regular monitoring – An example for this is the Yallourn mine batter failure (Victoria, Australia) due to accidental water pressure increase in a coal joint [6]. Despite early signs and regular monitoring, the large failure could not be predicted.

6) Minimal scope in GAM plans – Many agencies have GAMs which cover only a limited scope. They target only a specific asset type (e.g. slopes).

7) Poor understanding of the asset life-cycle – GAM is still new to many transport agencies. Hence, there is a lack of understanding of geotechnical asset life-cycle compared to other assets.

8) Uncertainty in future condition prediction models – As per any asset, prediction of future conditions of geotechnical assets is based on the present condition. Consequently, future spending estimates are also based on present deterioration levels. However, the predictions can vary greatly causing discrepancies in projected and actual spending.

9) Incompatibilities of datasets in different GAM programs – There are heterogeneities in datasets collected by the agencies. This hinders the integration of datasets to create a common framework.

10) Difficulties for local governments – US Department of Transportation identified in 2007 that there are unique problems experienced by local governments in the areas of inventory building, condition monitoring, dataset management etc.

11) Need for more research – There is scope for more work in relation to data collection and integration, condition assessment, performance modelling, risk analysis, obtaining recognition and infrastructure management education.

III. GEOTECHNICAL ASSETS IN AUSTRALIA

With a land area of over 7.6 million square kilometres, Australia owns a vast amount of both natural and man-made geotechnical assets. Being a continent itself and because of country's population is largely concentrated along the coastal line, Australia has to deal with a unique problem with distance to maintain connectivity between different parts of the country. Blainey (1966) termed this problem as the "tyranny of distance"[7].

At present, Australia has a road network of about 900,000 kilometres and spends nearly A$30 billion on road infrastructure annually. This amount accounts for 49% of the total spending on infrastructure of the country [8].

Despite the mammoth importance of geotechnical assets to road infrastructure in the country, transport agencies have not fully recognized the value of GAM. Austroads – the overarching authority for roads in Australia – has a guide to asset management in place [9] for road infrastructure based on ISO55001. However, there is only a limited scope for geotechnical asset management in this guide. Part 14 of the guide [10] briefly mentions geotechnical assets under 'other assets.' It is up to Austroads' member agencies (state road authorities) to develop their own GAMs following the guide.

Austroads guide, nevertheless, states the importance of GAM highlighting the need for a conservative management approach [10]. It acknowledges the unique nature of performance predictability for geotechnical structures and the significance of a failure (e.g. collapse of rock-bolted rock face or retaining wall) could have on road traffic. The responsibility of condition monitoring and identification of specified maintenance is assigned to geotechnical engineer under this guide. As recommended by the guide, the three key areas to be incorporated into the GAM plan are regular monitoring of critical features, routine operational maintenance particularly for drainage provision and proactive programmed maintenance.

However, it is uncertain whether adequate attention is paid by state road authorities to develop comprehensive GAM plans for their assets and if there are adequate measures for monitoring/benchmarking of actions resulting from the GAM.

IV. IMPACT OF CLIMATE CHANGE

Road infrastructure have long expected life spans. Typical design life for roads and bridges are 20 – 40 years and 100 years respectively. Road planning agencies, designers, engineers and managers need to understand the deteriorating effects that clime changes will impose on all road related structures including geotechnical structures. Knowing the damaging effects of future climate conditions on the existing assets help road agencies to better prepare to handle them.

A. Future Climate Predictions

Intergovernmental Panel for Climate Change (IPCC) has published future climate predictions at a global scale. According to the report published in 2014 [11], surface temperature is expected to rise continuously over the next century. As a result, many regions will experience more often and longer heat waves with higher peaks. Extreme precipitation events will become more intense and frequent in most parts of the globe. Though not directly related to road infrastructure, it is worth knowing that mean sea level will rise while the ocean continues to warm and acidify [11].

Future climate predictions for Australia can be found in [13]. Overall, Australia will experience increased temperatures and less precipitation.

The average annual temperatures are predicted to go up by 10 C to 60 C by 2070 and the trend is expected to continue. Change in rainfall will vary across the country with a maximum reduction of about 35% in some areas and a modest 10% increase in other areas.

Due to the increase in air temperature, ground will also get warmer. Costa et al. [12] simulated the ground response to climate change for six locations in Australia. Their findings indicate that ground temperature will also increase over the next century.

B.Impact on Geotechnical Assets

Asset managers are yet to fully recognize the impact of climate change on geotechnical assets. Even among the handful of transport agencies who have taken climate change effects into account, only the changes in average conditions (temperature and precipitation) have been considered [14]. However, this can be misleading. For example, in most parts in Australia, effects of increase in temperature is neutralized by the decrease in precipitation. This is not necessarily true regarding the impact of extreme events. More intense and more frequent extreme events (e.g. heat waves, storms, droughts) can have severe detrimental consequences.

Prolonged high temperatures will wilt the ground into excessive shrinking and formation of drying induced cracks.

In many geotechnical assets, cracks are problematic and cause instability and unserviceability [15].

Worse consequences will be experienced by expansive soils (highly reactive clays) which covers about twenty percent surface landmass in Australia [16].

Whereas the cracks generated during normal dry periods are usually minor, larger and deeper cracks will occur under high temperatures and prolonged heat/dry conditions. While any form of cracking is unwanted in soil, minor cracks have the likelihood of self-healing during wet periods. On the contrary, large cracks can get wider during rainfall event due to sidewall collapsing. Embankments, retaining structures and unsealed road pavements are some of the assets that are most likely to be affected.

Similarly, extreme precipitation events will cause damages of high magnitudes. Flash floods can destroy the structural integrity of subgrades, embankments, foundations and pavements. Sudden rise in water table diminishes the shear strength of soil (increased water pressure reduces the shear resistance in soil) leading to eventual failure. This is more critical in cut slopes.

To demonstrate the hazardous impact of extreme precipitation, an OECD study [17] modelled a major flood in Paris and concluded that 30% to 55% of the direct damages was on infrastructure. Moreover, it was also noted that 35% to 85% of business losses were due to interruption to transportation and power supply.

C. Challenges for Geotechnical Asset Management

Future condition prediction is one of the biggest challenges to GAM from climate change. Predicting performance under extreme events require sophisticated modelling tools and reliable climate datasets. Climate change predictions themselves have high uncertainty. Scientists have to rely on several expected greenhouse gas emission scenarios when simulating the climate conditions for the next hundred years and beyond. The scenarios considered can change significantly over the years. This compels engineers and managers to consider the worst scenario even though this might lead to an overestimate of resources and systems required.

Another challenge is condition monitoring. Most geotechnical assets require specific monitoring techniques and devices. The range of operation of devices currently being used, may not be sufficient to cover extreme events. Some devices might get damaged or generate inaccurate readings.

Recently, there has been a growing attention on building resilient infrastructure which can resist the impact of climate change [18]. This demands for development of new materials, innovative designs and novel construction methods. Furthermore, appropriate systems need to be in place for testing performance of these designs in relation to resilience offered to climate change.

V. FUTURE RESEARCH NEEDS

Understanding the full impact of climate change on geotechnical assets and developing appropriate GAMs need more research in following several areas.

A. Ground response

The impact of climate change on geo-infrastructure will depend on how ground would response to those changes. As mentioned above, preliminary studies indicate [12] that ground temperature will increase. However, more in-depth investigation is required to learn the effects on water table, suction (negative water pressure) and reactive zone depth. Changes in these parameters directly affect the swell-shrink potential of soil thereby causing distress on structures built on them.

B. Real-time data collection

One of the most challenging tasks in GAM is the present condition monitoring and data collection. Real-time remote data collection for geotechnical assets has gained attention of researchers as a solution. Bhreasail et al. [19] reported recent advancements in using remote sensing by Highways England. However, more work is necessary to overcome some specific challenges related to diversity of scales, techniques, data analysis and management. Real-time data needs to be used to calibrate existing models and increase confidence in their use.

C. Climate resilient infrastructures

During natural hazards, biggest economic losses are incurred by the damages to infrastructure. Resilient infrastructure can sustain such damages and continue to be in a serviceable condition [18]. Design and construction of resilient infrastructure demand high performing materials and novel construction techniques.

For geotechnical assets main construction materials are soil and rock. Mitigating their sensitivity to climate conditions is the key to make soil and rock more resilient and high performing. Investigations into novel additives that can increase tensile strength, reduce porosity, cracking potential and erodability are required.

D. Population growth

Accurate estimation of future population is important as population growth exerts heavy demands on road infrastructure need. Apart from natural growth and migration, some cities/ region will experience an influx or outflow of people due to climate change. Cities with more pleasant future climates will attract more people. This fact was taken into consideration in the assessment conducted by Austroads [14]. However, more accurate and robust estimations are needed to incorporate these into design procedures.

VI. CONCLUSIONS

There is a primary need to recognize the importance of geotechnical assets in the asset management practice. This is more significant in road infrastructure system as it heavily depend on geotechnical assets. Impact of climate change can no longer be ignored when preparing GAM plans. There is much work to do in order to fully understand the effects of climate change on geotechnical assets and to develop performance monitoring and predicting methods. This is an emerging area of research and practice that needs attention of planners, designers, engineers and managers of geotechnical assets.

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UP COMING **EVENTS**

EVENT	DATE	LOCATION
March 2020		
Sydney - Asset Management Maturity	18/03/2020	Sydney
Melbourne - Maintenance Plan Optimisation & AGM	19/03/2020	Melbourne
Adelaide - Asset Management's role in mitigating fire start risk from powerlines	19/03/2020	Adelaide
Brisbane - Risk Assessment in Asset Management	31/03/2020	Brisbane
April 2020		
Perth - Unlocking Facility Value Through Lifecycle Thinking	2/04/2020	Perth
Melbourne - Asset Management Maturity Workshop	16/04/2020	Melbourne
May 2020		
Webinar - Connecting Asset Care Plans to Capital Plans to maximise ROI	5/05/2020	Webinar
Sydney - Investment Decision for Asset Management	14/05/2020	Sydney
Melbourne - Role of Leadership and Management, Accountability Models	21/05/2020	Melbourne
Commercial Property Forum	22/05/2020	Melbourne
June 2020		
Sydney - Bring a Problem Night	17/06/2020	Sydney
Data Symposium 2020	18/06/2020	Sydney
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Site Visit to Gateway Bridge	18/06/2020	Brisbane
July 2020		
Sydney - AM System Benefits for Industry and Government	16/07/2020	Sydney
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Maintenance & Reliability Summit 2020	22/07/2020	Perth
Defence Summit 2020	28/07/2020	Canberra, ACT
Brisbane - Reliability Engineering and Condition Monitoring: Methodologies, Tools and Techniques	30/07/2020	Brisbane
August 2020		
Sydney - Site Visit to Sydney Metro Control Room	13/08/2020	Sydney
Melbourne - Asset Information Lifecycle Management	20/08/2020	Melbourne

EVENT	DATE	LOCATION
September 2020		
Brisbane - Communications, Leadership and Culture	10/09/2020	Brisbane
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Brisbane - Risk Assessment in Asset Management	31/03/2020	Brisbane
October 2020		
Brisbane - Smart Cities	8/10/2020	Brisbane
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Sydney - WiAM Group Night	15/10/2020	Sydney
November 2020		
Brisbane - Workshop: Implementation of Asset Management Systems	12/11/2020	Brisbane
Brisbane - Planning for 2021	17/11/2020	Brisbane
Sydney - Mining Automation and Asset Management	18/11/2020	Sydney
Melbourne - Technical and Networking Session	19/11/2020	Melbourne
December 2020		
Sydney - End of Year Review and Celebration	3/12/2020	Sydney

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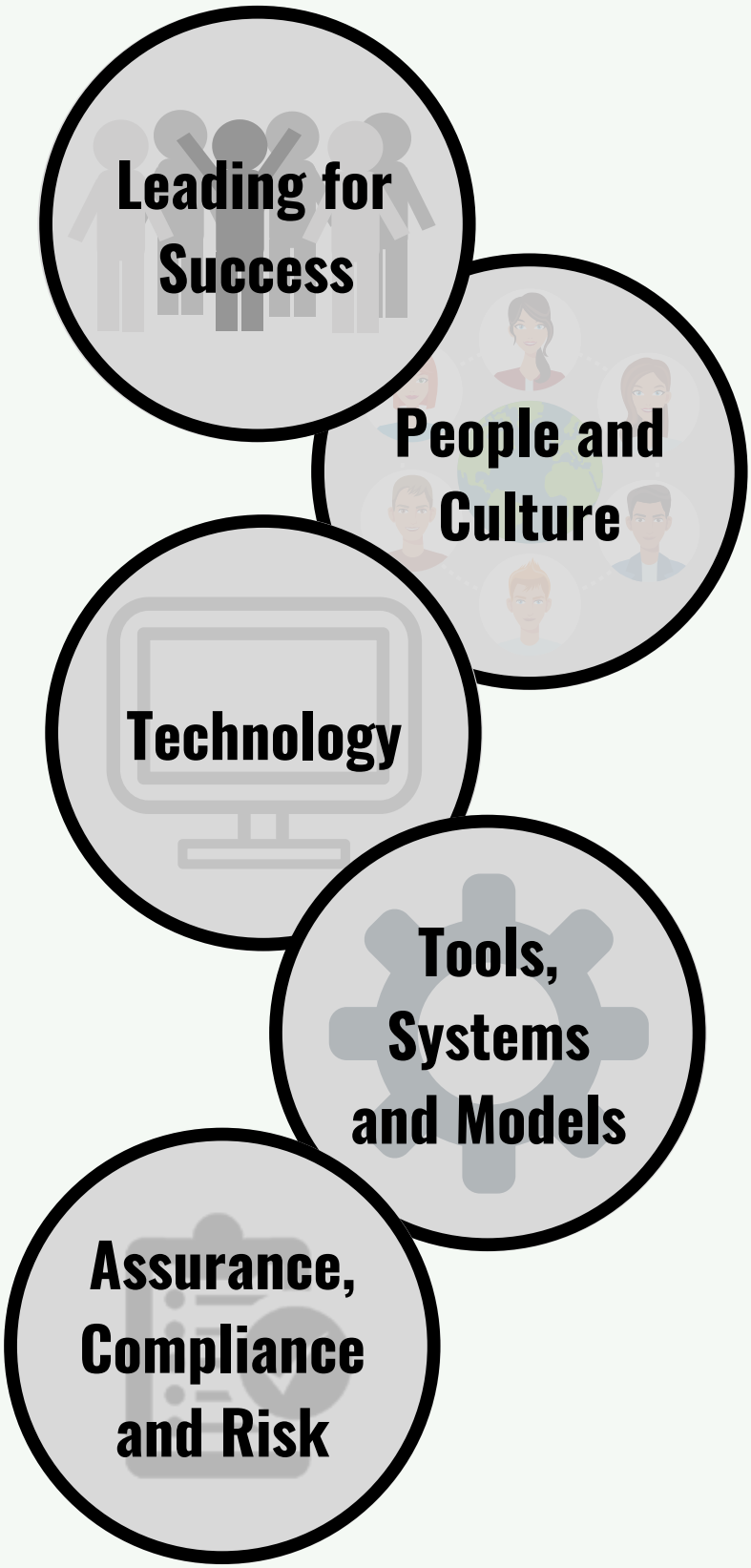

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ASSET MANAGEMENT COUNCIL

THE ASSET JOURNAL

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AM SECTOR REPORT 2020

STATE OF THE ASSET MANAGEMENT SECTOR 2020 REPORT

PREPARED JANUARY 2020

ASSET MANAGEMENT COUNCIL

1. INTRODUCTION

The Asset Management Sector is continuing to gain prominence around the world and has grown sharply over the last few years with the realisation that the use of asset management within a business can bring great value.

Globalisation, technology, movement of people and changes in climate are key factors impacting asset management across the globe. The asset management response to these factors are interpreted differently in each local community.

The Asset Management Council is the peak professional body for asset management in Australia and as a not-for-profit organisation endeavours to improve society by enabling value from effective asset management. It assists in meeting today's asset management challenges in three main actions:-

Engage -
improving society by strengthening our asset management community

Influence -
providing leadership by sharing information and knowledge

Empower -
develop our members by building capacity and capability

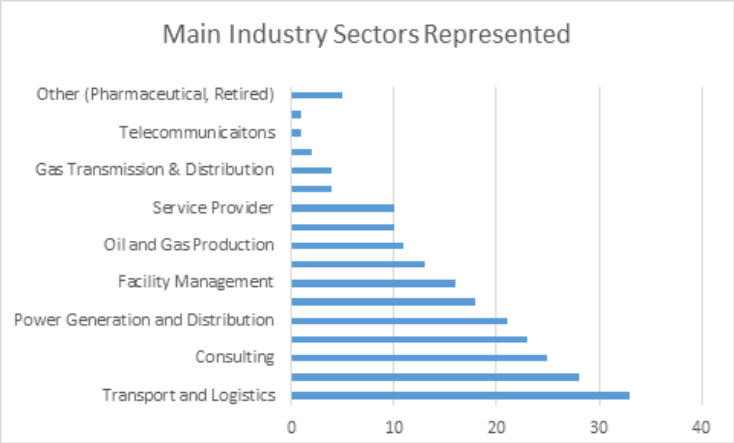
The members of the Asset Management Council were invited to contribute to the State of the Asset Management Sector Report 2020 and assist in the research that underpins this report. This report outlines the findings from the research collating respondents' responses to:-

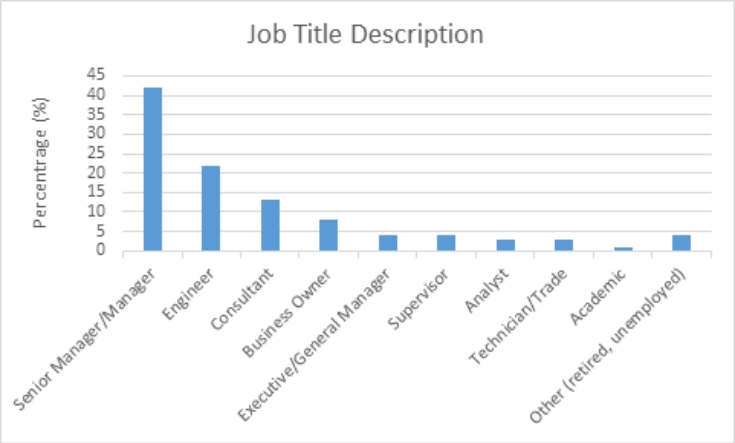
- Top Asset Management priority areas for 2020
- Implementing Asset Management Systems and Frameworks
- Role of Technology in Asset Management
- Skills and Capabilities of the Asset Management workforce

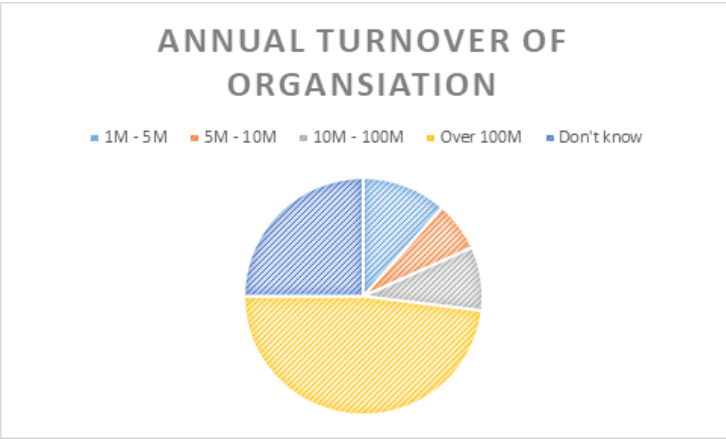
2. BACKGROUND

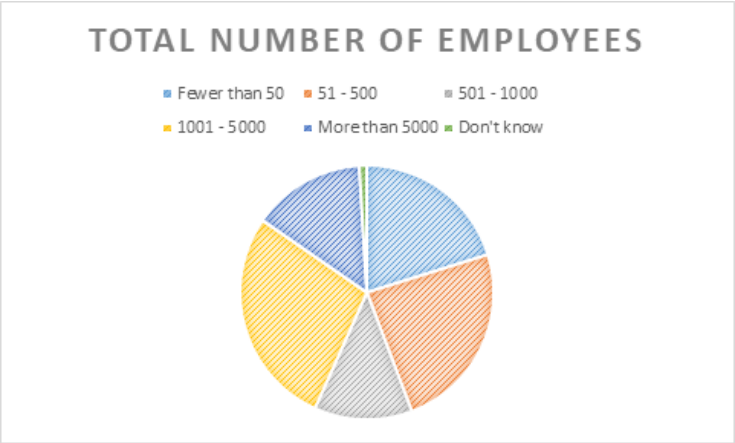
2.1 Demographics of Research Participants

Business Profile of Research Participants



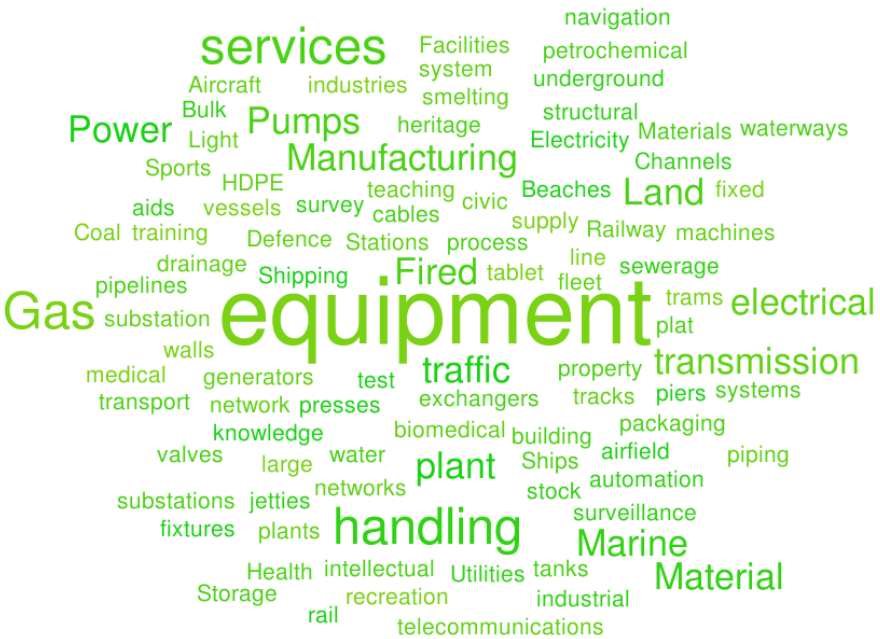






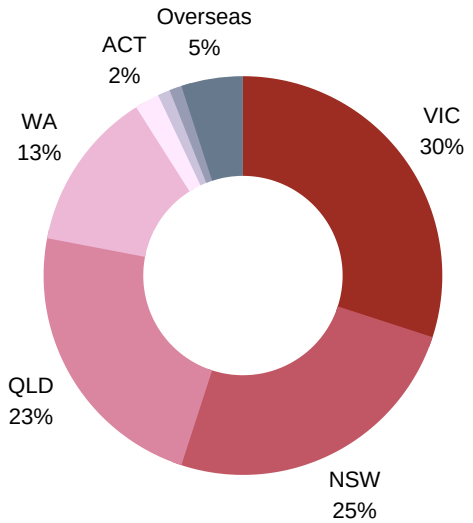
Types of Assets

A snapshot of the vast types of assets that are used in organisations of those who responded to the research



Geographical Profile of Research Participants

Which Australian State do you Reside?



2.2 Research Methodology

A survey questionnaire was sent to all Asset Management Council members in late 2019 inviting input to the State of the Asset Management Sector 2020 report.

During January 2020 the responses to the survey questionnaire were collated and analysed and the findings of the report then disseminated.

The findings are to be tested with a series of focus groups with the Asset Management council corporate member key nominees.

2.3 Short Comings of Method

The data has been collected from the Asset Management Council members and the assumption made that the members of the Asset Management Council represent a cross section of the wider asset management sector.

It is recognised that there are others in the community who are not connected with the Asset Management Council who have not contributed to the research.

3. TOP ASSET MANAGEMENT TRENDS

The top trend in the asset management industry for 2020 is reported as technological change.

The second trend is reduced resource availability in terms of availability of funds and availability of skilled staff.

List of the top 5 trends in the asset management industry for 2020

The top 5 trends in asset management industry	%
Technological change	35.5
Reduced resource availability	19.5
Changing community expectation	17.7
Role of government capital	12.6
Demographic change	9.5
Other	5.2

3.1 Top Asset Management Priority in the Workplace for 2020

Aligning the organisation's asset management processes and functions by gaining engagement from others in the organisation and promoting the value of asset management to the organisation's leaders is the top challenge for 2020.

Long term planning, optimising capital programs and maintenance programs and managing risk and criticality over the whole of life of an asset is the second highest asset management priority for 2020.

The third area of priority for asset management is around issues of collection, management and analysis of asset data for decision making. Different sections of an organisation have different requirements and uses for asset data.

The fourth asset management priority is around the people undertaking the asset management functions in terms of capability - finding capable people or upskilling those who need to undertake the asset management function. Finding resources available to do the job.

Other areas of priority include explaining the value of asset management, increasing performance, undertaking gap analysis, managing changing stakeholder expectations, implementation of an asset management system and framework.

Summary of the most common asset management priorities in the workplace for 2020

Change management, leadership and culture of the organisation, gaining alignment of processes and functions across an organisation	24%
Long term planning, optimising OPEX and CAPEX, maintenance planning, managing risk and criticality over the whole of life of an asset	19%
Data management and accuracy of data for decision making and digitisation of the data	16%
Capability and capacity, resourcing, finding the skilled people to do the job	15%
Value - explaining the value of asset management to upper management and to the organisation	7%
Increasing performance, undertaking gap analysis to understand where and how to improve asset management maturity	6%
Stakeholder management, managing changing expectations	5%
Asset Management Systems, designing an asset management system and implementation of systems	5%
Other	3%

3.2 Top Asset Management Achievements in 2019

Looking back at 2019 the best achievements were listed as:

- Achieving personal certification and organisation certification to ISO55001
- Developing and implementing an asset management strategy
- Creating a standardised asset management framework or approach for managing asset data

The 10 most popular asset management achievements in 2019 were reported as:

1. **Achieving certification for a course**
2. **ISO recognition**
3. **Developing/Implementing an AM strategy**
4. **Creating a standardised framework/approach for data/assets**
5. **Managing a number of AM projects**
6. **Completing AMMA**
7. **Improving knowledge & collaboration**
8. **Creating risk-based maintenance programes**
9. **Policy development & employee buy-in**
10. **Won awards**

3.3 Asset Management Interest Areas to Watch

The top three areas of asset management interest are:-

1. Strategic asset management
2. Operations and maintenance and
3. Life cycle and health of assets

Top 10 Main Areas of Asset Management Interest
1. Strategic Asset Management
2. Operations and Maintenance
3. Life Cycle and Health of Assets
4. Continuous Improvement
5. Whole of Life Planning and Costing
6. Maintenance - planning, scheduling, strategy, tactics
7. Risk management and Criticality
8. RAMS - Reliability, Availability, Maintainability and Supportability of systems and equipment
9. Condition Monitoring
10. Asset Management Tools and Techniques

3.4 Overall value of asset management to organisations

It was found that a large proportion of respondents are still in the early stages of implementing asset management and as such found it hard to respond with quantitative evidence of recorded value from implementation of asset management within their respective organisations. However, many were able to advise the initial reasons why asset management was implemented and could identify the value the organisation was looking to gain from implementation of asset management.

Some of the areas of value organisations have found or are looking for in implementation of asset management include:

- Better profits for the business
- Better decision making
- Ensuring reliability and readiness of assets
- Organisational stability
- Whole of life management and sustainability
- Optimised performance and safety for lowest possible cost

4. IMPLEMENTING ASSET MANAGEMENT SYSTEMS

59%

of respondents have implemented an asset management system within their organisation

26%

of respondents have been accredited to ISO55001 or are considering becoming accredited to ISO55001

4.1 Bottlenecks in Implementation of Asset Management Systems

Bottlenecks in implementation were found to lie in the culture and alignment of the organisation. Lack of robust business case, lack of skills, knowledge, resources and funding were all identified as reasons for bottlenecks in implementation of asset management systems. Technology was also a reason that implementation of asset management systems was impeded.

Most Common Bottlenecks in Implementation of Asset Management Systems

1 Culture & Alignment
2 Business Case
3 Lack of Resources & Funding
4 Skills & Knowledge
5 Adopting Technology
6 Silos (O&M Focus)

4.2 Benefits in Implementation of Asset Management Systems

The top ten benefits in implementation of asset management initiatives were recorded as:

1. CAPEX planning and prediction
2. Data government/quality
3. Cost reduction
4. Condition based monitoring
5. Better decision making ability
6. Cultural change
7. Life-cycle planning and prioritising projects
8. Effective framework for the business
9. More consistent approaches across the business towards asset management
10. Marketing credibility (consultants)

5. TECHNOLOGY, DATA & INFORMATION FOR DECISION MAKING

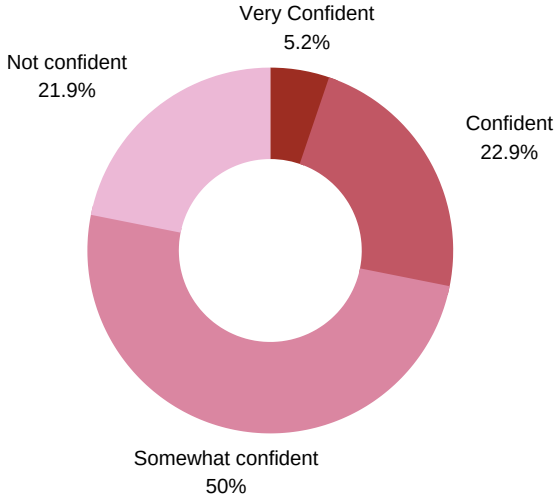
5.1 Use of technology within businesses

Use of the following technology within organisations:	Yes %
Sensors for monitoring assets	62
Predictive analytics	43
Drones for condition monitoring assets	32
BIM and digital engineering	28

5.2 Confidence in data used for decision making

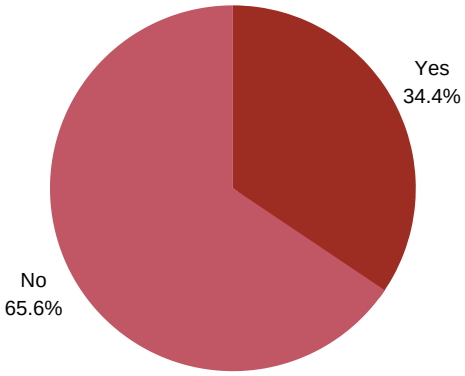
Nearly half of respondents have doubts in the confidence of the data they are using for decision making whilst the other half are somewhat to very confident in the accuracy of their data

How confident are you that the information you receive about your company's assets in accurate?



5.3 Integration of AM data with the finance system

Is your AM data integrated with your finance system?



5.4 What asset management software do you use?

SAP	19%
MAXIMO	18%
In house bespoke	12%
Excel spreadsheets	6%
Ellipse	6%
Assetic	5%
AWB	5%
MEX	5%
Technology One	5%
Conquest	4%

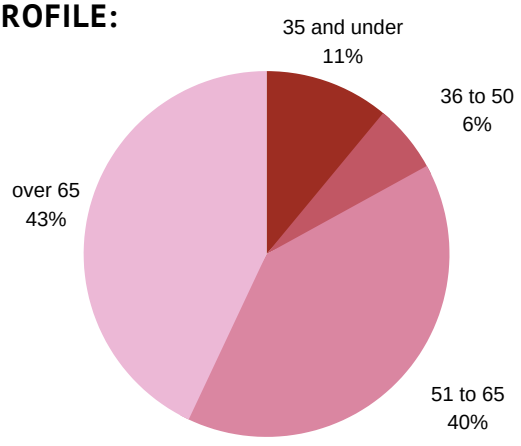
Others include: Infor EAM, IFS, RAMS, Asset Asyst, Asset Facilities Mgt Online, Confirm, Mainpac

6. PEOPLE

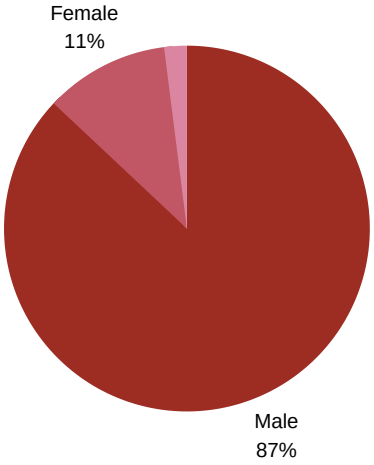
6.1 Age Profile of the Asset Management Profession

Age and gender profile of research participants

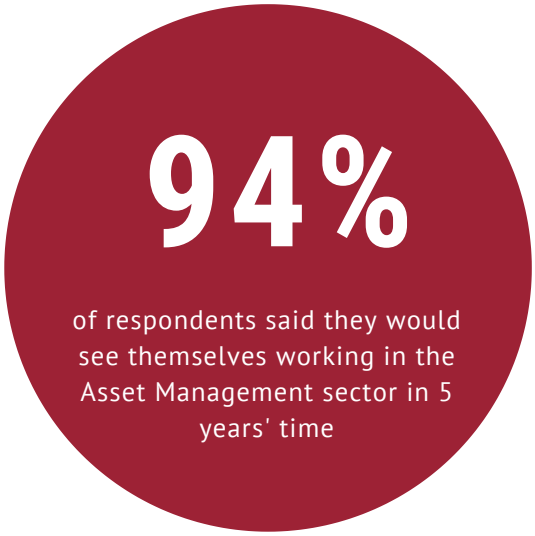
AGE PROFILE:



GENDER:



6.2 Likelihood to stay in profession in next 5 years



6.3 Asset Management Knowledge Retention

Processes organisations use to retain knowledge

1 Data Management System & Enterprise Asset Management System
2 Various unintegrated systems
3 Digital / IoT
4 Mixed
5 Archives / Database programs
6 Sharepoint
7 Training
8 Linked In
9 No such processes
10 Hard copy folders

6.4 Asset Management Information Sources

Where do you find your asset management information?

1 Web Research
2 Books/Journals
3 Webinars
4 Associations
5 Emails
6 Events
7 AMBoK
8 Standards
9 Colleagues
10 Linked In Groups

6.5 Asset Management Skills Gaps

1 AM fundamentals
2 Training & technical knowledge
3 Technology use
4 Data management
5 Senior / Exec level knowledge & understanding
6 Appropriate standards
7 Practitioner level
8 Strategic model implementation
9 Practitioners vs Trades
10 Service requirement identification
11 Risk management
12 Risk management
13 Negotiating and reassuring value of AM

6.6 Support Needed to Address Skills Gaps

What do you think should be done to address the skills gap?

1 Improved programmes beyond basics
2 More events / workshops
3 Sharing more industry examples of practice & implementation
4 More promoted key & available information
5 Improving visibility and image of AM to government, regulators & businesses
6 Wider approach to promoting AM to the industry organisations
7 Increase access to regional/rural members & organisations
8 Develop the 'What' and the 'How' with AMBoK
9 Fit for purpose training at various levels
10 AM value promotion to all stakeholders & potential member organisations
11 Continued webinars & chapter events
12 Coaching & Consultancy

7 ACKNOWLEDGEMENTS

Thanks to all the Asset Management Council volunteer members who contributed to the research that underpins this report.