Too, Eric G. (2010) ***A framework for strategic infrastructure asset management.*** In: Amadi-Echendu, Joe E. and Brown, Kerry A. and Willet, Roger and Mathew, Joseph (Eds.) Definitions, Concepts and Scope of Engineering Asset Management. Engineering Asset Management Review, 1. Springer, pp. 31-60.

Introduction

The concept of asset management is not a new but an evolving idea that has been attracting attention of many organisations operating and/or owning some kind of infrastructure assets. The term asset management have been used widely with fundamental differences in interpretation and usage. Regardless of the context of the usage of the term, asset management implies the process of optimising return by scrutinising performance and making key strategic decisions throughout all phases of an assets lifecycle (Sarfi and Tao, 2004). Hence, asset management is a philosophy and discipline through which organisations are enabled to more effectively deploy their resources to provide higher levels of customer service and reliability while balancing financial objectives.

In Australia, asset management made its way into the public works in 1993 when the Australian Accounting Standard Board issued the Australian Accounting Standard 27 – AAS27. Standard AAS27 required government agencies to capitalise and depreciate assets rather than expense them against earnings. This development has indirectly forced organisations managing infrastructure assets to consider the useful life and cost effectiveness of asset investments. The Australian State Treasuries and the Australian National Audit Office was the first organisation to formalise the concepts and principles of asset management in Australia in which they defined asset management as " a systematic, structured process covering the whole life of an asset"(Australian National Audit Office, 1996). This initiative led other Government bodies and industry sectors to develop, refine and apply the concept of asset management in the management of their respective infrastructure assets. Hence, it can be argued that the concept of asset management has emerged as a separate and recognised field of management during the late 1990s.

In comparison to other disciplines such as construction, facilities, maintenance, project management, economics, finance, to name a few, asset management is a relatively new discipline and is clearly a contemporary topic. The primary contributors to the literature in asset management are largely government organisations and industry practitioners. These contributions take the form of guidelines and reports on the best practice of asset management. More recently, some of these best practices have been made to become a standard such as the PAS 55 (IAM, 2004, IAM, 2008b) in UK. As such, current literature in this field tends to lack well-grounded theories.

To-date, while receiving relatively more interest and attention from empirical researchers, the advancement of this field, particularly in terms of the volume of academic and theoretical development is at best moderate. A plausible reason for the lack of advancement is that many researchers and practitioners are still unaware of, or unimpressed by, the contribution that asset management can make to the performance of infrastructure asset. This paper seeks to explore the practices of organisations that manage infrastructure assets to develop a framework of strategic infrastructure asset management processes. It will begin by examining the development of asset management. This is followed by the discussion on the method to be adopted for this paper. Next, is the discussion of the result form case studies. It first describes the goals of infrastructure asset management and how they can support the broader business goals. Following this, a set of core processes that can support the achievement of business goals are provided. These core processes are synthesised based on the practices of asset managers in the case study organisations.

Development of Asset Management

The concept of asset management is not a new but an evolving idea that has been attracting attention of many organisations operating and/or owning some kind of infrastructure assets. The term asset management have been used widely with fundamental differences in interpretation

and usage. Woodhouse (2006) suggested that there is at least 6 distinct current uses of the term as follows:

- The financial services sector has long used the phrase to describe the management of a stock or investment portfolio – trying to find the best mix of capital security/growth and interest rates/yield.
- Main board (usually financial) directors and some city analysts use the term in relation to mergers and acquisitions– buying and selling companies, re-organising them, divesting low value elements and trying to raise capital value and/or yields.
- Equipment maintainers have also adopted the name in an attempt to gain greater credibility and respect for their activities. As 'maintenance' has for so long been treated as a necessary evil and low on the budgeting priority list, perhaps calling it 'Asset Management' instead will raise awareness on the corporate agenda. 'Asset Management' becomes, therefore, a more sellable way of saying 'better and more business-focussed maintenance'.
- In line with the maintainers seeking greater corporate clout, the large number of software vendors selling 'computerised maintenance management systems' (i.e. asset registers, work management, history gathering, materials & cost databases) have relabelled their products as "Enterprise Asset Management Systems".
- In the information systems world, "Asset Management" is interpreted as just the bar-code labelling of computers and peripherals, and the tracking of their location/status.
- An increasing number of critical infrastructure or plant owners and operators have adopted 'Asset Management' to describe their core business – the combination of investing in, exploiting and caring for appropriate physical plant and infrastructure over its entire life.

In this paper, the last interpretation is adopted. This term of asset management has been adopted as the label for the integrated, whole life, risk based management of industrial infrastructure, as evolved principally in the North Sea oil and gas industry during the late 1980's and early 1990's (Woodhouse, 2003). Deregulation and privatisation of infrastructure such as utilities, transport and public services in the late 1980's and early 1990's have resulted in many organisations need to transform their infrastructure assets from cost centres charged with carrying out budget projects into profit centres charged with contributing to earnings growth. This has indirectly encouraged organisations to adopt this more holistic whole life approach to manage their infrastructure assets and hence the adoption of asset management.

However, two main barriers were observed that prevent the advancement and development of asset management in the context of infrastructure organisations. The first barrier to the adoption and advancement of asset management is found in the 'step child' status that is often bestowed upon asset management groups within organisations. Recognition and prestige are always accorded to finance and investment activities of new construction and development. On the other hand, asset management is frequently associated with only maintenance, asset inventory, and its related services and therefore considered to be of less strategic importance. For example, there are many asset management systems that have been used for years. These asset management systems focus on databases, asset inventories, technical models and other analytical tools. Most of these systems are used to monitor conditions and then plan and program their projects on a 'worst off' basis. As such, these systems typically function at the operations level and focus on one particular asset. This approach to asset management in general, and resource allocation and investment analysis in particular, is tactical rather than strategic. This view is supported by the findings and conclusions from the Australian National Audit Office Report No.27 (Australian National Audit Office, 1995) in their audit of asset management practices common to 24 organisations. One of the main weaknesses identified related primarily to the lack of a strategic approach to asset management. Similarly, Woodhouse (2004) argued that emphasis has been disproportionately aimed at getting the jobs or functions done more efficiently resulting in "doing the wrong work 10% quicker and cheaper" and does not lead to a better total performance. Consequently, the concept of asset management as applied to infrastructure organisation is viewed in research more from an operational (engineering and maintenance) and asset management functional perspective rather than from the strategic and holistic management perspective. In view of the amount of emphasis in the analytical tools and technical models, there

is a risk of leaping to the conclusion that the implementation of asset management should start through the development of more advanced technical modelling and other analytical tools that can talk to one another. The focus is more on individual assets rather than the long-term asset management needs of an organisation and is echoed by Stapelberg (2006) who noted that most asset management frameworks fail to have a system wide focus. Hence, a compelling argument against the progression of the concept of asset management is the general lack of interest from an organisation due to its operational perspective and therefore it is not able to contribute value to their stakeholders.

The second barrier is the contentious state of what constitutes asset management. Over the years many definitions of asset management have been provided. Some of these definitions are shown in Appendix 1. From the various definitions given, it can be noted that different perspectives have been taken by agencies and organisations to align their corporate objectives with their own asset management practices. These different frameworks were developed and used to suit each different organisation's business and corporate objectives and hence each has its own focus. Consequently, these diverse frameworks and guides, issued by different organisations being used in practice cover different aspects and principles of asset management in accordance with what asset management means to them. Stapelberg (2006) conducted a comprehensive review of various asset management models and frameworks of infrastructure and industrial assets owners both in the public and private sectors as well as those of asset management service providers. This review reveals that there are many asset management frameworks and models that have been developed in practice. These frameworks range in their level of complexity, design and specific details. Although many models and frameworks have been developed, they can be generally classified into 3 main categories.

1. The asset management framework adopted by industrial asset owners tends to be typical of the initial Enterprise Resource Planning (ERP) process frameworks that were developed in the 1990s (Stapelberg, 2006). They include industry strategies; enterprise management; supply chain management; and manufacturing and plant operations management.
2. The manufacturing sector is more inclined to adopt technology models that include components such as demand management, system engineering, configuration management, integrated (logistic) support and total quality management (Hardwick, 2008).
3. Thirdly, asset management frameworks adopted by infrastructure organisations such as utilities, transport and those of asset management service providers are more inclined towards a life cycle process approach. The processes range sequentially from asset planning, creation, operations, maintenance to performance measurement. These asset life cycle frameworks incorporate risk, quality and environmental management to form a total asset management framework.

The diverse and fragmented adoption of asset management by different organisations does not help in the development and advancement of asset management but rather, creates more confusion to practitioners. Consequently, organisations are struggling to come to terms with the constitution of asset management and how this can improve the performance of their infrastructure asset and this can have an enormous impact across the entire organisation.

The development of asset management discussed above suggests that infrastructure organisations need to pay attention to two key issues in order to improve their performance. Firstly, asset management needs to be viewed from a strategic approach in order to create value to the organisation. As owners, operators and maintainers of infrastructure assets, infrastructure organisations assume a significant responsibility in ensuring the successful performance of the assets to meet the service needs of their customers and expectation of stakeholders. Hence any infrastructure organisation should be striving to improve its operations, whether from the point of view of customer satisfaction, increased productivity, better asset quality, better environmental performance or any host of other performance indicators. For asset management

to become a true value-adding pursuit within a corporate framework, it must be primarily concerned with filling a strategic role, i.e. an asset manager must be proactive not reactive in their approach. They must be able to forecast the needs of their organisations and make forward plans that will support the aims of the organisation in the future. This strategic view is important as it takes a long-term view of infrastructure performance and cost. A strategic approach can thus provide a better understanding of how to align the asset portfolio so that it best meets the service delivery needs of customers, both now and in the future (LGV, 2004). The need for a strategic and integrated approach has slowly gained attention. For example, Too et al. (2006) reviewed some of the current asset management practice by government agencies in Australia revealed that despite the different frameworks adopted in the practice, they are all advocating a strategic approach. Accordingly, it is pertinent to adopt a strategic approach to asset management that can support the broader and more strategic business goals.

Secondly, there is a need for a clear understanding of what asset management is. Asset management is more than a new management buzz word. There are still many questions about what asset management really means. Asset managers want and need a better understanding of its meaning, impact, and value to their organisations. The definitions given in Appendix 1 reveal that asset management is in some ways no different than what infrastructure organisations have always done. Decisions must be made about operating and maintaining infrastructure assets. New investments need to be planned. Resources need to be allocated, and budgets need to be specified. Knowledge about the condition of the equipment and structures has always been, and continues to be, valuable. A closer examination of the definitions reveals key unifying themes that form the heart of asset management and are described below:

1. Alignment of assets and operations with corporate objectives: The key goal of asset management is the creation of value to the organisation stakeholders from infrastructure asset (Jones, 2000, Humprey, 2003). It is about understanding and managing the trade-offs between financial performance, delivered operational and service performance and risk exposure (Jones, 2000). Hence, asset management provides a structure for driving and integrating customer expectations, legislative requirements, operating requirements, and financial objectives throughout an organization.
2. It links decision-making and action with information: Asset management is about obtaining the knowledge needed to optimise trade-offs among financial performance, operational performance and risk exposure (e.g. Jones, 2000, Sklar, 2004). It is about decision-making, rather than the blind pursuit of technical performance (Humprey, 2003). Decisions are driven by the actual condition and performance of assets individually and collectively as well as by the risks to corporate objectives from asset failure. Analytical methods and information integration are central.
3. Life-cycle costing is a key concept: Costs are minimized, starting with the initial investment, continuing through operation and maintenance, and ending with disposal (e.g. Austroads, 1997, Queensland Government, 1996, NSW Treasury, 2004, Brown, 2005). The connections between the choice of assets and the implications for the cost stream from maintaining those assets are critical.
4. It is a process: To understand asset management, we need to identify and define the activities involved. Asset management is about designing and implementing a new business process that can deliver higher returns to corporate stakeholders (Kennedy, 2007). One of the precepts of the discipline is that all business units should make decisions based on the same criteria. A sound asset-management process ensures that business units do not sub optimize by emphasizing parochial criteria at the expense of overarching corporate objectives (Humprey, 2003).

Synthesising the above discussions and themes, strategic infrastructure asset management can be defined as follows:

> Infrastructure Asset Management is a strategic and systematic process of optimising decision-making in resources allocation with the goal of achieving

planned alignment of an infrastructure asset with corporate goals throughout its lifecycle.

This definition can provide guidance on the development of core infrastructure asset management processes. Craig & Parrish (2003), Brown (2004) and Sklar (2004) all support a holistic view of asset management as an integrated business process designed to optimise the use of a utility's assets while balancing the varying needs of key stakeholders. Similarly, Tao et al. (2000) proposed that from a business perspective, it requires an asset management framework that comprised of dynamic business processes to link all asset types together under a single business context. To enable organisation to develop infrastructure, it need a strategic framework to identify the specific infrastructure service needs, facilitate the selection and implementation of infrastructure projects, and to monitor the performance of infrastructure assets and services. Establishing a strategic infrastructure asset management process is therefore fundamental to improving efficiency and effectiveness of infrastructure delivery. To have structure and process in place, an organisation needs to identify and define the activities involved. Hence, there is a need to develop core asset management processes that can provide the bedrock for effective use of available asset management tools and systems (Clash and Delaney, 2000). This stronger focus on the integrated processes will then be able to deliver higher levels of customer service and reliability while balancing off the financial objectives for the business. For this reason, this paper aims to understand the core strategic processes involved in the management of infrastructure assets.

Method

This study used a multiple case design that allowed a replication logic, that is, a series of cases is treated as a series of experiments, each case serving to confirm or disconfirm the inferences drawn from the others (Yin, 2003). To build a better theory through multiple cases, the choice of cases must be based less on uniqueness of a given case, and more on the contribution to theory development within the set of cases (Eisenhardt, 2007). A particularly important theoretical sampling approach is based on a typology of cases. For organisations that manage infrastructure assets, the typology are (1) Infrastructure types (namely, water, airport, seaport, rail, road) (2) Level of privatisation (government owned corporation, government owned department, full privatisation) (3) Spread of infrastructure (co-located or spread over large geographical areas). Appendix 2 describes the three case organisations studied.

Data Sources

The data is obtained from discussions with senior managers responsible for the management of infrastructure assets and analysis of documents obtained from the organisations. The interviews are organised around two research questions: (1) What are the goals of infrastructure asset management? and (2) What are the core processes involved in achieving these goals?

Interviews: The purpose of the interviews was to understand the strategic core processes in delivering overall improvement to the management of infrastructure assets. Infrastructure asset management being a boundary-spanning function, three separate groups of interviewees were identified as representative of the infrastructure asset management function within each case. These three groups include executives from (1) senior management, (2) asset management and (3) asset operations. Interviews at each case organisation included at least one executive from each of the three groups to ensure adequate depiction of the infrastructure asset management function for each case.

Supporting Documents: In this research, interview transcripts were linked to other internal and external documents. For examples, while the interviews were taped, written notes were also made to record direct observations and other data. These notes include sketched diagrams used by interviewee to help explain their replies as well as their body language and the way they responded to certain questions. Direct observation when conducting the interviews can provide

additional information about an organisation. The interview data was also supported, cross checked and compared with data from a broad range of sources. These documents include:

1) Organisation policies and procedures such as departmental strategy, contractor selection procedures, corporate plans, annual reports, risk assessment guides, IT Strategic Plan etc.
2) Organisation charts
3) Master Plans, Development Plans, Expansion Plan, Land Use Plan, etc.
4) Minutes of meetings, progress reports and memoranda, change management report, maintenance records, customer surveys etc
5) Consultant Reports such as economic reports, traffic reports, environmental reports, aviation reports, etc.
6) Government reports such as Auditor General reports, Strategic Asset Management Plans, Rail Transport Infrastructure Plan, Infrastructure Plan and Program, etc.

Many of these documents are available in the case organisations' website. In addition, some of these organisations have provided access to their internal library that contained collections of many internal documents and reports. These documents offer more insights as they may not be directly observed during interviews. All these documents were reviewed to corroborate and augment the evidence gathered from interviews.

Data Analysis

A two-stage analysis suggested by Eisendhardt (2002) is adopted for this study; namely (1) Within-Case Analysis and (2) Cross-Case Analysis. Within-Case analysis is conducted initially by coding, that is, to 'chunk' the text into broad topic areas, as a first step to see what is there (Bazeley, 2007). This was done in the analysis of the first case to sort answers according to different components of asset life cycle such as asset planning, asset creation, asset maintenance, etc. This initial coding is useful to identify areas, which will need more data and identify text that is particularly relevant to the study. This process also help to make the text manageable by selecting only the relevant text for further analysis (Auerbach and Silverstein, 2003).

Based on these broad-based nodes, further coding or 'coding on', a term coined by Richards (2005), from already coded text is performed. As 'coding on' continues, coded text can be analysed through categorization to reflect conceptual advance. From the broad-based nodes, further coding involved recording the repeating ideas by grouping together related passages. These repeating ideas were organised into some initial themes such as the asset management goals, significance of the strategic processes, the challenges faced, and approaches that can be adopted to support the business goals. Emerging themes such as significance of the strategic process in creating value to an organisation were further grouped into more abstract concepts consistent with the theoretical framework (Auerbach and Silverstein, 2003). This further coding gave rise to preliminary themes associated with the core strategic processes to support business goals of infrastructure organisations.

After the within case analysis for each case is done, the cross case analysis is next performed. The emerging ideas and concepts from each case were compared (Glaser and Strauss, 1967) to identify common themes and initial propositions. The purpose of this analysis is to test the overall validity of the proposed capability. This is to prevent the danger of reaching a premature and false conclusions as a result of information processing biases such as limited data(Kahneman and Tversky, 1973), overly influenced by the vividness (Nisbett and Ross, 1980) or by more elite respondents (Miles and Huberman, 1994), ignored basic statistical properties (Kahneman and Tversky, 1973), or sometimes inadvertently dropping disconfirming evidence (Nisbett and Ross, 1980).

The preliminary findings from the data analysis were compiled into a preliminary report to seek further validation. The report was sent to senior managers of case organisations for feedbacks and comments. Further meetings were arranged to discuss the findings face-to-face. These feedbacks were incorporated to refine the findings.

The goals of infrastructure asset management

From the strategic perspective, the principles of asset management must be soundly based on the alignment and fit of the organisation's resources, to best meet the needs of the customer within the environment in which it is required to compete in order to maximise returns to its stakeholders. The asset manager being the custodian of infrastructure organisation's main resource i.e. infrastructure assets, needs to align the goals of infrastructure asset management with those of the strategic business goals as defined by the asset owner so that it can achieve the long-term stakeholder value.

As in most organisations, the main reason for infrastructure organisation existence is to sustain the long-term shareholder value. Case data revealed that the most important context for managing infrastructure assets is to support the performance required by business operations. This is aptly shared by managers as follows:

> "we are managing for the performance required by the business that uses the asset." (Port)
>
> "it all started with a business plan and underneath it you build an asset plan that support the business … these asset plans contain both maintenance and an investment strategy." (Rail)

As in most organisations, the main reason for an infrastructure organisation's existence is to sustain the long-term shareholder value. It is fair to say that the shareholder is constantly looking for financial return for their money invested in an organisation. Informants from all cases have viewed the financial returns from infrastructure assets as important in the management of infrastructure assets. Some of the managers commented:

> "shareholders … are looking for return on their investments … and they want maximum return … they will not want to invest million of dollars if there is no guarantee that it can generate a good steady income." (Port)
>
> "we make a full commercial return on our assets from the coal business." (Rail)
>
> "the driver is that the asset must give us a return." (Airport)

However, Cokins (2004) cautioned against financial return being the only end goal and excessive focus on a financial goal is unbalanced because non financial goals can influence the eventual outcomes. The above suggests that in the formulation of goals of infrastructure asset management, it is important to look at stakeholders' values. Two obvious categories of stakeholders i.e. customers and owners / investors' are central to organisations that manage infrastructure assets. Other stakeholders such as managers, employees, suppliers, community and general public may also need to be considered. There are many conflicts of goals between different stakeholders in the management of infrastructure assets. For example, to comply with the safety regulations, it is imperative to incur more cost and hence increase the cost structure. But this is in conflict with a shareholder view of maximising return. These differences must be recognised and addressed. To this end, goals and objectives should be a result of the interactions and consensus between various stakeholders. Hence, it is clear that the goals of asset management cannot include every concerns and wishes of all stakeholders. Woodhouse (Woodhouse, 2002) argued that the secret of success at the heart of asset management is "choosing the right direction despite the uncertainties and conflicting stakeholder expectations,

and taking the whole organisation with you." Consequently, the infrastructure asset management goals need to address a few dimensions that reflect the interest of a wide range of stakeholders.

Organisations can achieve sustained shareholder value according to Kaplan & Norton (2004), by either a productivity strategy or a growth strategy. To achieve the growth strategy, businesses goals must aim at enhancing the opportunity to expand revenue and increase customer value. To achieve a productivity strategy, the business goals should be to improve the cost structure and increase asset utilisation. This relationship is shown in Figure 1.

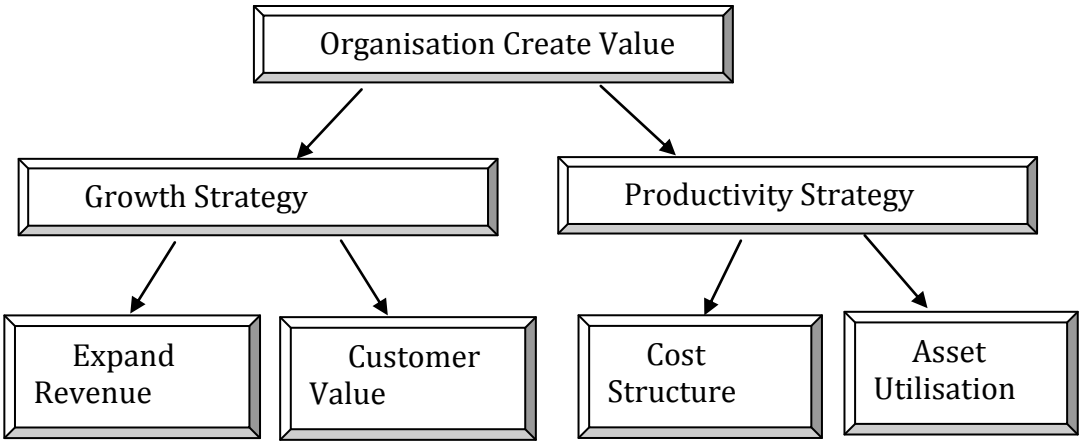

Figure 1 How organisation creates value (Adapted from Kaplan and Norton, 2004)

Regardless of the type of business, all organisations will have to consider these strategies in order to increase their performance. In the management of infrastructure assets, the asset manager should view the infrastructure assets under their care as an integrated business resource that needs to be managed as a total enterprise (Too and Tay, 2008). If infrastructure assets are a business resource, then the goals of infrastructure asset management must support the business goals i.e. infrastructure assets must generate revenue and meet the business needs without compromising the sustainability and competitiveness of the business in future. Hence, they need to develop the asset management goals that are aligned to these broad strategies in order to create value to the organisation.

These asset management goals must achieve one of those broad business goals in order to add value to organisations. Data from this research indicated that there are many goals being pursued in the management of infrastructure assets in order to support business operations. These goals are shown in Table 1.

Goals	Port	Rail	Airport
Cost Efficiency	to achieve the design life of an asset at minimum maintenance cost	some are very cost sensitive ... keeping cost down is a very important priority	manage them efficiently, within the budget, to keep the asset in good conditions without spending too much money on it.
Extend Service Life	to increase the service life of an asset with cost effective preventive maintenance	we will extend the life of the assets as long as the conditions allow us to do it	we can continuously maintain, upgrade, replace some of the components and extend the life

Capacity Matching	once the occupancy rates reach more than 50%, it signifies that it is time to expand the wharf facilities… based on those forecasts, we conduct modelling to anticipate the infrastructure requirements	depends on business context and customer demands, we will invest to provide those capacity planning that analyse the demand and capacities and services needed and plan what kind of assets that we need to support those services	…. ensure we are able to optimise existing capacity relative to demand
Quality & Durability	aims to achieve excellence in engineering.... No point giving them an asset that they are not satisfied with.	durability and robustness of our asset	we have to present our assets in a very good condition, in a very good way
Availability	maximum availability of assets to support our business	it is really the business / customers demand aspects.. both the reliability and availability	make sure assets are available when our customers need them
Reliability	the reliability of that asset	reliability can be paramount like the city network where we run the commuter service.	keep the assets operational and in good working order
Compliance	We have a big environment section that monitors all sorts of environment issues including noise, air, spillage, storm water etc.	we do the work under the regulation in a regulated monopoly scenario there is a prudency of scope and prudency of price test	Legislative requirement, because a lot of our assets and security revolving around the airport …maintain it to regulatory requirements
Market Leadership	we want to be the trend setter and we want to be the leader of the pack we look at trends that are emerging, we try to be well and truly ahead of the game we need to make sure we stay at the cutting edge of the port facility business	We need an innovative way of making things happen	If we do not enhance our infrastructure assets to serve newer aircrafts, airlines may not want to fly here ..can affect our efficiency and our reputation as a premier airport

Table 1 Goals of Infrastructure Asset Management

Figure 2 illustrates the symbiotic relationship between business goals and asset management goals as observed from the case data.

Figure 2: Symbiotic relationship between the Asset Management Goals and Business Goals

Asset Management Goal 1 – Cost Efficiency

To achieve the broader business goals of improving cost structure, case evidence suggests that most asset managers interviewed are constantly looking at ways to improve their cost efficiency. In other words, the asset management goal is to manage and operate their infrastructure asset cost efficiently. For example, the following comments were noted:

> "we aim to achieve the design life of an asset at minimum maintenance cost." (Port)

> "we manage them (infrastructure assets) efficiently, within the budget, to keep assets in good condition without spending too much money." (Airport)

Asset Management Goal 2 – Capacity Matching

To achieve the business goals of asset utilisation, there is a need to match the capacity to the business needs to ensure that infrastructure assets are not over or under provided. Hence, another asset management goal is matching the capacity of infrastructure assets to support business needs. As one informant noted:

> "certainly the capacity is fundamental but then the issue is of what services do you want to run to match that customer." (Rail)

> "we are constantly looking at projected growth of the terminal and travelling public … our operations department will feedback on capacity of current assets and the capacity going forward … what we can do and what we can handle." (Airport)

Asset Management Goal 3 – Meeting Customer Needs/Requirements

To enhance customer value, it is necessary to provide an asset that users need and want. Customer value can be enhanced through providing "quality" assets which can be broken down into more detail such as reliability, dependability, compliance to safety and environmental regulation and timeliness. In addition, these infrastructure assets must not only be available but must also be in good, durable and reliable conditions that comply with regulatory requirements. The need to provide customer value is noted by some other informants as follows:

> "we must ensure there is maximum availability of assets to support our business …no point giving them an asset that they are not satisfied with …" (Port)

> "its maintaining reliability to meet customer standards and service …" (Airport)

> "there is also a compliance side of things where we have regulatory requirements to maintain and operate assets within certain guidelines." (Rail)

Asset Management Goal 4 – Market Leadership

To grow the revenue opportunity, it is interesting to note from the cases that one of the asset management goals included a need to be innovative and set standards in order to be a leader to remain competitive. In other words, asset management aims to be forward looking in order to sustain competitive advantage through market leadership, innovation and creativity. This sentiment is echoed by managers interviewed:

> "we want to be the trend setter and we want to be the leader of the pack … The other main goal is to adopt the best practice principles to make sure that we are adopting the best in everything we do." (Port)

> "The key driver is to maintain excellence in service delivery and standards … if we do not enhance our infrastructure assets to serve newer aircrafts, airlines may not want to fly here … it can affect our efficiency and our reputation as a premier airport." (Airport)

> "… this is like an innovative way of making things happen". (Rail)

In short, the above goals will require asset managers to make decisions that will maximise their financial performance, achieving excellence in their service level and minimising their risk exposure. However, the difficulty is that these goals are not all independent but actually all outputs of the same infrastructure asset performance. The interdependency means it would be necessary to understand the interplay between these goals in order to effectively maximise overall infrastructure asset performance – or value (Jones, 2000). The asset manager has to make an informed and weighed decision to achieve a balance between these goals. Following this decision, strategies need to be developed to achieve the set goals. Core asset management processes underpin these strategies. The next section reports the findings from the interviews on the core asset management processes.

Emerging Framework: The Strategic Infrastructure Asset Management (SIAM) Processes

Having established the goals of infrastructure asset management, the strategies must be identified within the asset management function to describe how these goals can be accomplished. Brown (2005) suggested that these strategies within the context of asset management framework, are in fact processes in which an asset is effectively managed throughout its entire life cycle. The importance of asset management processes in any infrastructure organisation cannot be overstated, as it will ensure full accountability of the asset condition, use and performance (Brown, 2005). Specifically, the ability to improve business core processes involves the integration of business core operational processes and organisational strategic goals. This process effectively delivers the organisation's business objectives to match the corporate direction for the organisation within a pre-determined planning horizon (IMEA, 1994). These processes will require consideration from the start of the asset planning phase to allow investment decisions to be made on an asset's entire life cycle rather than the asset's initial purchase price (NPWC, 1996).

Stapelberg (2006), in reviewing the various asset management frameworks suggested that most infrastructure organisations are more inclined towards adopting an infrastructure asset life cycle process approach. Similarly, Hardwick (2008) suggested that all the frameworks developed in practice can be integrated into asset life cycle processes. Kennedy (2007) confirmed that the asset management process itself is a life cycle process and believed good asset management processes were essential. This thinking recognises asset management as an overarching business process that integrates into all aspects of the way the business functions to deliver its comprehensive corporate plans (NSW Treasury, 2004). This paper will thus identify the core processes around the infrastructure asset life cycle that are necessary for improving the performance of infrastructure asset. The infrastructure asset life cycle processes can generally be grouped into three clusters namely asset planning, asset creation and asset operation. Figure 3 illustrates how core asset management processes can support the asset management goals and the broader strategic business goals in order to create value to organisations.

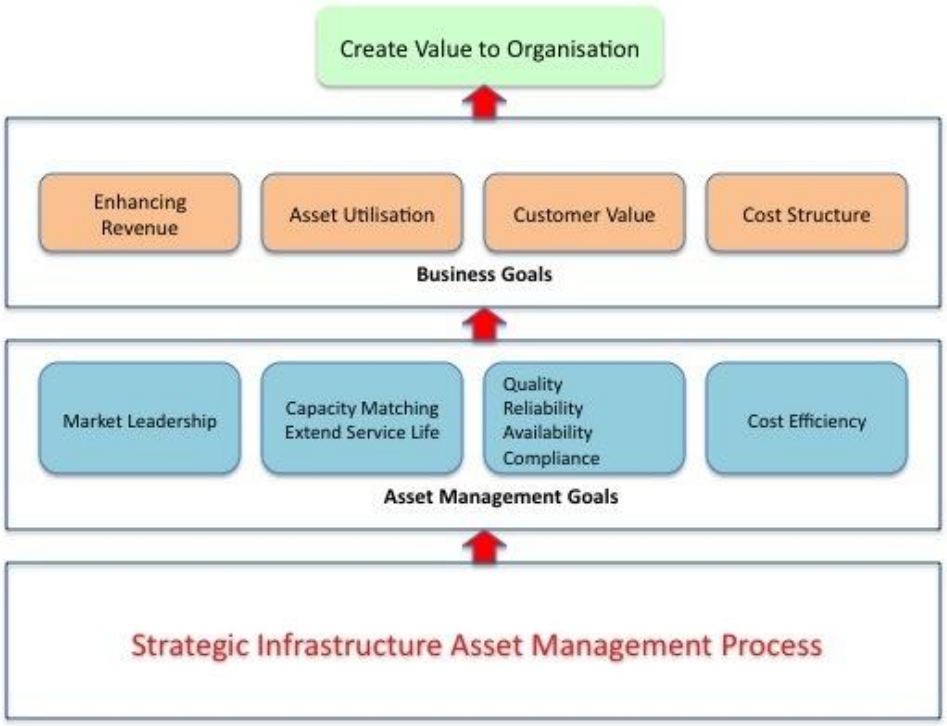

Figure 3: Core asset management processes must support asset management goals

Many organisations have found that good business processes–work that runs from end to end across an organisation–can lead to dramatic enhancements in performance, enabling organizations to deliver greater value to customers in ways that also generates higher profits for shareholders (Hung, 2001). In general, organisations will have many processes as are necessary to carry out the natural business activities defined by the life cycle of the infrastructure assets. However, many scholars also acknowledge that not all business processes can be a source of competitive advantage. For example, Kaplan & Norton (Kaplan and Norton, 2004) suggested that managers must identify and focus on the critical few internal processes that have the greatest impact on strategy and can create value to the organisations. When economic and technological complexity increases, such as is the case in infrastructure asset management, managers must devote more attention to definition and improvement of the few critical business processes that determine success and failure (Zehir et al., 2006). In order to create value to the organisation, such business processes must support the business goals (e.g. Zehir et al., 2006, Kaplan and Norton, 2004). Hence, the main concern of this paper is to understand what are the core asset management processes that can create value to infrastructure organisations.

The interviews with managers yielded information relating to the core processes of the participating organisations. The interviews revealed that many of these processes are fragmented and are developed based on senior management intuition. For example, all the organisations interviewed either did not have a framework guiding their infrastructure asset management practices or are still in the process of documenting their practices. As one manager noted:

> "We are still documenting how we do things but we operate under the strategic asset management plan that sets out our overarching goals for asset management." (Rail)

The focus on individual functional improvement does not always result in enhanced performance of infrastructure asset as a whole. Added to these difficulties is the complexity of infrastructure asset management processes as they usually involve many activities that are performed by different people over considerable time frames. The general feeling is that there is a lack of integration in such an approach. This sentiment is shared by a manager:

> "structurally we are organised more around the major functional activities because of the demand of managing them and then we seek to integrate those back in to provide the service that the customers want … so you need the integration." (Rail)

Thus to resolve this complexity, there is a need to identify those processes that can significantly impact the performance of the infrastructure asset are being considered rather than trying to track each individual decision. To this end, the processes described here are the core processes, that is, the essential activities the infrastructure organisation must undertake to puts its idea for value creation into action on a sustained basis (Sanchez and Heene, 2004). From here, these core processes will be known as the Strategic Infrastructure Asset Management (SIAM) processes. Based on the informants' accounts of their current practices in infrastructure asset management, the findings are synyhesised to describe the framework of strategic infrastructure asset management processes as adopted in practice. This framework will be generic and can be applied to various types of infrastructure assets such as rail, airports, seaports, etc. because it focuses on the core processes of infrastructure asset management that applies across all infrastructure organisations. The following sections will provide case evidence to show common and recurring themes that emerged through the interviews leading to the identification of the core processes of infrastructure asset management.

The literature (e.g. Stapelberg, 2006) has suggested that asset management frameworks adopted by infrastructure owners such as transport and those of asset management service providers are more inclined towards a life cycle process approach. Since these forms of infrastructure are the scope of the current study, the processes illustrated here are based on the life cycle phases of infrastructure assets i.e., asset planning, asset creation and asset operation. Each of the phases consists of a number of supporting core processes that will contribute towards achieving the asset management goals. These are: (1) capacity management (2) options evaluation (3) procurement & delivery (4) maintenance management (5) asset information management. Central to this framework is the asset information management process that store important information and knowledge.

These core processes are diagrammatically presented in Figure 4 and will be discussed in the following sections.

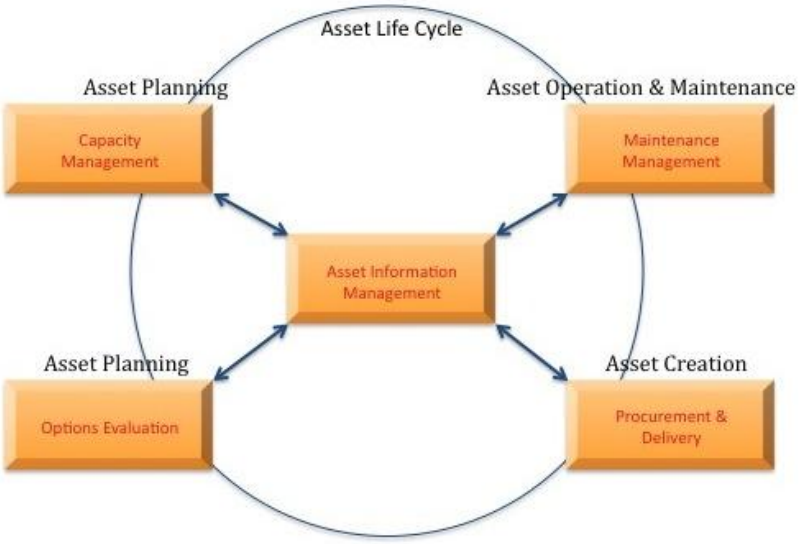

Figure 4: Strategic Infrastructure Asset Management Processes

Capacity Management Process

Capacity management is the process of ensuring optimal provision of infrastructure assets. Effectiveness in this process will enable the infrastructure asset owners and their stakeholders to receive full value on their investment. The Institute of Public Works Engineering of Australia (IPWEA, 2006) has suggested that in order to provide the maximum return, infrastructure assets must be utilised effectively and deliver the required level of service. This suggests that in infrastructure capacity management, organisations must ensure (1) the high utilisation of assets and (2) that the assets support their business operation.

To ensure high utilisation of infrastructure assets, infrastructure organisations need to examine their current infrastructure capacity and their productivity. This is important because capacity can be increased through various means such as operational efficiencies and/or improved maintenance efficiencies and not just through new capital investment. This is shared by comments from the managers interviewed:

> "you can keep adding capital to a certain amount … the other one is knowledge of the industry such that when you designing the port layout that is integrated with a proper and logical flow you can make the operation more efficient … this can saves us from building more assets" (Port)

> "capacity increases can come from investment in physical assets such as additional trains, port expansions, stockpiling equipment, or from increased operational efficiencies by rail and port operators." (Rail)

Hence, capacity can be increased through more efficient use of existing infrastructures via design, reconfiguration and integration of infrastructure assets. To have proper operational control to support business operations, capacity management process must be able to predict capacity under various circumstances and provide a clear picture of the risk of failure. Managers interviewed share this:

> "we do capacity planning to get an idea of (what) the potential (for) failure of our infrastructure asset might be." (Airport)

> "we analyse the capacity and services needed and plan what kind of asset that we need to support those services." (Rail)

Additionally, providing the right infrastructure is critical as it takes a long time to build and the asset is designed to last even longer. For example, in providing a wharf for the case of a seaport, which has a designed life of 50 years, they have to ensure that it is suitable for the ship and trades expected in that kind of lifetime. Similarly, getting the timing right is just as important as shown by the following comments from managers interviewed:

> "the fundamental problem I see in the industry is to get the timing right … especially when we deal with such large assets it is all about the timing … building infrastructure too early and not getting the return needs to be balanced with building infrastructure too late and missing the opportunity." (Port)

> "we only build if the demand is there but when the demand is there it is generally too late because we take 3 to 4 years to build." (Rail)

Capacity management is therefore essential to ensure that the goal of capacity matching is achieved and the right infrastructure can be planned and optimally provided to support business needs. All case participants echoed the importance of the capacity management process. This is summarised in Table 2 below.

Case	Evidence showing the importance of Capacity Management
Rail	Certainly capacity is fundamental … we need to know what kind of assets that we need to support those services … a railway is a network asset ... with any network, one of the key issues is capacity
Port	Managing the capacity and managing the growth are the key drivers here … it is the key to the future because we don't want surprises
Airport	Capacity planning is a significant focus and an important aspect that can affect our business operations … proactive capacity management can ensure that our operations are not affected … it can indirectly affect our efficiency and our reputation as a premier airport

Table 2 Importance of the Capacity Management Process

Options Evaluation Process

From the many capacity-enhancing options identified, evaluations will have to be conducted to select the "best" and optimal solution that meets the business needs. This practice is shared by managers as follows:

> "the business case will then compare a series of options." (Rail)
>
> "any new infrastructure need to be evaluated ... we collect all the relevant information and build a business case" (Port)

Being commercially run organisations, financial return is the key hurdle to be clear before other evaluations are conducted. Table 3 illustrates this finding from the interviews.

Cases	Evidence
Rail	If somebody is there willing to pay and commit to a certain amount of tonnage then we can justify … we then work out which one is the best that can give us the best return …the team usually work together and consider the various options and various issues whether they are safety, environmental, operational, or technical
Port	Once it financially make sense with our current rate of return …it goes through quite a lot of evaluation … our evaluation is very much a balance … we have to do more evaluation to make sure it is timely and appropriate
Airport	Finance is key … the asset must give us a return … we then look at a host of other criteria … there is a huge process that goes through many evaluations by various departments and the public for comment

Table 3 Financial Consideration in Options Evaluation

When the financial viability of an option is established, a series of other evaluations are carried out before deriving at the final option. Such an approach allows organisations to focus on responsible use of resources such as investment, technology and technical development to ensure the activities pursued will benefit not only its bottom line but also the community, the environment and the economy. A balance and comprehensive evaluation of each factor can ensure the long-term profitability of the business is maintained at a level of manageable risk. This translates into providing the right mix of infrastructure assets so as to provide the optimum value for stakeholders. The need to have a comprehensive and balanced evaluation, in addition to financial consideration, is evident in all cases from the following quotes from managers interviewed:

> "in the past based on the government model we just built if it was required by the State … now we adopt a more balanced evaluation to make sure it is timely and appropriate." (Rail)
>
> "… everything has an impact and that needs to be modelled and understood." (Port)

"it will go through many evaluations … there are obviously many evaluations to be considered … you cannot take the economic issue only because the community may not agree" (Airport)

The data also suggests that infrastructure organisations evaluate the infrastructure asset options based on a multi-criteria approach. The following criteria were observed from the case study: financial, technical, environmental, safety, and service quality. Table 4 summarises the criteria used in the evaluation of asset solutions.

Criteria	**Rail**	**Port**	**Airport**
Financial	we conduct a cost/benefit analysis and the prediction of end of service life" Most of our investment decisions are analysed based on business cases using DCF analysis	we do financial analysis first, and if it financially makes sense with our current rates of return, the asset life and its life cycle cost etc.	We do a lot on whole life analysis and cost of all the assets to determine and make sure that these things will operate within the life they are designed for and it is economical to run until then
Technical	There is a series of fundamental engineering inputs Technical obsolescence with both signalling and communication is an issue to be considered … these assets become technically obsolete before they actually wear out	there is a technical evaluation such as engineering and ground condition we have to evaluate the technical aspect such as design and constructability, future maintainability	The technical aspect such as how we can plan the new investment with different stages to prevent disruption to operations
Environmental		There is evaluation that looks after the town planning and environment. For example, if we build a wharf on reclaimed land we will destroy many hectares of mangrove.	We also need to consider the environmental issues as well Sustainability is an important issue … we have to consider the community issues and social cost
Safety	You need to have a maximum speed on different portions of the track for safety reasons and we need to ensure our signalling system won't let another train on the track until the first train is clear	Safety is very important for port operations, so we have to evaluate the safety aspect	We also look at users comfort and safety parameters and other compliance requirements
Service Quality	The service design can impact the network configuration and asset configuration and call up asset investment needs	We also have to assess from the operations perspective	You have to make assessment based on circulation space and see how long it takes for passenger movement and queuing assessment

Table 4 Criteria for Infrastructure Asset Evaluation

In addition to the above findings, the importance of the options evaluation process is underscored by the need to minimise financial and legal risks as well as maintaining accountability to the stakeholders. The evidence gathered from the case interviews in this regard are presented below:

"on top of our evaluation, we also have some independent studies for legal reasons and risk, accountability and verification." (Airport)

"everything has an impact and that needs to be modelled and understood … this include risk assessment such as financial risk, forecasting risk such as how likely is the trade growth and those sort of issues." (Port)

Procurement & Delivery Process

Procurement has been defined as 'the action or process of acquiring or obtaining material, property or services at the operational level' (McGraw-Hill, 1984). Construction procurement has been defined by the CIB W92 Working Commission on Procurement Systems as 'the framework within which construction is brought about, acquired or obtained' (Sharif and Morledge, 1994). The main goal of procurement and delivery of infrastructure assets includes maximising efficiency and effectiveness of organisational resources, meeting customer expectations, minimising adverse customer impacts and adhering to project scope, schedule and budget, and managing needed changes in projects and programmes (AASHTO, 2002).

Appropriate procurement strategies are needed to help achieve optimal solutions in terms of cost, time and quality (Kumaraswamy and Dissanayaka, 1998). Selecting the right service provider/supplier can help reduce time to completion and improve cost effectiveness by addressing project complexity, supplement staff skills with specialised expertise, and ensure more effective use of in-house resources more effectively. In the past, under a government owned model, most infrastructure assets were procured and delivered using only in-house resources and capabilities. For example, a manager from Rail case noted:

"we have certainly moved away from our traditional culture of doing it ourselves as we don't trust anybody to do it." (Rail)

This position has changed in recent years. Infrastructure organisations tend to adopt a more formal method of evaluation. In deciding the most appropriate providers, most of the infrastructure organisations consider factors such as price together with a few other factors such as quality and delivery. Increasingly, infrastructure organisations that are considering outsourcing will rigorously evaluate their own capabilities, in terms of resources such as cost, equipment and expertise, against those of the external providers to determine an appropriate procurement strategy. Evidence from this research suggests that the procurement options used depend on project complexity (which includes risk, time, cost and quality) and the availability of in-house skills and expertise. For example, one informant indicated:

"the procurement method to use is driven by the complexity of the project … we consider our interest, resource/skill capacity; consider the risk involved, consider time, cost and quality and size of the project". (Rail)

Literature on strategy in selecting a supplier has noted that when uncertainty is low and a project is uncomplicated, the decision is made primarily on the basis of differences in technical capability (Hoetker, 2005). In other words, if an external provider is more competent to deliver the project this procurement method should be adopted. Conversely, if in-house resources are more competent, the project should be delivered using in-house resources. This is evident in the following quotes:

"we outsource most of our projects as this is not our core business." (Airport)

"we have experience, expertise and skill because we have done a lot of it." (Rail)

"a wharf is a repetitive work where we have experience and in-house expertise … so we usually do the design work in-house." (Port)

> "all dredging is done in-house because we have all the expertise and specialised people to do the job … and we have invested in all the costly dredging equipments… so we can get better value if we do it ourselves." (Port)

For larger and more complex infrastructure projects, the tendency is to outsource to an external provider. The potential benefits of such an approach include lower costs, improved service, and opportunities to leverage the expertise of private companies, overcoming in-house staff constraints and risk-spreading.

> "for bigger projects however, our in-house resources are struggling to cope … we have to develop ways to partner with external organisations … we are currently trying working out how to be slightly more innovative to deliver the tremendous increase in infrastructure project needed." (Rail)

Hence, the asset procurement and delivery process is considered an important process that can deliver value to an infrastructure organisation. The importance of process is echoed by all the case participants:

> "we always try to generate value from our procurement … such (an) arrangement allows us to have a better price and value from the service provider." (Rail)
>
> "we try to achieve effective use of our external providers … it is a cost and quality driven one." (Airport)
>
> "we try to outsource what we can if it is efficient to do that and it is cost effective." (Port)

Maintenance Management Process

The maximum opportunity to reduce maintenance expenditure exists within the area of maintenance management of the overall operation and maintenance phase (NSW Treasury, 2004). The need to deliver maintenance is a fundamental requirement for any infrastructure organisation. The ability to deliver the required maintenance can have a significant impact on cost and operations. It is a business objective for any asset manager to focus on investing the minimum levels of maintenance dollars to deliver the services desired by the organisation, while meeting statutory obligations for the organisation's risk management and public liability as shared by one informant:

> "to keep our asset in good condition without spending too much money on it." (Airport)

To achieve that, infrastructure organisations must continue to improve their maintenance management process. Maintenance planning is recognised at all levels of the industry and is becoming a key business driver because of the increasing demand pressure on infrastructure assets. The following views were shared by a manager interviewed:

> "… improving our planning of maintenance is significant to create value to our customers." (Rail)
>
> "we have for some time now increasingly given attention to (maintenance) planning." (Rail)

To ensure that maintenance planning can be carried out on a consistent and sustainable basis to achieve its objectives, all maintenance activities need to be captured via a common system (Killick and Thomas, 2008). Two main approaches to maintenance planning are evident from the cases. Firstly, maintenance activities are planned based on some rules and standards. This can be regulation mandate or manufacturers' recommendation. Secondly, maintenance activities are

planned based on the assessed risk of asset failure based on conditions of the infrastructure assets. This includes predicting essential maintenance work that needs to be carried out to prevent failure of critical assets so as not to affect business operations. The two approaches are summarised in Table 5 below.

Cases	Rule based planning	Risk based planning
Rail	Some of the maintenance is cyclical and programmed which is more rule based and does not depend on finding defects such as rail grinding to be done after so many thousand tonnes over the track	We start with the plan to monitor the condition and as defects are found, we prioritise and plan to fix the defects within the time frame of priority … nearly all our maintenance depends on the result of condition monitoring and inspection We are doing probabilistic maintenance planning with our rail asset especially those that cannot afford to breakdown such as our signalling system
Port	We try to first meet all the standards and requirements … this is the cyclical maintenance that is rule based and standard and we know when they are exactly required	We need to include in our planned maintenance work based on the result of planned general inspection … from PGI we will know which type of maintenance work must be done by a certain time We do risk assessment based on past data to assess the likelihood of asset failure … and see how we can plan the maintenance to prevent the failure of such assets
Airport	We review the manufacturers' manual to find out what maintenance works are required under Australian Standards We have guideline and regulations that dictate the type of maintenance to be carried out	To ensure that we are able to plan well, there is a bit of data capture and analysis of those data… for example, on the runway we need to do friction testing because of the rubber build up We will do failure analysis to see whether the assets is going to fail We also do risk assessment to plan based on probabilistic

Table 5 Maintenance Planning Methods

To facilitate effective maintenance planning, infrastructure organisations need to collect data on the conditions of their asset. A number of organisations are recognising the need to move away from the traditional time-based-maintenance approach to a more pro-active condition-based-maintenance philosophy. Jarrell & Brown (1999) support a condition based maintenance approach that provides benefits to the organisation in the areas of efficiency, reliability, and safety of the maintenance process. This will require constant monitoring of the conditions of the infrastructure assets and rigorous review and analysis of these data, to ensure the right mix of maintenance activities are delivering the improvements needed to provide sustained business success. This sentiment is shared by a manager:

> "we need information on condition assessment and risk assessment … to prioritise what we need to do first … this will help us decide what our maintenance strategy is." (Rail)

In short, the maintenance management process is essential to minimise the risk of asset failure that can have a devastating effect on business operations.

Asset Information Management Process

Infrastructure owners and operators are constantly struggling with the lack of knowledge about the condition of the assets they possess. This means that the scarce resources that are available for maintenance and repair are often used inefficiently and inappropriately (CERF, 1996). What is needed is a coherent picture of the current asset stock, its contribution to service delivery and the current costs of providing the assets (LGV, 2004). Information on current assets that are relevant include physical (e.g. location and condition); financial (e.g. service potential, risks and liabilities); and performance (both service performance and asset performance). All

case participants echo the importance of asset information management as evident in the quote below:

> "our key resource is information … information is everything … you live and die by information." (Rail)

> "one of our catchphrases is 'right job, right place and right time' so information is the oil for that machinery." (Rail)

This can be achieved by having an IT system that acquires and stores the most updated and pertinent information on infrastructure assets known as the asset information management system. Some managers interviewed commented:

> "IT database is the only way to be able to get an accurate reflective history of your assets." (Rail)

> "we can actually pull out all information from the database and it can help us for better planning and control to promote improved asset performance." (Port)

> "it got to be consistent and reliable … if you work based on the wrong information, you work to a wrong priority and put resources in the wrong place." (Airport)

The importance of this process is evidenced from the cases where all organisations have adopted some form of computerised asset information management systems. This is summarised in Table 6 below.

Case	**Computerised Asset Information Management System**	**Information Captured in the System**
Airport	We use a program called MAXIMO	all our assets data such as cost, location, scheduled periodic maintenance; record all the breakdown maintenance, etc. It also gives reports and things like that
Port	We have MP2 maintenance system	all the asset details including location, age, etc. all the maintenance recording, work scheduling details, cost of history and so on
Rail	Because of the diversity of assets …not one place that tends to be a portfolio of assets register with some metadata that links them up we are still working to make this happen with the help of a consultant	overhead traction system is documented by people in electrical engineering, that configuration of data will sit at one place; in another place the people that manage the signal system have drawings and configuration data and so on

Table 6 Computerised Asset Information Management Systems

Despite the availability of some computerised asset information management systems, case organisations are observed to be in the process of developing in-house asset information management systems to further improve the accuracy of their infrastructure asset information and to link them to infrastructure asset planning. For example, in Port case it has been said:

> "we are currently developing software, specific for the port by our consultant called SAMMP, Strategic Asset Maintenance Management Plan. SAMMP is a planning tool." (Port)

In linking to infrastructure asset planning, it also suggests a recognition that the asset management system should extend beyond the asset portfolio by having a knowledge database of information that can be actively used to assess how a current asset can be best utilised to achieve improvement in service to a customer. For example, one manager noted:

> "we need information … to help us decide that the capacity is not right and we need to do something else or we may just need to refurbish it." (Rail)

Hence, asset information management is an important process for capturing all the necessary information to support decision-making of the other core processes.

Conclusions

The increasing use of infrastructure asset management has prompted the need to understand the processes involved. This paper has documented the core strategic processes adopted by case studies organisations that manage infrastructure assets. The emerging framework is built based on the principle that these core processes can have direct consequence on assisting organisation to achieve the "best value" for its stakeholders. Synthesising these processes, a SIAM is proposed as a strategic, fully integrated approach directed to gaining greatest lifetime utilisation, effectiveness and value from infrastructure assets. At the heart of SIAM is a concept of continuous improvement to facilitate asset manager to identify, formulate and implement the most effective strategy and plans for improvement. It is based on a comprehensive strategy linking market conditions, business, and infrastructure assets. Given that there are many different approaches adopted in practice, care is taken to ensure that the proposed framework or processes are not over prescriptive but permit a certain degree of flexibility that ensures the characteristics and needs of individual organisations are taken into account. The framework, presented as a process model from a corporate level, is generic and can be applied to various types of infrastructure assets such as roads, rails, utilities, airports, seaports, etc.

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Appendix 1: Definition of Asset Management

A methodology needed by those who are responsible for efficiently allocating generally insufficient funds amongst valid and competing needs (Danylo and Lemer, 1998)	The American Public Works Association Asset Management Task Force (US)
A systematic process of operating, maintaining and upgrading transportation assets cost effectively. It combines engineering and mathematical analyses with sound business practice and economic theory. The total asset management concept expands the scope of conventional infrastructure management systems by addressing the human element and other support assets as well as the physical plant (NYDOT, 1998)	New York State Department of Transportation (US)
The set of disciplines, methods, procedures and tools to optimise the whole life business impact of cost, performance and risk exposures (associated with the availability, efficiency, quality, longevity and regulatory / safety / environmental compliance) of the company's physical assets (IAM, 2008a)	Institute of Asset Management (UK)
The systematic and coordinated activities and procedures through which an organisation optimally manages its physical assets and their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organisational strategic plan (IAM, 2004)	British Standard, PAS 55 (UK)
The combination of management, financial, economic, engineering and other practices applied to physical assets with the objective of providing the required level of service in the most cost effective manner for present and future customers (IPWEA, 2006)	International Infrastructure Management Manual 2006 Edition (Australia, NZ and UK)
A comprehensive and structured approach to the long term management of assets as tools for the efficient and effective delivery of community benefits (Austroads, 1997)	AUSTROADS (Australia)
Provides a flexible service delivery approach, driven by present and future needs, and using both asset and non-asset solutions (NPWC, 1996)	The National Public Works Council (Australia)
Lifecycle management of physical assets to achieve the stated outputs of the enterprise (Kennedy, 2007)	Asset Management Council (Australia)
Provides a structured and systematic resource allocation approach to infrastructure and physical asset management so that resources are aligned with the service objectives of agencies (NSW Treasury, 2004)	NSW Total Asset Management (Australia)
The process of guiding the acquisition, use and disposal of assets to make the most of their service delivery potential ad manage the related risks and cost over their entire life (Victorian Government, 1995)	Victorian Government Asset Management Series (Australia)
Aims to provide an approach to the management of assets, encompassing the principles of integrated planning, asset planning, asset accountability, asset disposal and the internal control structure (Australian National Audit Office, 1995)	Australian National Audit Office, 1995 Auditor General's Report No. 27
The process of organising, planning and controlling, the acquisition, use, care, refurbishment, and/or disposal of an organisation's physical assets to optimise their service delivery potential and to minimise the related risks and costs over their entire life (CIEAM, 2008)	CRC for Integrated Engineering Asset Management (Australia)

Appendix 2: Case Profile

Type of Organisation	Informant	Key Infrastructure assets	Level of Participation
Rail	• General Manager • Executive Project Manager • Maintenance Manager	The track; structures such as culverts and bridges, bridges that support the railway and those that run overhead; right of way such as the access road & drainage; signalling systems that control of the safe working of trains; power supply and substations; overhead traction system.	Government-Owned Corporation
Airport	• General Manager • Terminal Asset Manager • Engineering Group Manager	The key assets are runways and all the assets on the terminal buildings such as baggage handling system, the check bag screening, aero-bridges, building fabrics, hydraulics, chillers, all the HVAC system, electrical system and communication system.	Full Privatisation
Sea Port	• Senior Manager • Infrastructure Planning Manager • Maintenance Manager	All port infrastructures that include channels and berths, wharfs and terminals, all services roads, water, power, telecommunications, sewer, storm waters. Properties include warehouses, buildings, and container handling equipment.	Government-Owned Corporation