A Capability Model to Improve Infrastructure Asset Performance

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Abstract

Infrastructure organizations are operating in an increasingly challenging business environment as a result of globalization, privatization and deregulation. In an external business environment that is constantly changing, extant literature on strategic management advocates the need to focus on factors internal to the organization such as resources and capabilities to sustain their performance. Specifically, they need to develop dynamic capabilities in order to survive and prosper under conditions of change. The aim of this paper is to explore the dynamic capabilities needed in the management of transport infrastructure assets using a multiple case study research strategy. This paper produced a number of findings. First, the empirical evidence showed that the core infrastructure asset management processes are capacity management, options evaluation, procurement & delivery, maintenance management, and asset information management. Second, the study identified five dynamic capabilities namely stakeholder connectivity, cross-functional, relational, technology absorptive and integrated information capability as central to executing the strategic infrastructure asset management processes well. These findings culminate in the development of a capability model to improve the performance of infrastructure assets in an increasingly dynamic business environment.

Keywords: Infrastructure Assets, Management, Strategic, Dynamic Capabilities

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Introduction

Accountability is a requirement for any organization. Those in charge of economic resources, such as infrastructure assets, must give account of their stewardship (Grimsey & Lewis, 2002). In recent years most of the industrialized world has faced many challenges in the development and management of infrastructure assets. In fact, over the past two decades, the performance of government-owned infrastructure suffered from low labor productivity, deteriorating fixed facilities and equipment, poor service quality, chronic revenue shortages and inadequate investment (Kessides, 2004). The pervasive government involvement in finance, regulation, and actual delivery of many infrastructure services has led to poor performance in many cases – by weakening managers' operational and financial responsibility, imposing conflicting objectives, and politicizing decisions on investment, pricing, labor, and technological choice (Kessides, 1993).

In the quest to improve performance of infrastructure assets, many governments has adopted some form of reform proposed by Kessides (2004) that include a combination of competitive restructuring, privatization, and establishment of regulatory mechanisms. In fact, the late 1990s were characterized by a significant shift from the public to private sector for the provision of infrastructure services. Organizations that manage infrastructure assets have adopted a management culture that focuses on customer needs, accountability of results, and competition between public and private bodies for contracts to deliver services that achieves cost recovery and value (Manning, 2002). The focus has shifted to clients instead of citizens and communities, and by pursuing business-like outcomes instead of public policy-making (Charih & Roulliard, 1997).

The reform towards deregulation and privatization of infrastructure provision has changed the structure and environment of the business dynamic. Under such business environment, infrastructure organizations need to maximize the investments they have made in their existing infrastructure assets in order to reduce their capital and operating expenditures. To create value in these environment, extant literature in strategy advocates that organizations should focus on internal factors such as resources and capabilities to sustain their performance (Ravichandran & Lertwongsatien, 2005). For example, Ma (2000) suggests that kinetic advantages, which are often knowledge-based and capability-based (Juga, 1999), will more likely to produce sustainable superior performance. The reason is that one can hardly actually plan ahead due to abrupt business environmental changes (Mintzberg & Westley, 2001). This tension magnifies when business environments change to a new level while the organization still possesses the same stock of resources or old capabilities. In such situation, the organization will not be able to sustain its competitive advantage unless new stocks of resources and capabilities are obtained.

An organization can only gain advantage and achieve superior performance when it has the right capabilities (Smallwood & Panowyk, 2005). Capabilities represent the ability of the organization to combine efficiently a number of resources to engage in productive activity and attain a certain objective (Amit & Schoemaker, 1993). When organizations are unable to develop required capabilities in transforming resources into valuable services, the acquired resources are likely to become overhead, rather than assets to the organizations (Amit & Schoemaker, 1993). The challenge for infrastructure organizations is, therefore, the optimal allocation of the scarce resources among competing initiatives to acquire relevant capabilities. It is thus, significant to identify the

capabilities that infrastructure organizations should develop that will make a difference in infrastructure asset performance.

This paper uses multiple case studies to identify the capabilities needed to execute the core processes for effective management of infrastructure assets. It is structured as follows: Next section introduces the concept of capabilities and its relevant in the development of infrastructure assets. Next, it describes the research method adopted in this study. It then presents the findings from case studies of transport infrastructure organizations. The paper closes by discussing the implications and limitations of the study and identifies important areas for further research.

Capabilities for Infrastructure asset management

Under the Resource-Based View (RBV) framework, an organization's long-term survival rests on the organization's ability to develop capabilities and innovation. The notion of organizational resources and capabilities can be traced back to Penrose (Penrose, 1959) and Andrews (1971). Penrose (1959) suggested that resources consist of a bundle of potential services. While these resources or factor inputs are available to all organizations, the 'capability' to deploy them productively is not uniformly distributed. Thus, organizational resources are seen less as being productive in themselves and more as working through an organization's ability to assemble, integrate, and manage them via organizational capabilities (Eisenhardt & Martin, 2000). Capabilities, therefore, transform inputs to outputs of greater worth (Amit & Schoemaker, 1993; Sanchez et al., 1996) and can include skills, such as technical or managerial ability, or processes, such as systems development and integration (Wade & Hulland, 2004). For the performance of an activity to constitute a capability, it must have reached some threshold level of

practice or routine activity and at a minimum must work in a reliable manner (Helfat & Peteraf, 2003). Thus, capabilities represent the ability of the organization to combine efficiently a number of resources to engage in productive activity and attain a certain objective (Amit & Schoemaker, 1993). This is known as "operational capability" and enable organizations to sustained their performance in the present (Winter, 2003).

As markets become more globally integrated and new forms of technology and competition arise, organizations cannot rest on their laurels. Organizations must adapt to and exploit changes in their business environment, while seeking opportunities to create change through technological, organizational, or strategic innovation. To survive and prosper under condition of change, organizations must develop the "dynamic capabilities" to create, and extend, and modify the ways in which they sustained their performance (Helfat et al., 2007). In other words, dynamic capabilities concern change and is the capacity of an organization to purposefully create, extend, or modify its resource base (Helfat et al., 2007).

Deregulation and privatization of infrastructure provision in recent years has no doubt brought challenges and difficulties to infrastructure organizations. Furthermore, in markets with ageing infrastructure, organization must continuously find new ways to design and deliver high-quality infrastructure and services in a timely manner. Rapid advances in technology and global information, also, mean that infrastructure organization must maintain the ability to respond quickly and effectively to changing customer needs and expectations. Under these changing structure and environment of the business dynamic, the various stakeholders will continue to demand value for money for their investment in infrastructure. To satisfy the needs and conflicting

demand of the various stakeholders, asset managers have to understand everything about infrastructure assets. This includes the need to meet the expectations for quality and safety, operational efficiency and durability, and accountability as guardian of infrastructure assets.

Infrastructure organization have, in the past, competed using similar strength and skills because they are traditionally managed by government and semi-government organizations (Too & Too, 2010). In the era of deregulation and privatization where the emphasis is focused on customer and accountability of results, infrastructure organizations must look at heterogeneous advantage (Ma, 1999) and play a totally different game such as better serving the customers through different skills, resources combinations or products. The underlying rationale appears to be that, although technical and market changes can never be fully controlled, proactive development of appropriate infrastructure asset to support business direction can influence the competitive success, adaptation, and renewal of organizations. To achieve this, infrastructure organization must constantly re-examine its core processes for success, survival, and renewal of organizations. This includes the ability to connect the processes that define the organizational capabilities to the external environment and enable organization to compete by anticipating market requirements. In other words, the operational capabilities in the past may not be sufficient as the business environment continue to change. There is a need to look at the dynamic capabilities needed in managing infrastructure organizations.

Accordingly, infrastructure asset management must aim at achieving organizational long-term goals and effectiveness through dynamic alignment of the required

infrastructure assets to meet changing customer needs. To understand infrastructure asset management, there is a need to identify and define the activities involved. Infrastructure asset management activities is about designing and implementing core business process that can deliver higher returns to corporate stakeholders (Kennedy, 2007). Brown (2004) and Sklar (2004) all support a holistic view of asset management as an integrated business process designed to optimize the use of infrastructure assets while balancing the varying needs of key stakeholders. Similarly, Tao et al. (2000) proposed that from a business perspective, asset management framework must comprise all dynamic business processes to link all asset types together under a single business context. Establishing a strategic infrastructure asset management process is therefore fundamental to improving efficiency and effectiveness of infrastructure delivery.

To achieve superior performance, appropriate capabilities must support these strategic asset management processes. Day (1994) argued that capabilities and organizational core processes are closely entwined, because it is the capability that enables activities in a business process to be carried out. Hence, the effectiveness of strategic asset management processes is inseparable from the appropriate capabilities that support them. However, there are many processes involved in performing the natural business activities around the infrastructure asset life cycle. Many scholars acknowledge that not all processes can be a source of competitive advantage. For example, Kaplan & 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 organizations. Furthermore, Zehir, et al. (2006) suggested that when economic and technological complexity increases, as in the case in infrastructure, managers must

devote even more attention to the definition and improvement of the few critical business processes. Therefore, to create sustained performance, organizations need to develop and deploy a range of capabilities around the core processes which can be helpful in responding to different challenges in the markets (Collis, 1994). Each area of business processes may require many capabilities. Organizations should invest only in those capabilities that can support each stage of the core asset management processes and thus creating value to the organization. Figure 1 illustrates the relationship between strategic goals, infrastructure asset management processes and capabilities.

Insert Figure 1 Here

Research Method

This paper aims to identify the dynamic capabilities needed to support the core infrastructure asset management processes during the period of constant change. Due to the limited knowledge in the concept of capabilities in the management of infrastructure assets, this study identifies capabilities by examining the dynamics that are present in the organizations that manage infrastructure assets. To explore such dynamics from the organizations' perspectives, this paper uses inductive studies of executives managing the processes of infrastructure asset as the primary empirical background, supplementing these data with relevant research from the extant literature.

In identifying capabilities that are the sources of performance difference, they need to be contextually grounded (Ethiraj et al., 2005). To address the context specificity of capabilities, the focus of data collection is on the challenges faced in the management of infrastructure management processes and the approaches adopted to overcome them.

The ‘snapshots’ views of the executives in action are used to draw out the dynamic capabilities needed to adapt to the changing business environment. The following discussion describes the cases, data collection and data analysis.

Case Selection

Each infrastructure organization is unique in terms of the ways they manage their infrastructure assets. The differences may result from the constraints imposed, the specific organizational structure, political climate, and the objective regarding managing assets (McNeil et al., 2002). The management and operation of different types of infrastructure also have many features particular to a type of infrastructure. In order to build a model applicable across organization and to meet the replication requirements, this paper uses multiple case studies involving three types of transport organizations namely rail, seaport and airport. Multiple cases enable comparisons that clarify whether an emergent finding is simply idiosyncratic to a single case or consistently replicated by several cases (Eisenhardt, 2007). Table 1 provides the case profile.

Insert Table 1 here

Data Collection

Asset management being a boundary-spanning function, I have selected two separate groups of interviewees within each case to ensure adequate depiction of the asset management function. These two groups include executives from (1) senior management; and (2) asset operations and management. In stage 1 data collection, partially structured field interviews with senior managers were conducted to identify the core processes in the management of infrastructure assets. The outcome was the development of a framework for core asset management processes. With an

understanding of the core processes in infrastructure asset management, stage 2 data collection, again using partially structured interviews, was conducted with operational managers that manage infrastructure assets. Given that capability is a relatively new concept in infrastructure management, the identification of the capabilities for each core process was through deduction by asking the interviewees questions relating to the challenges faced and approaches adopted to overcome these challenges. While there are fundamental skills and knowledge needed for the routine operations of the core processes, focusing on challenges and difficulties circumstances can best draw out the core capabilities required in managing a particular process.

Yin (2003) suggests that while interviews are an essential source of case study data, they should only be viewed as verbal reports requiring corroboration from others before the accuracy of data can be assumed. The interviews data was cross-checked and compared with a broad range of sources to corroborate and augment the evidence. These documents include:

1) Organization policies and procedures such as departmental strategy, contractor selection procedures, corporate plans, annual reports, risk assessment guides, IT Strategic Plan etc.
2) Organization 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.

Data Analysis

A two-stage analysis suggested by Eisendhardt (2002) was adopted for this paper; namely (1) Within-Case Analysis and (2) Cross-Case Analysis. Within-Case analysis was conducted initially by coding, to sort answers according to different components such as importance of the process, the challenges faced, and approaches adopted in the management of infrastructure asset. This initial coding is useful to identify areas, which will need more data and identify relevant text. This process also helps to make the text manageable by selecting only the relevant text for further analysis (Auerbach & 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 analyzed through categorization to reflect conceptual advance. This involved recording the repeating ideas by grouping together related passages into some initial themes. This further coding gave rise to preliminary themes associated with capability for the infrastructure management process.

After the within case analysis for each case was done, the cross case analysis was next performed to identify common themes. The emerging ideas and concepts were compared to identify common themes and initial propositions. Firstly, categories or dimensions suggested by existing literature were analyzed by looking for within-group similarities coupled with inter-group differences. To examine the subtle similarities and differences, a second tactic was to select pairs of cases and then list the similarities and

differences between each pair. These forced comparisons results in new categories and concepts not anticipated initially. A third strategy was to divide the data-by-data source. These tactics exploits the unique insights possible from different type of data collection. Through these approaches, cross-case analysis can enhance the probability of moving beyond initial impressions, especially through the use of structured and diverse lenses on the data, to capture the novel findings, which may exist in the data.

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 organizations for feedbacks and comments. Further face-to-face meetings were conducted to discuss the findings. These feedbacks were incorporated to refine the findings. The next section will describe the findings from the data analysis in detail.

Findings

Strategic Infrastructure Asset Management Processes

The informants' accounts of their current practices in stage 1 interviews identified a number of supporting core processes. These are: (1) capacity management (2) options evaluation (3) procurement & delivery (4) maintenance management (5) asset information management. Figure 1 diagrammatically illustrates these core processes which are the essential activities the infrastructure organization must undertake to puts its idea for value creation into action on a sustained basis. I refer them as the Strategic Infrastructure Asset Management (SIAM) processes from here onwards.

The following discussion presents the findings of the data analysis to identify the dynamic capabilities for each of the SIAM processes.

The Capacity Management Process

Capacity management can optimally support business needs by ensuring the provision of the right infrastructures. Proactive development of appropriate infrastructure asset to support business direction can influence the competitive success, adaptation, and renewal of organizations. All case organizations consider capacity management as one of their essential processes. A manager best sums up the importance, *"capacity planning is a significant focus and an important aspect that can affect our business operations … it can indirectly affect our efficiency and our reputation".*

Cases from this study suggest that infrastructure organizations must overcome some challenges for effective management of capacity. First, is the challenge to provide the right infrastructure assets at the right time that would meet business operation need. To adjust the infrastructure asset portfolio in response to change requires accurate forecasting of demand. Part of the difficulty is the possible time lag between demand and actual supply. The long lead-time for supplying built infrastructure can derail the forecasted demand.

Second, transport infrastructure organizations usually form part of a very complicated supply chain with regard to increasing the infrastructure capacity. For example, the rail network is only one part of the supply chain for transporting coals from mines to buyers. Any capacity increase on the rail track may not necessarily increase the capacity of the overall supply chain. Similarly, the capacity of the airport and seaport is constrained by surface transport capacity. This suggests that there are many ways to increase the capacity of transport infrastructure and each of the transport organizations is only part of the system.

To overcome the challenges, it is pertinent for infrastructure organizations to work with the most recent and updated information to accurately forecast the demand for infrastructure assets. This includes information such as projected growth, trends of the industry, and the current capacity of infrastructure assets. However, these information and knowledge spread across the members of the supply chain and stakeholders. For this reason, there is a need for a collaborative relationship between all the members of the whole supply chain. The data suggests that the case organizations are actively gathering trend information to enhance their knowledge of the industry through collaborative efforts with their stakeholders. For example, rail's intelligence generation is through several sources such as commitment and request from their customers, government policies and regulations, independent expert opinions, as well as the intentions of other ports to expand their unloading capacity. Airport adopts a similar approach where they constantly review the Airbus and Boeing forecasts and orders so that they are aware of the appropriate infrastructure needed to serve the airlines. Airport also engage specialist consultants to prepare the aviation forecasts that include parameters such as income of travelers, prices of air transport, airline service characteristics, tourism needs, population projections, gross domestic product, and national aviation policy. Similarly, a port manager noted, *"our mode of operation is to spend time with the customer and try to understand their needs, we have a lot of discussions and develop the requirements together on what they expect from the assets."* Table 2 summarizes the discussion in relation to the challenges and approaches adopted in the capacity management process.

Insert Table 2 Here

Prior research supports the approaches adopted to overcome these challenges. For example, Hyvonen and Tuominen (2007) suggested that organizations can share special resources and technological knowledge that are necessary to improve performance and to deliver value to their stakeholders. Furthermore, effective information sharing among supply chain partners can enhance the visibility of project risks and reduces uncertainty in infrastructure provision (Handfield & Betchel, 2002). An example from the case is with regard the management of capital investment risk. Data from the interviews suggest that collaborative relationships with members of the supply chain and stakeholders can provide greater certainty for capital expenditure and investment since it considers the needs of all stakeholders. A rail manager noted, *"through some consultative process with the industry (stakeholders), we can get them to sign off on their willingness to support our investment in the coal system."*

In summary, a good connectivity with stakeholders to understand the requirements and constraints of various stakeholders (e.g. customers, suppliers, regulators, etc.) can enhance the effectiveness capacity management. This is to ensure that all infrastructure decisions are capable of delivering the greatest stakeholder value from the money invested. To achieve this, infrastructure organizations need to develop their stakeholder connectivity capability, which will allow them to have knowledge of stakeholder needs, access to stakeholders' specialized knowledge, and exchanging of information between organization and stakeholders.

The Options Evaluation Process

From the many capacity-enhancing options identified in the capacity management process, infrastructure organizations must conduct evaluations to select the "best" and

optimal solution that meets the business needs. The options evaluation process investigates and analyzes each of the alternatives that precede the decision in order to minimize legal and financial risks. The data from the cases suggests that infrastructure organizations adopt a balance and comprehensive evaluation of infrastructure asset options based on multiple criteria. Some of these criteria include financial, technical, environmental, safety, and service quality. Such an approach allows organizations to focus on responsible use of resources to ensure the activities pursued will benefit not only its bottom line but also the community, the environment and the economy. This translates into providing the right mix of infrastructure assets to provide the optimum value for stakeholders.

To achieve optimization, each option represents a trade-off in achieving multiple criteria. Options evaluation is thus a risk analysis exercise, i.e., assessing the risks each option present in achieving these criteria. Risk arises because of limited knowledge, experience, information, and uncertainty about the future. Thus evaluating the risks of the various infrastructure asset options through the whole life cycle of a long-term asset raises a key challenge in terms of data. First, there is a need to factor the various evaluation criteria into the life cycle model in terms of maintenance, refurbishment and operational costs. Second, the life expectancy for a long-term asset is typically in excess of twenty years, which compounds the level of accuracy in the model. Hence, the tools are only as good as the data input as noted by a manager, *"there is always a certain degree of uncertainty to make sure our model is appropriate … what we do is to minimize the guessing by collecting as much information as possible."* In short, the challenge is to adequately accounting for all risks in the options for an accurate assessment.

Given the level of complexity, the cases studied have each shown that no one expert can comprehend and assess all the risk factors adequately to make an informed asset decision. To overcome this challenge, case organizations use different functional teams to assess the risk of each option against the different criteria. The underlying reason for this approach is that the functional diversity of these teams reduces the risk through increasing the amount and variety of information available to make decisions on the appropriate asset solutions. The availability of relevant information provides the evaluation team with a more holistic appreciation of the different proposed asset solutions and thus improves the asset evaluation process. Moreover, the knowledge sharing facilitates the anticipation of downstream problems such as maintenance difficulties and operational mismatches before they occur. Managers interviewed concur with the need to synthesize a variety of information during option evaluation process. Table 3 presents the findings relating to the option evaluation process.

Insert Table 3 Here

The use of cross-functional teams is supported by existing literature and is particularly useful when novelty or technical complexity of the project is high (Tidd & Bodley, 2002). Cross-functionality, thus can to enhancement in efficiency and effectiveness of the process and reductions in multi-task lead-time and redundancies (Webber, 2002). Infrastructure organizations must continue to develop their cross-functional capability by developing competencies across a wide range of staff. Through such measures, they will have the necessary information and confidence to select the most appropriate options that can support the business into the future.

The Procurement & Delivery Process

Deregulation and privatization of infrastructure provision in recent years have brought the level of business competition to new heights. Specifically, the shortage of technical staff has created a need for an organization to tap on the services of external providers to deliver the infrastructure assets. Evidence from the cases suggests that there is an increasing use of innovative procurement approaches through the utilizing of external resources. The external resources represent valuable contributions to infrastructure organizations. All the case participants echoed the importance of outsourcing in the procurement and delivery process in delivering value to their organization:

"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)

The growing use of external resources in the procurement of infrastructure suggests the need to address systematically the issues of engaging external providers in order to maximize their value as well as to optimize their availability. A key issue with the increasing use of external resources is to ensure that there is a constant pool of capable external providers who are able to provide services when needed. Furthermore, getting the external providers with the right technical expertise will continue to be a challenge, particularly for the highly specialized and complex infrastructure industry. To ensure the availability of a pool of competent external providers, evidence from data shows case organizations actively pre-qualify the available providers to determine the fit with the needs of the procured infrastructure, making them available for selection when

needed. One of the sources for competent external providers is the past provider. It is therefore important to build up a good relationship with competent past providers. This is especially pertinent for infrastructure projects where technical complexity and uncertainty are high. Managers interviewed echoed the importance of a good relationship with external providers. Table 4 provided the evidence from the cases for the challenges and approaches adopted for procurement management process.

Insert Table 4 Here

The ability to deliver infrastructure through external resources to support business operations and improve business performance has made relationship with these service providers paramount of a successful infrastructure organization. Partnering and strategic alliances are examples of preferred arrangements in a more mature contractual service provision relationship. In fact, recent scholars have argued that an organization's performance may be strongly influenced by its inter-firm ties or its 'strategic networks' (Gulati et al., 2000). In the same vein, Gulati (1999) argued that an organization's network may offer a valuable source of information for organizations. The shared understanding and the dependencies can create win-win situation such as enhanced quality of specification from client to service. Therefore, in broad terms, the careful nurturing and systematic management of the relationships with external service providers enables infrastructure organizations to have access to a ready pool of competent providers. These providers, in turn are critical for supporting the delivery of infrastructure assets needed for business operations. Infrastructure organization needs to enhance their relational capability for the procurement and delivery process.

The Maintenance Management Process

The need to deliver maintenance is a fundamental requirement for any infrastructure organization. The ability to deliver the required maintenance can have a significant impact on cost and operations by minimizing the risk of asset failure that can have a devastating effect on business operations. Hence, it is a business objective for any asset manager to provide an optimum level of maintenance for infrastructure assets to perform effectively and efficiently to deliver the services desired by the organization. A manager noted, *"The key is to get just the right amount of maintenance, not over and not under."*

To identify the risks of asset failure effectively, the asset manager first needs information about the current functional state of the infrastructure assets through condition monitoring. Given the large quantity of assets that the case organizations are responsible for, collection and interpretation of condition data are both tedious and complex. Thus, experienced personnel who can understand and anticipate the maintenance requirements are of central importance. However, with the shortage of skilled staff in a tight labor market where employee movement is common despite the best human resource policy, these organizations must ensure that they do not rely solely on an individual employee to carry out this task well. Hence, a key challenge in the maintenance management process is to deal with the lack of skilled and experienced personnel. Furthermore, in any business that operates at full capacity, lost operating time equates to lost revenue. Optimizing maintenance activities in order to minimize downtime will always be one of the major sources of value add. Hence, a second key challenge identified across all the three cases is the reduced window of time available to

carry out inspections on the condition of infrastructure assets and to carry out maintenance works.

One of the ways to overcome these challenges, as observed from the cases, is to introduce more technologies into the maintenance management process. There is currently a variety of diagnostic tools available to assist asset managers in determining the maintenance regime required to deliver the appropriate levels of service at an accepted level of risk. For example, the leading areas of innovation of technology resources in infrastructure asset management are those of condition monitoring and reliability/maintenance strategy analysis. In these fields, techniques, tools and understanding are moving fast – in fact, the technology is no longer the limiting factor. Despite the widely available technologies to support maintenance management, all case organizations acknowledged that there is scope for greater use of technology and accepted the need to embrace more technologies to supplement the human inspection and judgment in order to perform the process more efficiently. The availability and continual development of many new technologies with different capabilities represents an under-utilized avenue to address the challenge of finding experienced maintenance personnel. Table 5 below illustrates the challenges and approaches for the maintenance management process.

Insert Table 5 Here

Literature has argued that the key source of competitive advantage is the rate at which organizations develop or acquire new technological capabilities, not the technologies they can currently access (Helfat, 1997). In order to embrace the use of technology, infrastructure organizations must first be willing and proactive in bringing in new

technology. The encouraging trend is that the case study organizations interviewed are getting involved in some forms of research into new technologies, benchmarking, and strategic partnership with technologies companies. According to Miles & Snow (1978), the most proactive organizations act quickly to take advantage of technological opportunities that emerge in the market through the development of new products, markets and technologies. Thus an organization that is proactive in investing in technology will be more innovative than an organization following other kinds of strategies.

However, tools and technologies alone do not define organizational capabilities. It is only through people that tools and technologies get a 'meaning' (Davenport et al., 1997). Therefore, too much emphasis on technologies, without paying adequate attention to people's perceptions about technologies and market realities, is likely to create irrelevant knowledge (Berggren, 1992). From the interviews, it was apparent that despite the advancement in maintenance management technology, significant human input and judgment are still required. While technology may be useful for processing and analyzing data, engineering knowledge, expectations, inference and range estimating are the prime source of information that needs to come from experienced maintenance personnel. Hence, while all case organizations deemed new technology as important, this does not negate the need for human input. Hence, infrastructure organization must not only active in acquiring new technology but also need to develop their technological readiness, defined by Parasuraman (2000) as people's propensity to embrace and use new technologies for accomplishing goals.

Thus, asset managers need to dedicate time and effort to increase their technological absorptive capability. Technological absorptive capability should include the two dimensions discussed above, i.e. awareness of new and capable technology and getting the people ready to embrace new technology.

The Asset Information Management process

All stages of the infrastructure asset life cycle need information. However, 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. All case participants supported the importance of asset information management process and a manager's remark best summed up the sentiment, *"our key resource is information … information is everything … you live and die by information."*

Data from cases revealed that infrastructure organizations typically manage a wide variety of assets. Many divisions are involved in the collection and storing of different infrastructure asset data into different systems. Two problems arise because of the multiple collection and handling of asset information. First, the quality and consistency of the collected data is affected. Second, different departments in charge of individual areas of asset management may adopt separate information systems and these are not necessarily compatible. As a result, the knowledge generated from the different asset information systems tend to be fragmented and isolated. As such, the lack of integration of asset information can seriously impede the efficiency and effectiveness of asset management. A manager aptly summed up the challenge for asset information

management, *"it is all about integration, about information management and consistency across the network."*

To overcome this challenge, case organizations focus on the development of their IT systems that can maximize business value. In fact, all case organizations are currently embarking on some form of re-structuring of their asset information management process. For example, rail is currently developing their Asset Information Management System with the formation of a team consisting of IT personnel, an asset manager and a management consultant. The goal is to make appropriate asset information available to staff in a consistent and readily accessible format. As part of the re-structuring to develop a good asset information management system, all case organizations recognized the need to ensure that their functional business managers understand and know the potential of IT. Table 6 below presents the evidence for the asset information management process.

Insert Table 6 Here

Hence, the integration of IT and asset management knowledge is necessary to facilitate the collection and storing of good and consistent asset management data that are useful for asset managers to make key decisions. Literature has recorded the need for organizations to integrate IT assets with their deep pools of business knowledge and competencies (Ravichandran & Lertwongsatien, 2005). Reinforcing this view, Benjamin & Levinson (1993) concluded that performance depends on how organizations integrate IT with organizational, technical and business resources. Analysis of the data from the case study also agreed that integration of IT with SIAM processes could create business value for infrastructure asset management.

This overlapping pool of knowledge and a common understanding can lead to the improvement in the asset management process. To summarize, infrastructure organization need to strengthen the development of their Integrated Information Capability. This requires first, complementarity between IT, systems and SIAM processes. Second, asset managers with both IT and asset management knowledge and skills are necessary to support and effect the integration.

A Capability Model to Improve Performance

The above discussion systematically examined the challenges and approaches in managing each SIAM core processes. Based on the challenges faced in executing the SIAM processes and the approaches adopted across the three case study organizations, it conceptualized the core capabilities of the individual SIAM processes. Table 7 summarized the discussion.

Insert Table 7 Here

Discussion earlier suggested that SIAM processes were the building blocks of achieving asset management goals. Effective management of its core processes can help achieve these business goals. In turn, the right capabilities can ensure the effectiveness of these core processes. As such, to develop the dynamic capabilities that will enhance the SIAM processes and hence contribute to the goals of asset management. This leads to the creation of value to the organization by contributing towards the performance of the infrastructure organization as a whole. Graphically, figure 2 provides a capability model on how infrastructure organizations can improve their performance and create value to their organization.

Insert Figure 2 Here

The importance of these findings is twofold. First, the SIAM processes identified provide a holistic and strategic framework for investigating infrastructure asset management for researchers. Specifically, through the findings of this study, the capabilities identified to manage the SIAM processes effectively illustrate the applicability of management concepts to augment infrastructure organizations' competitiveness. This paves the way for a more multi-disciplinary approach to the research of infrastructure asset management. Secondly, at a practical level, the lack of research in capabilities for infrastructure asset management undermines the importance and relevance of this aspect of infrastructure asset management as a value-adding function to the overall performance of the organization. This paper provided findings that will guide practitioners in developing the most appropriate and critical capabilities for their organization. This can be useful in helping managers to identify the resources they should seek to manipulate in order to develop such capability.

Implications for Managers

While the results of this study might have shown that dynamic capabilities are important for effective infrastructure asset management, a first step towards the development of these capabilities may be to amend radically many practitioners' mental models of what infrastructure asset management is. An appreciation of capabilities for infrastructure asset management and more importantly the linkages in contributing value to an organization could lead to nothing short of a paradigm shift. This paradigm shift affect how asset managers understand the scope and content of infrastructure asset management, its role in an infrastructure organization, and how to communicate to the managers in the top echelon and other functional areas.

Once the acceptance and understanding of the contribution of asset management to the business goals by management, asset managers must next identify the capabilities that they currently possess. This involves the cataloguing of each capability. In the spirit of the SIAM capability model presented here, a cross-functional team can aid in both listing such capabilities and affording an opportunity to begin the necessary dialogue across organizational boundaries about capabilities and its impact on organization performance. Asset managers must then make an assessment about the current strength of each of the capabilities they possess. The challenge is to measure the parameter of each capability. Some infrastructure organizations might be unaware of the capabilities parameters they already possess such as their relationship with strategic partners, customers and other stakeholders. Articulating and measuring such parameters, however crude they may be, will familiarize asset managers with the notion of dynamic capabilities.

The other fundamental strategic choice that asset managers face is the optimal allocation of the scarce resources among competing initiatives to acquire the identified dynamic capabilities. In other words, they need to purposefully create, extend, or modify its resource base. Specifically, asset managers need to purposefully build capabilities by focusing on resources that are interconnected, deeply rooted within the organization's relationships and knowledge base, and span the organization's business functions and hierarchy. For example, this study has identified technology absorptive capability and integrated information capability as those that are core to the maintenance management and asset information management processes respectively. The development of these two capabilities both requires the integration of people and

technology. This interconnectedness between the two capabilities therefore makes them a more resource-efficient option in the development of capabilities.

Limitation & Recommendation for Future Research

Evidently, there are certain limitations in the case study approach. The success of a case study is largely dependent on the willingness of the participants to provide information, fully and without bias. For example, time and access difficulties with respect to senior management during the stage 1 interview meant that it was only possible to obtain a 'snap-shot' understanding of the core strategic processes of each infrastructure organization. To counter the problem of not obtaining full and unbiased information, I corroborated the views of the participants with other information such as published reports and documents.

An important rationale for conducting this study is the current limited understanding on the concept of capability in infrastructure asset management. Due to the poor understanding of the concept of capability, I have adopted an indirect approach to draw out the dynamic capabilities for infrastructure asset management by focusing on the challenges faced and approaches adopted to overcome these challenges. This may have narrowed the consideration of some of the differing viewpoints and experiences thereby limiting the richness of experience available to this research. Nevertheless, the approach adopted does provide a strategy on how infrastructure organizations can improve their core processes by investing in the proposed capabilities.

Although this paper serves as a major step in developing a capability model for strategic infrastructure asset management, many questions remain unanswered. The above-cited limitations of this research suggest a number of directions to stimulate the conceptual

and empirical investigation into this important area of inquiry. Firstly, since this study has identified the dynamic capabilities that infrastructure organizations need in order to improve their performance, future study can pursue their interrelationship and the relative impact on the productivity of infrastructure asset management. Further research to test this model and examine whether it can generate improved and sustained performance may be another avenue. In this respect, quantitative studies of these capabilities and factor analysis may be appropriate to test these capabilities and their effect on organizational performance.

Conclusion

The purpose of this paper is to explore the dynamic capabilities needed to improve the performance of infrastructure organizations. In time of rapid change such as those experienced because of privatization and deregulation in the infrastructure industry, management literature emphasizes the need to concentrate on factors internal to an organization such as capabilities to generate sustained performance. Based on the empirical evidence from multiple case studies and theoretical explanations, this paper has identified the SIAM processes and dynamic capabilities needed in the management of infrastructure assets. The three case studies provided new evidence that infrastructure organizations need to strengthen the five dynamic capabilities namely stakeholder connectivity capability, cross-functional capability, relational capability, technological absorptive capability, and integrated information capability. They must thus concentrate on developing these capabilities to support their business operations in order to survive in an increasingly competitive environment. By developing these capabilities, infrastructure organizations can achieve better performance and create value for not only asset owners but also the larger society. The improved asset

performance will send a powerful signal to senior management on the strategic importance of asset management in contributing to the business goals of the organization. On the macro-level, improved infrastructure asset management enhances the credibility and accountability of infrastructure asset owners by achieving better value for their investment.

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