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A framework for the engineering asset management system

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Keywords
asset, framework, management, system, engineering

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A Framework for the Engineering Asset Management System

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Abstract

Purpose: The role of Engineering Asset Management (AM) system as a controlling element within organisations is not well defined or understood. This view includes the role of AM in the organizational strategy making, an issue that has not received sufficient attention. The focus of this paper is on how such role is maintained by the AM system activities, relationships and mechanisms over the asset-related activities of an organization.

Design/methodology/approach: As an approach, a reference framework is required that allows research of this area. By combining a number of possible views of an organizational management system a comprehensive view can be established. A review of literature was used to establish a framework identifying the AM system as an integrated part of the organization's management system.

Findings: A framework is established that focuses on planning and controlling asset-related activities by involving a set of activities, relationships between these activities and feedback mechanisms. A system functional model is proposed integrating the established framework as part of the control of the enterprise system.

Research limitations/implications: The framework and system functional model are established on a theoretical basis and practical experience requiring applicability to be proven by further research.

Practical implications: Asset managers in capital intensive organizations can utilise the framework and the system functional model in order to study their AM system, its relationships and to consider how it may be improved.

Originality/value: Exploring a holistic and relatively new concept.

Keywords: Asset management, assets, asset lifecycle, management system, strategy

Paper type: Conceptual framework development

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1. Introduction

AM varies in interpretation and definition. In the financial sector, it refers to the management of financial assets. In capital intensive industries AM is used to identify how an industrial organization deals with the management of its physical assets through their life cycle to achieve its strategy. The output generated with these assets should justify their ownership. Development of new and extended bodies of knowledge and frameworks incorporating a multi-disciplinary view is underway (Frolov, Megel et al. 2009). A growing number of industry groups, professional societies and research organisations that consider AM are forming, for example, (IPWEA 2006; CIEAM 2008; Asset Management Council 2009) is evidence of an increasing emphasis on the area of AM. AM may be regarded as an essential technical as well as a business process, and is increasingly considered as a contributor to an organization's objectives through managing asset performance with the intention of achieving the competitive strategy. The development of a discipline called AM seems to be based on the idea of a collection of management activities among the organization's activities that together manage these assets. The Asset Management Council (2009) defines AM as: "The life cycle management of physical assets to achieve the stated outputs of the enterprise". The AM system may subsequently be defined as: "The system that plans and controls the asset-related activities and their relationships to ensure the asset performance that meets the intended competitive strategy of the organization" (El-Akruti and Dwight 2010). As a control system AM involves a set of planning and control activities at different organizational levels. This definition provides an integrated view of the AM system within the whole organization's management system.

It is proposed that there are two main aspects of AM when it is defined in this way: the lifecycle management of physical assets and the holistic system control of asset-related activities directed at achieving the organizational strategy. These two aspects are not easily separated when analysing AM.

Lifecycle management can be considered to involve AM activities associated with an existing organization (Amelsberg 2002; Charles and Alan 2005). Typically such an organization is initially concerned with the utilisation phase of these existing assets. Any decision concerning the portfolio of assets is built on the accumulated information of managing this stage(Evan 2008). At any time it may be determined for example that the current design of one or more assets is not capable of achieving the required performance given the current or projected future environment (Dwight and El-Akruti 2009). Concurrently, organizations must identify the business needs, and make decisions to launch any change or project to enhance assets, their design, operation, maintenance or logistic support (Charles and Alan 2005; Du Preez and Louw 2008; Narayanamurthy and Arora 2008). AM projects may involve, upgrading, expansion, support system redesign, replacement or retirements of assets. Systems engineering principles implies that the AM system must normally have a strong influence over the acquisition phase of any asset given that usually this provides the greatest opportunity to control the life cycle cost and life cycle performance or system effectiveness of assets(Arnold and Lawson 2004; ISO/IEC 15288 2008; Blanchard 2009). The challenge in managing the entire asset life effectively lies in integrating the fragmented activities through the various stages (Charles and Alan 2005; Luan, Siew et al. 2007). This leads to integrating the need identification, alternative analysis and project selection to the business management focus. The decisions should be considered strategic and need to be closely linked to the engineering technical perspective within the organization (Dwight and El-Akruti 2009). There are temporal barriers to this integration: during the

acquisition phase, the emphasis is on implementing a project within the boundaries of the approved budget and prescribed time frame, while ensuring that the facility conforms to the technical specifications (Dwight and El-Akruti 2009).

It is assumed that the AM system that plans and controls asset-related activities, involves AM activities typically distributed among most of the organization's departments and at the different organizational levels. It is suspected that conformance to the enterprise competitive strategy can be achieved by an integrated decision making process that includes AM activities. Such integration involves the alignment of all decisions taken by individual departments and at the various management levels. But the relationship between the organizational competitive strategy and strategies related to the conduct of particular activities is more complex than the simple top-down hierarchical approach. For example in studying the manufacturing strategy Kiridena (2009) concluded that this relationship is far more complex than could be described by simple hierarchical links associated with the organizational structure. Such a relationship was either defined as an integration between activities and their alignment with competitive and corporate strategies (Russel and Taylor 2006), or as information flows that extend between activities (Slack, Chambers et al. 2006).

The requirement for interdisciplinary activity creates complexity raising integration challenges through the life cycle stages, between activities and along hierarchical levels within the organizational structure. This is highlighted in the link between AM and the organizational strategy making. At the operational level, the technical facet of AM is often left in isolation of the organization's strategic process at the business level. A recent study by Pinjala, Pintelon et al. (2006), cite a lack of studies on the relationship between business and some of the asset-related activities. For example, maintenance is typically considered as a 'necessary evil' and not involved at the strategic level as a business issue (Muchiri et al. 2010). (Muchiri and Pintelon 2007). On the other hand, a strategic approach to maintenance as an asset-related activity has been recognized especially in capital-intensive industries (Tsang 2002; Pinjala, Pintelon et al. 2006). Ouertani, Parlikad et al. (2008) suggest that maintenance is complex and deserves additional attention, but it is only one of the activities involved in managing assets. Others include choosing the right assets, using them appropriately, and balancing short-term performance against long-term sustainability. Thus, AM activities need to be built among many organizational activities, levels and through all life cycle stages.

An important activity following from the need for integration within an AM system is the need to build interfaces between disparate organizational asset-related activities, along and between organizational hierarchical levels and through numerous life cycle stages. This type of multi-dimensional integration can only be maintained with management activities. The effort required, the types of activities, and the benefits gained from such activities are part of the organization management system. It is suggested that organizations have difficulty in devising these management activities and justifying the application of resources to them. Through the establishment of a framework for AM the nature of the required activities, mechanisms and relationships can be identified.

2. Review of Existing Frameworks for Asset Management

Most AM-related frameworks typically concentrate on specific asset-related activities such as maintenance. There are a number of existing engineering and management frameworks and some standards and guidelines that have been considered applicable to study AM systems.

The available frameworks that have been considered for AM are generally not comprehensive. Their contribution has mostly focused on specific life stages or processes and has not considered a holistic approach that includes the interfaces between stages or processes. Charles and Alan (2005) indicated that most efforts have been directed to the primary drivers of the utilization phase. As cited in many publications, industry has primarily focused on maintenance management tools, e.g. TPM, RCM and BCM (Campbell 1995; Hoskins, Brint et al. 1997; Kelly, Mosier et al. 1997; Amadi-Echendu 2004). A major disadvantage of applying these tools in isolation is that they address only a limited set of technical life cycle activities (Barringer 1997; Waeyenbergh and Pintelon 2002). The design stage is more relevant to the need identification, alternative and selection decisions. Potential benefits are consequently lost due to short-term focus on cost during the acquisition. Decisions related to asset selection, development and deployment are often not taken based on proper synthesis, analysis and evaluation process. Blanchard (2009) highlighted the importance of a life cycle view in his elaboration of the system engineering approach. Several others have addressed the need to shift the focus from the technical aspects of physical assets to a more business oriented AM approach (Amadi-Echendu 2004; Frolov, Megel et al. 2009). Ouertani, Parlikad et al. (2008), proposing that a coordination of life cycle processes is vital to effective AM. An available model to consider for the asset acquisition phase is the system life cycle model (Blanchard 1990) which emphasises the value of coordinating between the acquirer and supplier organization. The concept of terotechnology cited in (Bamber, Sharp et al. 2004) is similar to system engineering (Blanchard 2009). These approaches tend to present a set of activities following the sequence of the life cycle stages and concentrating usually on one asset. Other frameworks concentrate on the maintenance activity and its relationships to the life cycle processes (Geraerds 1992; Dwight 1999). The (Australian Asset Management Council 2007) present a ‘technology model’. It is suggested that these frameworks do not adequately represent the collaborative asset decisions that involve strategic and technical organizational asset-related activities. For example, the decisions about the disposal of an asset, as well as decisions about the introduction of new assets are interrelated and require contributions by many organizational entities and levels through different life cycle stages as established previously. These decisions highlight the need for a holistic approach to AM.

Efforts have been made by some organizations to utilize some of the standards and guides. The Institute of Asset Management has produced some guidelines: (PAS 55-1&2 2008). Dependability standards including ISO/IEC 15288 (2008) are relevant to some aspects of AM. In addition, new AM-related standards are emerging (Kennedy 2010). Although the ISO/IEC 15288 (2008) standard and PAS 55 guidelines are relevant, they do not reasonably explain the task of linking AM to the competitive strategy development activity of the organization. As a limitation such standards do not detail activities, methods or procedures required to meet the requirements and outcomes of a strategy. Nor do they detail documentation in terms of format, explicit content and performance measurement. They do not give directions on how to select or modify the processes in order to tailor them to the need. They do not adequately instruct the process of linking the organizational strategy to the organizational activities. The PAS 55-2 (2008)

guideline indicates the link between AM system elements and the organizational strategy without identifying how such a link is maintained. According to the typical elements of the AM system in the guideline, the element that connects the AM system to the organizational strategy is the AM policy. However, this AM policy is several 'shall' statements that do not show the AM system's role in influencing the strategy. It states that "the AM policy shall be derived and be consistent with the organization's strategic plan" but it does not show the activities to be taken or the control required to maintain the relationship with the organizational strategy. ISO/IEC 15288: (2008) claims to provide for the assessment and improvement of the life cycle processes. As a unique collection of system life cycle processes based on system principles and concepts, that standard provides processes for both technical and non-technical systems (Arnold and Lawson 2004). In this mode there appears to be an assumption of a static external and internal environment. However, the reality is that environments are dynamic.

Following a set policy or general and static processes may not be consistent with the specific needs of the organization. There is a need to establish a conceptual framework that indicates the essential activities, relationships and mechanisms of the AM system. With the existence of an appropriate conceptual framework the needed management cycle can be formulated and acted on. This approach stems from a view that the enterprise is a system; changes to that system require consideration of their effects on the system as a whole. This leads to the need of coordination to support the overall organization objective. Achieving such objective requires synergy between the management activities within the various activities of the organization system (Geraerds 1992).

3. The Role of Asset Management in the Organizational Strategy

The current theory on strategic management is held not to effectively include consideration of factors relating to AM. While this paper focuses on physical assets, the strategic management process considers the wide range of tangible and intangible assets. This drives the emphasis away from the focus on the role of engineering or physical AM (Hafeez, Zhang et al. 2002). The link between strategy and AM can be explored by reviewing the approach to competitive strategy development and implementation and the available frameworks relative to this competitive strategy process.

Like other activities within an organization, AM system activities play a role in the organizational strategy development and implementation. The traditional approach to strategy is a top-down "cascade" approach, e.g. Thompson and Strickland (1989). However, many bottom-up initiatives can trigger the need to change the strategy. The development of strategy is an ongoing process (Robert 1984), that depends on the interaction between corporate or business strategies and the organizational activities. The strategy and structure of any strategy is built referencing the business 'competitive' strategy. Interrelationships with other activities must be considered. Strategic management research reveals the notion that an organization's personnel throughout the organisational hierarchy contribute to strategy making (Floyd and Wooldridge 1997), but how this process takes place is not yet fully understood. This idea was building on Mintzberg's 'Organigram' (1997) as a visual description of the key elements of an organization. It focuses on the organizational hierarchical interrelationships. Strategy making should be considered as an organizational capability that, if developed at multiple levels across the organizational hierarchy, leads to sustainable competitive advantage (Gordon 1998). The interactions and processes that underlie decisions have generally been left ambiguous

(Wooldridge, Schmid et al. 2008). It is suspected that AM is part of the organizational strategic management system and plays a role in the strategy development and implementation. Hence, any framework for the AM system should uncover its role in strategy development and implementation.

Competitive advantage can be understood through the famous value chain framework of Porter (1985). This may be complemented in the case of service organisations by the value shop framework introduced by Stabell and D. Fjeldstad (1998). Neither the value chain or value shop frameworks distinguish the AM 'activities' from others. In the value chain framework, 'activities' are embedded within two categories; direct and supporting 'activities'. The use of the value chain framework is based on viewing the organization in terms of a series of activities, focused on relating the value-add activities to customer value creation (Porter 1985).The AM value concept is related to the value contribution through providing assets that allow the organization to fulfil the strategic intent of the organization. This results from taking the proper action to define the need, provide the assets and manage their life cycles; acquisition, utilization and disposal. Asset-related activities such as maintenance are not dealt with directly by Porter's value chain. For example, Porter includes maintenance as a sub-activity of the primary activity of operations while asset acquisition is treated as a sub-activity of the supporting activity of procurement. Porter has not directly focused on these asset-related activities within the value chain. Pinjala, Pintelon et al. (2006), suggest that maintenance should be managed as a separate value chain activity so management can visualize the maintenance link to the business strategy. The value chain concept facilitates the identification of fundamental choices for performing activities differently than rivals so as to deliver the required value for the customer and so gain a margin for the enterprise. The value chain concept suggests that the value-add activities be identified but does not identify those management activities that govern these technical or business activities.

From Porter's work (1996), a competitive advantage stems from offering lower prices than competitors, premium products or services or providing unique benefits more than or offset a higher price. Porter's value chain framework (1985) presents the value chain as a stream of value. In this value stream, value can be created from supplier to the organization or from customer to the organization. Although, these mentioned value concepts set the basis for the relationship between the organizational activities and strategy, their interaction with the AM system is not clear. In relation to organizational activities, value has been defined and expressed in terms of performance attributes. For example, product value is a consumer utility function expressing relative satisfaction with a product's quality and cost (Omar, El-Akruti et al. 1996); as a function of performance related parameters of product or service at which they are delivered (Melnyk and Denzler 1996; Liyanage and Kumar 2003; Kiridena 2009).

It is suspected that the value creation process can be detected in terms of the asset performance. The output performance is a function of the production or operation process which depends on the capability and performance of assets during the utilization phase. The capability and performance of assets during this phase depends on the capability and performance of the design processes during the design phase. Therefore, the value creation process is dependent on the performance of the asset-related activities through the life cycle stages. As earlier indicated, those management activities are not adequately distinguished from operational or technical activities in Porter's value chain (1985). It is expected that these activities are part the organization management system and control the asset-related activities.

4. Asset Management System Activities

The interdisciplinary and collaborative nature of the AM system can be gleaned from the definition of the asset life cycle from a user-organization viewpoint proposed by Ouertani, Parlikad et al. (2008) as a succession of four stages:

a. Acquire - all activities involved in technical and financial analysis, justification, and planning for acquisition of new assets, as well as in managing acquisition.

b. Deploy- all activities associated with the installation, testing, and commissioning.

c. Operate/Maintain - all activities involved in most effectively maintaining asset availability (health), longevity, and capability (quality, performance & flexibility).

d. Retire - all activities involved in disposal of assets.

Organizations deal with these stages by structuring organizational departments such as technical support and development or maintenance department. Through the performing of asset-related activities by such departments, organizations make decisions regarding the need, design, operation, maintenance or disposal of assets. An organization's structure usually includes departments that perform activities such as procurement or finance that support these lifecycle activities The success of a capital intensive organization often depends on its ability to coordinate activities efficiently and effectively among these various asset-related activities.

Utilising the idea and format of the Porter model (1985), a typical representation of the main asset-related activities in an organization is shown in Figure 1. The relationships of the asset-related activities exist between the asset life cycle activities and the supporting activities.

As identified previously, the concept of an AM system is that the system incorporates overlapping interdisciplinary activities and is either part of or alternatively controls many asset-related activities. It also incorporates coordination activities to maintain relationships between asset-related activities such as those related to:

a. Procurement, finance and accounting which are important for establishing the requirements to enable investment, funding and budgeting, cost analysis and decision making.

b. The information technology department to establish the required information flow to facilitate linkages and integrate across all asset-related activities and create a data base. For example, a published case study (Holland, Shaw et al. 2005) reports that "BP connects its business processes with over 1500 suppliers to co-ordinate the maintenance, operation and repair of specialized exploration and production equipment."

c. External suppliers to establish their involvement in managing asset's life cycle and maintain value added relationships with suppliers and to make outsource verses in-house decision and maintain both-side-benefit relationship.

d. Technical support and development to establish the required development in assets or asset-related processes and the suitable technology or any new developments in technology for use in enhancing performance.

e. Human resources, inventory, quality and safety systems for better performance, less risks and safe environment.

Every capital intensive organization may undertake all the asset-related activities but may not exercise the required activities to plan, control and integrate them for the overall objective of the organization or its strategic goal. Deficiencies in the AM system activities may be due to missing some of them, their improper existence or lack in the means to undertake them such as expertise, technology or skill.

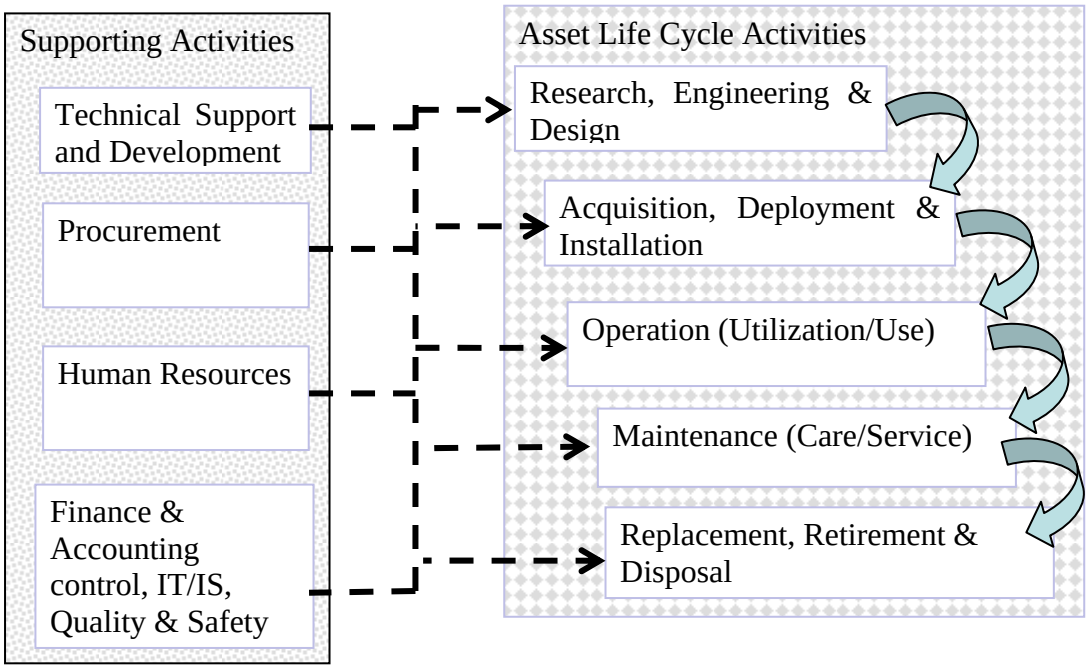

Figure 1: A Typical Representation of the Asset-Related Activities

5. The Nature of the Asset Management Activities

Organizational departments have always carried out activities that are related to assets or the life cycle processes such as design, operation or maintenance. Other AM activities such as measurement, analysis, planning, development, modification or any investment task are always done by relevant departments for the specific purpose of each department. Budgets are always specified, resources allocated and information about asset condition and performance are usually obtained in some format. These activities are done by various departments in the organization but may not be integrated and optimized for the strategic objectives of the organization. The purpose of this new discipline called AM is to establish the collaborative activities within the organization's system to accomplish the organizational strategy.

The AM activities may be classified relative to organizational hierarchical management levels. The activities at each level vary relative to context, life cycle stage and type of organization. Organizational management levels can be defined according to the planning horizon as strategic, aggregate or operational (Anthony, Dearden et al. 1989). They proposed that an organization, management control is facilitated by planning and control activities that can be considered to take place at these three levels:

a. Strategy formulation activities: strategic planning and control activities.

b. Management control activities: aggregate planning and control activities.

c. Task control activities: operational task control activities.

In structuring an information system in an industrial organization AL Marsomi (1997), similarly suggested three control levels. He defines these as management control levels and denotes them as: strategic level, tactical level and operational level. AM activities can be classified according to these levels. The new 'paradigm' is that the AM system comprises a set of planning and control system activities integrated over the enterprise asset-related activities in a coherent comprehensive manner. Interpretations by those in industry, as shown from some Swiss utilities (Kostic 2003) indicate that AM activities are considered to be associated with maintaining condition of equipment; acquiring equipment; asset life cycle; asset performance; fault management; risk management; asset criticality; asset safety and security; computing; return on investment; financial performance; asset value; asset history; or asset information system. Certainly the essence of AM system activities can be drawn out of an amalgam of these responses. In support of this view, Sinha, Lahiri et al.(2007), state that the enterprise AM system forms integrated activities as part of the management process in a utility businesses. This integration nature of the AM activities involves multiple disciplines. The key principles for such integration includes: proper design and management to maximize capability, reliability, availability and utilization whilst minimizing life cycle cost (capital, operating, maintenance, support and disposal cost). Kostic (2003) envisaged a set of activities under the three categories:

a. Enterprise-oriented activities: involving strategic decision.

b. Network-oriented (system) activities involving coordination between organizational activities

c. Asset-oriented activities focusing on an asset as a component a set similar type of assets

These categories of activities are consistent with the concept of AM as presented by PAS 55-1&2 (2008) with the 'typical priorities and concerns': management of asset portfolio, management of asset systems and management of asset life cycle.

These categories of AM activities fit the planning and control activities at the organizational management levels shown by Anthony, Dearden et al. (1989), Anthony and Govindarajan(1995) and Al Marsomi(1997).

6. A Framework for the Asset Management System

The AM system framework in Figure 2 sets out the organizational levels and activities, relationships and mechanisms of the AM system. It implies that the management of the asset-related activities is maintained by a control process constituted by a cycle of these planning and control activities of the AM system through the management levels. Each asset-related activity will have a planning and control process acting on it. This planning and control process or mechanism would usefully be iterative.

Through these activities at the three levels and with feed-forward and feedback mechanisms, the framework proposes that AM plays a role in the strategy development and implementation. Activities at the aggregated and operational levels should be directed at meeting the objectives

set out at the strategic level. Activities at this strategic level determine what the asset solution is to be set and/or the decisions required achieving the resulting asset performance to deliver the value contribution to the business. This presents the connection of the AM system activities with the business management system activities for strategy development. The AM planning and control cycle acts on the asset-related activities as shown in Figure 2. The control cycle is set and maintained by feed-forward and feedback links between those AM planning & control activities. This depicts a control mechanism for the AM system activities.

The AM-Strategic Planning & Control activities are depicted as analysis, evaluation and decision making activities. These decide on the asset solution and or define the asset performance to be reviewed by the organization. The basis for the decision on the asset life requirement should be determined and documented. Decisions on adjustment to be made on the assets design stage processes or utilization stage processes in the way assets are managed, operated, maintained or disposed are also represented by this part of the framework. These strategic activities should consider leading performance indicators as well as lagging indicators to determine the gap between current and projected business performance and the resulting asset performance. They also provide feed-forward results from analysis to decision making of higher strategic management.

In a top-down direction, these strategic activities facilitate feed-forward approvals and plans as control directions for the aggregate and operational level activities. In a bottom-up direction, these strategic activities demand feedback from the two lower levels activities to allow analysis, evaluation and feed-forward for further decision making. The effectiveness of the AM-Strategic Planning & Control Activities depends on available knowledge and information sharing across the organization.

The AM-Aggregate Planning & Control Activities require adequate information system and information management to translate the top-down decision into a bottom-up action. The aggregate activities and their information systems should also facilitate the interactions between asset-related activities such as design, finance (budgeting) and accounting (cost control), operation, maintenance, environment and safety (control), project management, and procurement. The activities represented at the aggregate level represent the coordination and integration activities aimed at delivering efficiency and effectiveness in action and interaction, and in identifying causes of conflicts, deficiencies and unwanted costs.

The AM-Operational Task Control Activities constitute the task control and measurement activities. These are operational in nature and are separately part of the various asset-related activities, however; they dominate the focus of literature on AM as a set of technical activities. The asset management control activities at the operational level may be divided into two categories: task control; and, measurement/monitoring of operational technical parameters.

The flow from a technical asset life cycle performance to a business performance reflects the value contribution of the AM system activities to an organization’s competitive strategy. The strategy making process takes the form of a cycle, simultaneously involving: the top-down planning and control directions and bottom-up performance measurement and feedback control.

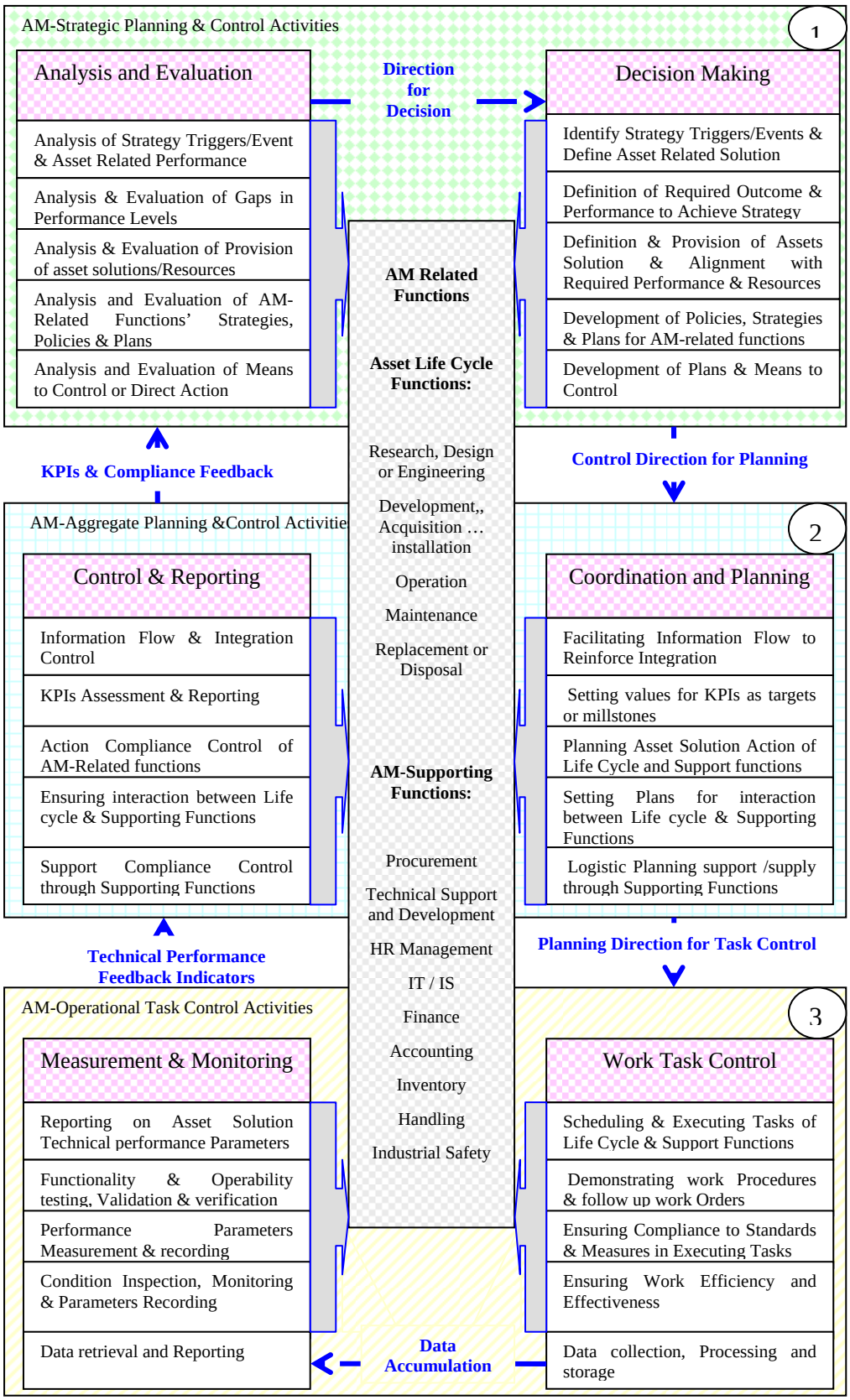

Figure 2: The Asset Management System Framework

7. The Integration of the Asset Management in the Enterprise System

It has been argued that the AM system is a management system with activities being a set of planning and control activities that exist at three organizational levels; strategic, tactical or aggregate and operational. As such the integration of these within the organization system needs to be defined and synthesized.

The form of the enterprise AM system can be identified in terms of these three levels as distinguishable parts of the organizational management system but are inseparable parts of the organizational activities. It should be noted that the activities under this view are not meant to reflect the sequence of the life cycle processes of an asset but constitute the overall levels of organizational management activities of the AM system, the control elements focusing on the life cycle processes or asset-related activities. The activities in each level are meant to control the asset life cycle activities and supporting activities depending on the problem at hand or strategy to be achieved.

This notion of having a set of planning and control activities existing over the organizational levels and also existing across the organization leads to the concept of a collaborative control system. As such the integration of the AM system within the enterprise system needs to be synthesized. This leads to consideration of the AM system as part of the enterprise management system. Figure 3 offers this perspective. It is of a general format that is applicable to the organization's system with its sub-systems. It depicts relationships between asset-related activities, control activities and the boundary between the system and its external environment.

a. This system model is developed building on the production model presented by Al Marsomi (1997) and the widely recognized in system theory and functional analysis, e.g. Hunger (1995). Such model is based on the functional flow of input, activities, output and feedback control. However, the framework developed here and integrated in this system functional model also includes the categories of life cycle activities and supporting activities as found in the value chain framework (Porter 1985), and the life cycle framework presented by Blanchard (1990; 2009).

b. In comparison to the value chain model (Porter 1985) the conversion flow is shown and denoted by the primary activities however two functional flows are shown Figure 3 as:The functional flow as denoted in the value chain: inbound-conversion-outbound; (purchase material-operate-deliver goods or service) and,

c. The life cycle functional flow: identification of need-design-utilization-retirement; (identify need-acquire-maintain-keep-develop or replace assets)

As a common dimension, both the value chain and this system functional model consider the same supporting activities. In contrast to value chain model, this AM system functional model presents the categories of management activities existing separately at three different levels including the control elements and their relationships. The mechanism depicted indicates an iterative process of planning and feed-forward for analysis and evaluation leading to decisions to control asset-related activities. This system functional model presents alignment of asset-related activities toward accomplishing the organizational strategy. Such alignment highlights that any deficiency can be identified or declared in any of these activities, at any time as a priority if that is going to help the competitive strategy of the organization.

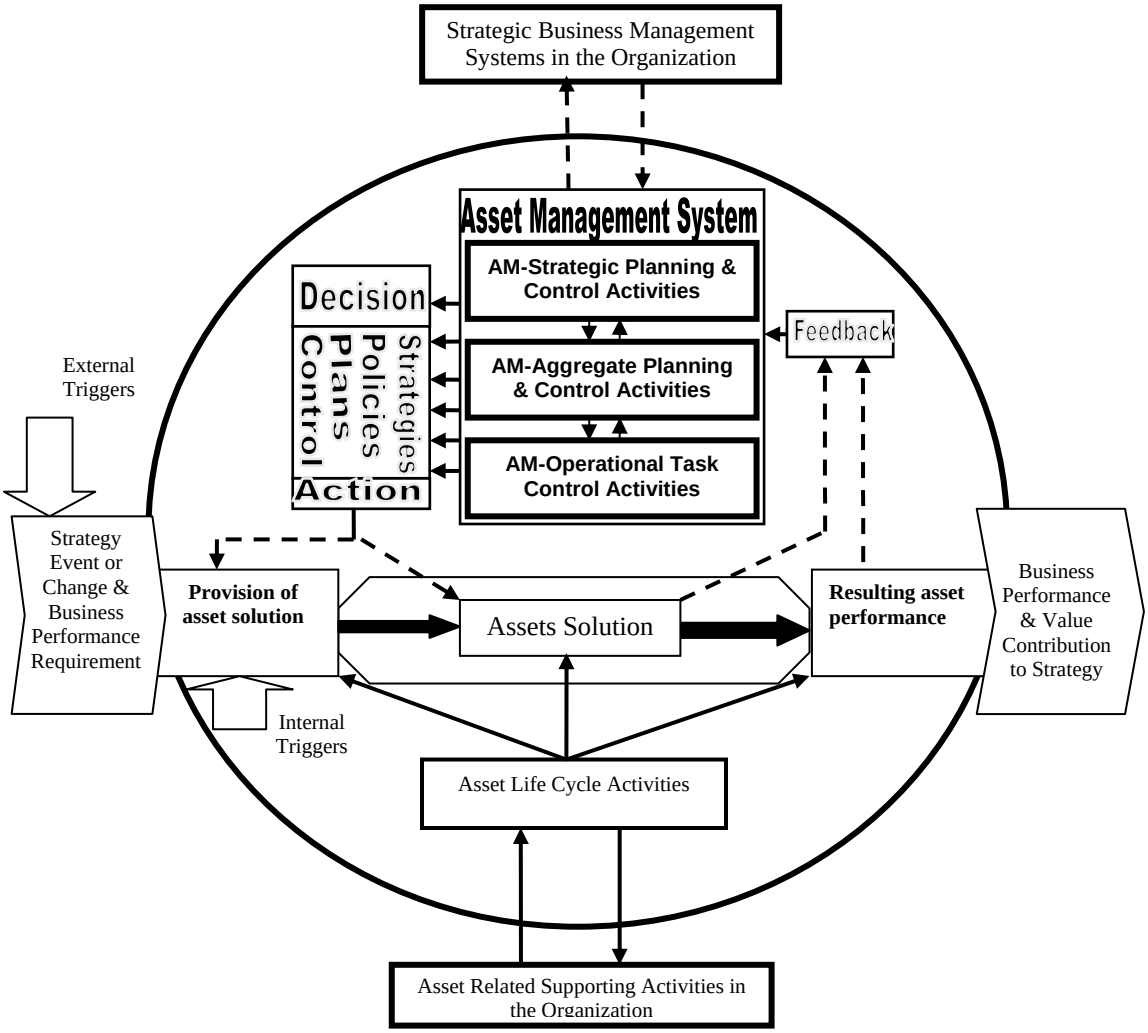

Figure 3: The AM System Functional Model (Integration of AM in Enterprise)

8. Conclusion

AM is considered to be a complex interaction to plan and control asset-related activities within an organization. A set of these typical asset-related activities has been established. AM can be viewed from various perspectives depending on the organizational management levels: operational; aggregate; and strategic. These perspectives can be combined into a single framework representing the activities, relationships and mechanisms that play a role in AM system effectiveness. This framework in combination with its integration into a system functional model are proposed as a guide to AM practice directed at achieving an organization's competitive strategy. It is argued that the proposed framework can be used as a reference to AM actions that should take place in the organization. The effectiveness of AM actions also depends on factors that facilitate the proper existence of the elements of the proposed framework. These factors may include information system and technology, knowledge and experience, and organisational culture and incentives. Three case studies were conducted in a research project to validate the framework. However, further applied research is recommended and organization can use it to reference the existence of the AM system elements in their practice.

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