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The strategic role of engineering asset management

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The current concept of an asset management (AM) system focuses on the lifecycle of engineered assets and little has been done in the literature on its link to organizational strategy. In this paper, the AM system's position within an organizational structure and its role in competitive strategy has been explored. Two case studies involving AM have been analyzed using a proposed framework which is comprised of a set of planning and control activities maintaining a control mechanism and a relationship with the strategy-making process. It is argued that the AM system structure and the mechanism play a key role in the organizational strategy. The existence of the AM system is hypothesized by this framework which stipulates the asset performance required for strategic success. The use of this framework allows for conclusions to be drawn on the requirements for building an effective connection between AM activities and strategy development. This connection is achieved through planning and control mechanisms acting on the asset-related activities. On one hand, the effect of inadequate or missing elements of the framework has been shown to result in negative impacts on cost, productivity, quality, business outcomes and ultimately strategy achievement. On the other hand, the existence of elements of this framework has been shown to have positive impacts on strategy achievement.

Keywords

strategic, engineering, role, asset, management

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Abstract

The current concept of an asset management (AM) system focuses on the lifecycle of engineered assets and little has been done in the literature on its link to organizational strategy. In this paper, the AM system's position within an organizational structure and its role in competitive strategy has been explored. Two case studies involving AM have been analysed using a proposed framework which is comprised of a set of planning and control activities maintaining a control mechanism and a relationship with the strategy-making process. It is argued that the AM system structure and the mechanism play a key role in the organizational strategy. The existence of the AM system is hypothesized by this framework which stipulates the asset performance required for strategic success. The use of this framework allows for conclusions to be drawn on the requirements for building an effective connection between AM activities and strategy development. This connection is achieved through planning and control mechanisms acting on the asset-related activities. On one hand, the effect of inadequate or missing elements of the framework has been shown to result in negative impacts on cost, productivity, quality, business outcomes and ultimately strategy achievement. On the other hand, the existence of elements of this framework has been shown to have positive impacts on strategy achievement.

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

1. Introduction

Engineering Asset Management (AM) as a discipline addresses the value contribution of AM to an organization's success (Amadi-Echendu *et al*., 2007). The AM system may 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". This system has significant potential to influence all aspects of asset's life cycle activities from concept design to disposal. The AM activities focus on controlling the life cycle activities of assets but their nature is both interdisciplinary and collaborative.

Most reported research on AM focuses on discrete activities: *e.g*., maintenance, and rarely extends to AM as a holistic system. Frolov, *et al*. (2009) state that historically AM was viewed as a technical activity driven by engineering design and narrowly focused on reliability and maintainability of assets. Charles and Alan (2005) explain that the concept of the AM system has not been considered from the whole life cycle approach and the whole related activities. Ouertani, *et al*. (2008) explain the importance of considering life cycle activities in AM.

It is suggested that the usefulness of a holistic system view of AM has been identified but is not fully developed. The concept of AM which involves more business related engineering disciplines has only emerged and reported in literature relatively recently (see, for example, Dornan, 2002; LoPorto and Udo, 2003; Mohseni, 2003; Amadi-Echendu, 2004; Charles and Alan, 2005; Narman, *et al*., 2006; Stapelberg, 2006; Haffejee and Brent, 2008; Asset Management Council 2009). It has become the focus of industry groups, professional societies and research organisations including IPWEA (2011) and Asset Management Council (2009). Based on the practice of particular organisations, several frameworks resulted from experience or specific personal understanding have been reported or published by individuals or their organizations. In general these are not grounded in existing theory nor analysed and investigated to determine their usefulness. Verification of the fitness of frameworks for the academic research or particular AM purpose is essential. According to Frolov, *et al*. (2009), the collaboration between organisations and academic researchers is under way to extend the body of knowledge in this area.

This relationship between the competitive strategy and asset-related activities such as maintenance has not been explicitly developed and is usually anonymous in most organizations. Literature reviews by Alsyouf (2006) and Pinjala, *et al*. (2006) indicate a lack of studies on the contribution of maintenance to positive business performance. Ouertani, *et al*. (2008) argue that maintenance has an impact on the capability and performance of assets and that this should be viewed in terms of value contribution. Maintenance is typically considered by organisations to be a 'cost centre'; for example, Alsyouf (2006) and Muchiri and Pintelon (2008) show that maintenance is often treated within organisations as 'subordinate to operations' or a 'necessary evil'. The link between the inputs to the maintenance process and the outcomes for manufacturing has not been explicitly established (Dwight 1999). Bamber, *et al*. (2004) indicate that both lean and agile manufacturing consider the role of maintenance as a key of competitive advantage.

It has long been recognized that organizations experience significant shortfalls in their strategy realization because of asset performance. Miles and Snow (1978) have shown that new strategies have failed due to inadequacy in the activities required to manage the new assets, systems or technology. Some studies have focused on the interface between project management and strategy (Morris, 2004; Srivannaboon and Milosevic, 2005). Other studies, *e.g.*, Donovan (2002) showed that inadequate feasibility studies and other system engineering activities have resulted in inconsistency between the strategic goals and the delivered system. It is shown that life cycle cost analysis rather than the accounting measure is required to allow for optimal replacement interval and supplier selection decisions (El-Akruti, 1999). Kaplan (1990) and Kaplan and Norton (1992) stated that financial measures are misleading and the constraints based on short-term financial performance measures alone destroy the true value.

It is proposed that capital intensive organizations have inadequate awareness of the potential role of the AM system in organizational strategy setting and implementation. Further, it is argued that the nature of activities, relationships and mechanisms in the AM system have not been adequately defined in literature. The activities of the AM system that are related to the development of an effective competitive strategy are not yet defined. The proposition is that the required AM system activities and relationships between these activities are not sufficiently in control in organizations. It is therefore to recommend that the AM system activities are inseparable from various other activities and relationships within an organization system as a whole. These general concepts raise questions such as: to what extent is this recognized by organizations and if not, then why not and how can an organization set up the missing elements?

It is believed that the AM system can play a key role in strategy making. In order for this role to be effective, certain AM system activities, relationships and mechanism need to be managed adequately within an organization. This paper establishes an AM framework that provides a holistic approach exploring the AM role in organization strategy development and implementation. The novelty of the developed framework is related to its holistic approach and systematic tactic in mapping AM activities and relationships. Two study cases are given in extensive detail to illustrate the approach utilizing the developed framework and demonstrating its potential in analysing relationships of AM related activities to establish proper links for strategy success. The case studies present a valuable contribution evidencing of the role of AM system activities in the success of an organization's strategy.

2. A Framework for Asset Management System

Utilising the idea and format of the Porter's vale chain (1985), a typical representation of the main asset-related activities in an organization has been developed by El-Akruti (2012). The relationships of the asset-related activities exist between the asset life cycle activities and the supporting activities. The

AM system framework as shown in Figure 1 (El-Akruti, 2012), incorporates coordination activities to control and maintain relationships between asset-related activities.
The AM activities may be classified relatively to organizational hierarchical management levels. Organizational management levels can be defined according to the planning horizon as strategic, aggregate or operational (Anthony, *et al*., 1989; Anthony and Govindarajan, 1995). They proposed that in an organization, management control is facilitated by planning and control activities that can be considered to take place at these three levels: strategy formulation activities, management aggregate control activities and task control activities.

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. (Kostic, 2003) indicates that AM activities are considered to be envisaged under three categories. In support of this view, Sinha, *et al*. (2007), state that the enterprise AM system forms integrated activities in management processes in a utility business.

The Asset Management Council (2007) in Australia derived an AM model based on Plan-Do-Check-Act process (Tague, 1995; Gupta, 2006; Moen and Norman, 2011) and the control management cycle for continuous improvement (ISO 9001, 2008; Anderson, 2011). The framework in Figure 1 has been derived based on the nature of the asset-related activities. The idea of the AM control cycle is similar in these models. This framework sets out the organizational levels, 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 activities of the AM system through the management levels. Each asset-related activity will have an iterative planning and control process acting on it. Through these activities at the three levels and with feed-forward & feedback mechanisms, the framework proposes that AM plays a role in strategy development and implementation.

This notion of having an AM system as a collaborative control system that exists over the organizational levels leads to an integration within the enterprise system. El-Akruti (2012, pp. 72, Figure 3.8) developed an AM system functional model that offers this perspective in terms of relationships between asset-related activities, control activities and the boundary between the system and its external environment. This system functional model is developed based on the widely used production model given by Hunger (1995). However, this model includes categories of life cycle activities and supporting activities as found in the value chain framework, and the life cycle framework presented by Blanchard (2009).

3. Research Approach

The approach adopted is based on the ideas of the contextualist methodology in case study given by El-Akruti and Dwight (2010). It uses a retroductive research strategy to explore the complicated processes in the case study to facilitate theory building (Ragin and Becker, 1992). The research design uses the hypothesized system model as shown in Figure 2. In this approach, cases are defined by identifying strategy events to which the asset-related solutions respond. Each AM-related solution has to be defined and must be examined according to the sequence of the phenomenon represented by elements 1-to-4. This involves identifying the strategy event, defining the asset solution and its provision, determining the asset performance and outcomes related to the strategy.

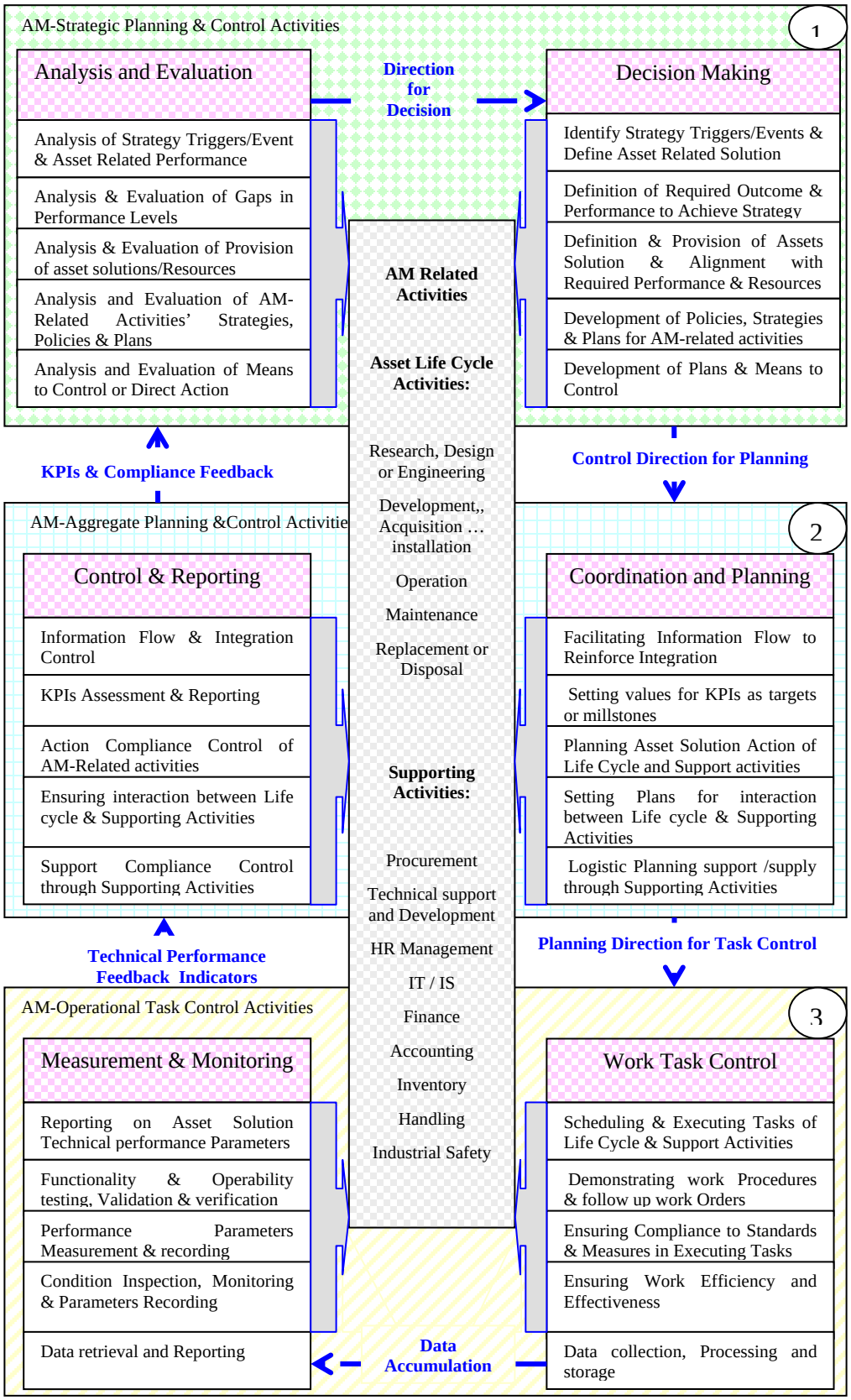

Fig. 1. Framework of AM System Activities, Relationships & Mechanism (El-Akruti 2012).

Element 5 in Figure 2, presents the control over the process of events. In this process, the required asset solution or solutions is established for any triggered strategy related event or change. The management behaviour related to the asset-related activities and the resulting asset performance can be assessed. This involves mapping the elements of the AM framework against the actions undertaken in actual practice and linking the adopted AM actions to existence or adequacy and/or absence or inadequacy of activities and relationship as proposed by the framework.

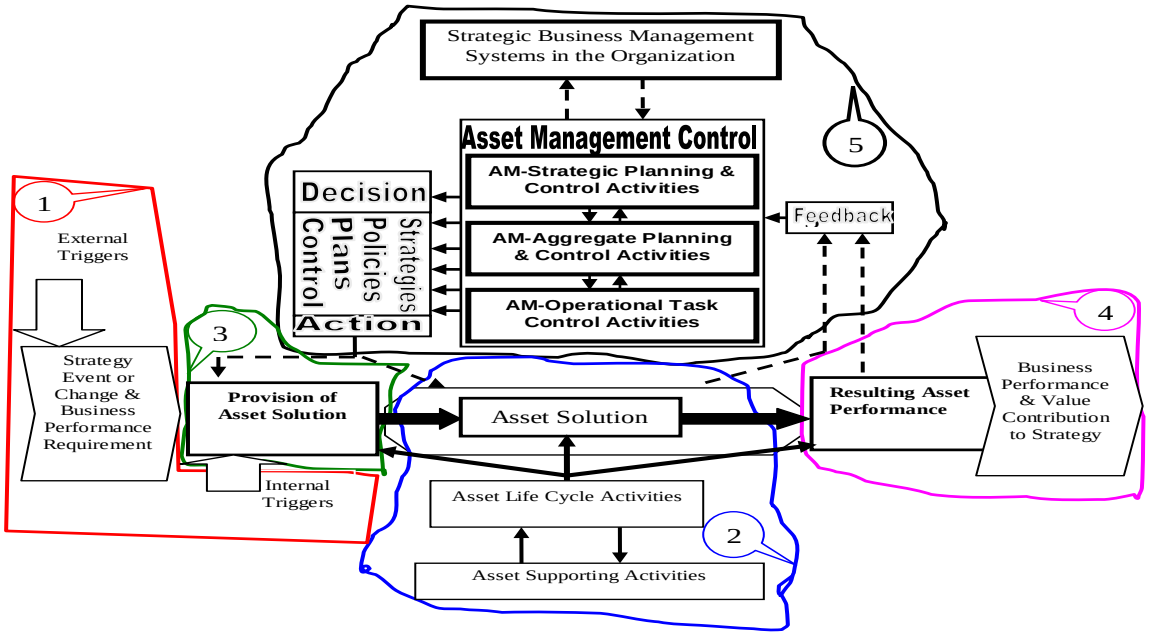

Fig. 2. Five elements of the hypothesized model.

4. Identification of Cases

An un-named company was selected with a large number of manufacturing plants and a working capital of about 1.3 billion US dollars. Over the preceding years, the company instigated improvements in quality management and therefore evidence of events or changes is expected.

In order to identify suitable cases, 25 company employees were interviewed and various documents reviewed. The strength of the findings rely on multiple sources of evidence: in-depth investigation by interviewing is done together with study on the archived records, website, newsletter, asset life history, manuals, financial activities, performance and contracts.

The asset managers stated clearly that many projects had been done and actions were taken in response to strategy changes. Two specific 'strategy events' were selected as a result of the actions taken to end up with a summary of two cases.

5. Analysis and Interpretation of Two Cases

5.1 Case 1 – Establishment of a new production module

5.1.1 Stage 1 – Establishing the phenomenon

a. **Establish the Asset solution in Response to a Strategy Event**

Case-1 is summarised in Table 1. Interviews indicated that the two projects were undertaken in response to the mission of growth to gain a better position in the international market by increasing and diversifying products. It is also indicated in the quality manual that the policy of the ministry was to make the industrial sector become a major contributor to the economy.

Table 1 Case 1 as a Strategy Event

Strategy Event	Asset Solution	Intended Contribution	
Diversifying Products for entering competition in international markets and covering local demand	Development Projects	New Products	Quantity (Tons)
	Hot-Briquetted Iron HBI Module	HBI	650,000
	Galvanizing and Coating Production Line (G&C Line)	galvanized & coated coils & sheets	Galvanized (80,000) and Coated (40000)

b. **Establishing Indication of Provision Actions**

With reference to interviews held with managers in charge of flat mills, there were many problems encountered in the commissioning stage of the *G&C Line*. Managers explained that when starting operations it was not anticipated that the coils had to be unwound and then re-wound before use in these lines, which necessitated introducing a process for preparing the coils for use, resulting in extra capital cost and caused major delays in starting the operation. The decision was taken individually by the chief executive and integration of this new project with existing plants was overlooked. The supplier was selected based on low initial capital cost. It was not clear from the contracting documents whether the supplier or the company did not provide information to avoid this problem. The marketing manager indicated that the feasibility study done by the foreign consultant showed that this *G&C Line* was an opportunity to supply part of the demand in Europe. However, the company failed to provide the proper asset solution as a response to this market trigger. In contrast to the *G&C Line*, managers indicated that a contract was signed for the HBI module with the same supplier that previously implemented similar modules at the establishment of the company. As a result, this supplier knew exactly what was required for the integration. Indications of this asset solution provision are in Table 2.

c. **Establishing Indications of Resulting Performance, Outcome and Contribution**

In most of the interview transcripts, there are indications that the HBI module performed well with positive contribution but the *G&C Line* performed badly with negative contribution to organisation strategy. This is confirmed by performance indicators in the company records over the years. Relevant indicators have been extracted from records: for HBI module these reflect high performance and positive impact on business outcomes as shown in Figure 3 but those for the *G&C Line* reflect poor performance and negative impact on the business objectives as shown in Figure 4.

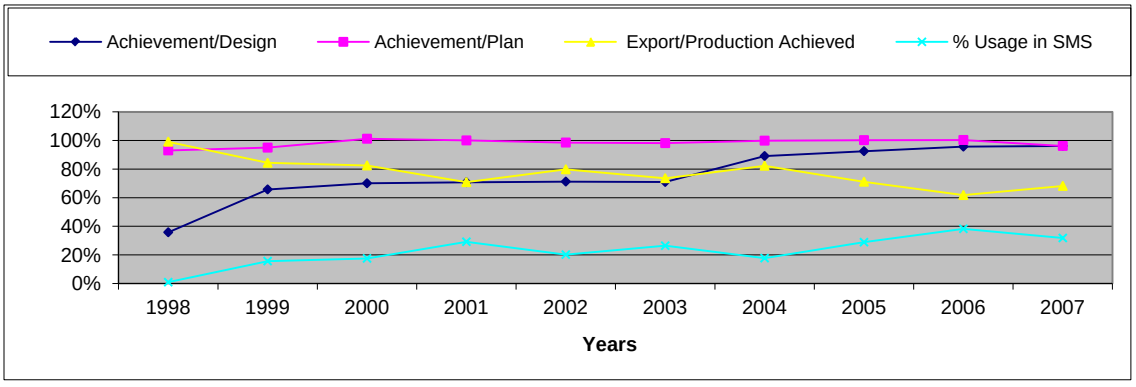

Fig. 3. Percentage of HBI Module Achievement Indicators over the years.

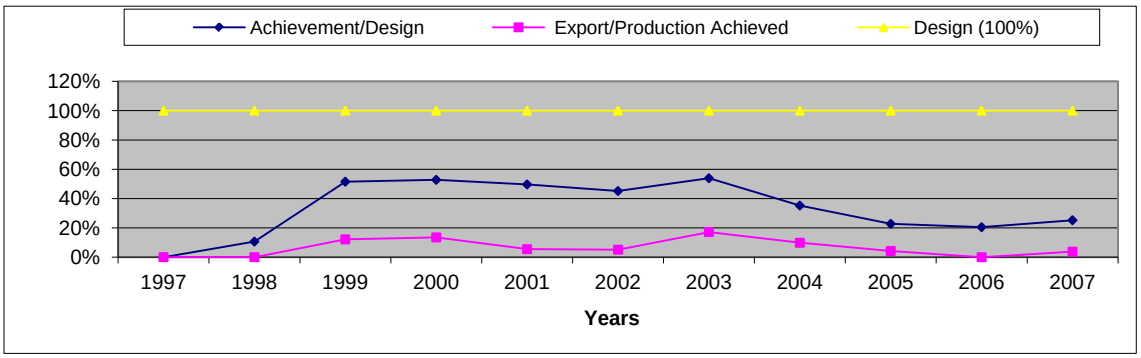

Fig. 4. Percentage of G&C Line Achievement Indicators.

Table 2 Resulting Asset Solution Provision and its Indications for Case 1

Asset solution	Provision of asset solution and its Indicators
Development Of new Galvanizing and Coating Line (G&C Line)	▪ Intended to add new products: galvanized and coated coils and sheets. ▪ The provision involved deciding on the required increase in capacity, selecting supplier, making contract and following up on implementation. ▪ The provision was done through outsourcing the design. ▪ Implementation was supervised by ad hoc project team ▪ Supplier had problems with compliance to requirement. ▪ Project was not delivered on time, unsuccessful commissioning. ▪ There were design integration problems resulting in unfit input coils. ▪ Problem in construction caused stoppage of operation and reconstruction.
Development Of a Hot-Briquetted Iron (HBI) Module	▪ Intended to add HBI as a new product. ▪ The provision involved deciding on the required increase in capacity, selecting supplier, making contract, and following up on implementation. ▪ The provision was done through outsourcing design. ▪ Implementation was supervised by ad hoc project team ▪ Supplier complied to requirement because of familiarity with existing company assets and plants. ▪ Project was delivered on time and successfully commissioned.

Many interviewees considered the *G&C Line* unfit for the strategy and a complete disaster. A summary of these resulting asset performance indicators is presented in Table 3.

The *G&C Line* experienced provision problems that resulted in low performance during utilization that impacted on the business outcome as low quantities of exports. Hot-Briquetted Iron (HBI) reflected a positive impact on the business objectives. The business performance and value contribution relative to case 1 can be summarized as shown in Table 4.

Table 3 Asset Performance and its Resulting Indicators for Case 1

Asset solution	Indications of resulting asset performance
Development of Galvanizing and Coating Line (G&C Line)	▪ Intended for introducing new products. ▪ Resulting in long stoppage of operation due to reconstruction. ▪ Resulting in low utilization rate. ▪ Achieving less than 50% of its production capacity. ▪ Experiencing shortage in input coils. ▪ Resulting in high production stoppages. ▪ Resulting in high production cost and high product unit cost. ▪ Economically became short of covering its fixed cost.
Development of a Hot-Briquetted Iron (HBI) Module	▪ Intended for introducing a new product. ▪ Resulting in high availability and utilization rate. ▪ Resulting in low stoppages and delays. ▪ Resulting in high productivity, reliability and production rate. ▪ Resulting in high product quality and export quantities.

Table 4 Resulting Business Outcome and Value Contribution to Strategy for Case 1

Asset solution	Business Outcome Indicators	Value Contribution Indicators
Development Of a Hot-Briquetted Iron (HBI) Module	▪ High achievement rate ▪ Low product unit cost ▪ High export quantities ▪ High revenues ▪ High profitability ▪ High quality products ▪ Customer satisfaction.	▪ Intended contribution was to enter new markets with new products that have competitive quality. ▪ Positive resulting contribution: became a major export (over 50% of company export). ▪ Financial gains: increased exports, revenues and profitability, increased market share and enhanced the good reputation.
Development Of a new Galvanizing and Coating Line (G&C Line)	▪ Low production rate: only less than 50% of design capacity is achieved ▪ High product unit cost ▪ Unable to cover fixed cost ▪ Cancelation of orders ▪ Low export quantities ▪ Customer dissatisfaction	▪ Intended contribution was to enter new markets with new products that have competitive quality and price. ▪ Negative resulting contribution: have not contributed to increasing export, financial losses, could not payback its capital cost, and became a burden on the company. ▪ Caused loss of opportunity to gain more share in international market

5.1.2 Stage 2 - Drawing Implications from the Phenomena

a. Mapping and Interpretation of Status of Activities

Evidence of the status of activities has been established by investigating records and data extracted from interviews with relevant managers. Actions were mapped relative to activities at the three organisational levels. The mapped strategic activities in Table 5 imply that the inadequacy of the AM system strategic planning and control activities resulted in inadequate specification of requirement for new assets, lack of determination of priorities, technical capabilities and design, and lack of integration of new assets with existing facilities. This is evident from the analysis and evaluation relative to requirement in the case of the *G&C Line*.

The decisions to adopt *G&C Line* or HBI projects were business driven and lacked technical consideration. The chief executive contracted a foreign consultant to do a research study to decide on a possible expansion to produce new products and enter the international market. According to many managers, the study was focused on what products should be introduced but overlooked the internal capability factors: it provided inadequate information on the integration of new assets with existing assets for technical capability.

The managers of existing assets were not involved in selecting suppliers or in setting the contracts. Therefore, the decision was taken without considering AM or consulting the managers of existing assets on the overall development priorities in the organisation, integration with existing assets, or their requirements.

Missing the analysis and evaluation for these actions in this case confirms the inadequacy of a critical part of the strategic planning and control activities proposed in the hypothesised framework. That these strategic activities were lacking was made evident by the production director and marketing manager. According to them, this inadequacy has led to the problem in the implementation of the G&C Line by resulting in a lack of coordination between supplier and implementation team due to inadequate contracting, incomplete information and lack of expertise of team members.

b. Mapping and Interpretation of Status of Relationships with Strategy

Evidences from company records and interview transcripts summarized in Table 6, indicate an absence of interaction between the asset managers and strategic decision makers proposed by the framework. This interaction was missing the required analysis and evaluation to provide feed-forward to support the decision. It was also evident from replies that if the analysis and evaluation activities existed, better alternatives could have been considered.

Although the evaluation and analysis activities were missing at the time, it is essential to determine what action led to a disaster in the G&C line and a success in the HBI module. The reason given by quality control manager was probably luck to contract with the same supplier of existing DR modules. Most managers did not say why or how the same supplier was selected but that the selection did make a difference. They also stated that the HBI module was similar to those old modules and the ad hoc team had experience with those similar modules. Furthermore, one of the project implementation supervisors stated that this HBI model was easy to integrate with existing facilities. It did not depend on input from other plants therefore integrating and fitting it to the old modules and supporting facilities or services was easy in addition to having the same supplier of the old modules.

Table 5 Mapping the AM System Planning and Control Activities Related to Case 1

Elements of Framework (Figure 1)	Status	Indication of Action and/or Resulting Outcome
Analysis and Evaluation	Absent	▪ No real analysis to define needs of new assets. ▪ No real evaluation to determine priorities, capabilities, design and integration of new assets with existing facilities. ▪ Inadequate analysis and evaluation of requirement in the case of the *G&C Line* resulted in poor performance that led to losses and lack of meeting the intended strategy. ▪ The selection of a supplier familiar with existing context in the case of HBI module served as a substitution for analysis and evaluation activities on the organisation side.
Decision Making	Inadequate	▪ Decisions were business driven and lack of technical consideration. ▪ Decisions were based on CEO's expertise and did not involve asset managers. ▪ Decisions to adopt G&C Line or HBI projects did not consider priorities, technical designs and capabilities for new asset or project selection and integration with existing assets and facilities.
Coordination and Planning	Exist/ Inadequate	▪ Existed at the aggregate level for implementation of projects. ▪ Handled manually by project teams that lacked expertise and experience. ▪ Inadequate planning and coordination with suppliers played a part in resulting problems during project implementation. ▪ Adequate coordination and planning for sales, operation and maintenance existed in terms of well managed departments.
Work Task Control	Exist/ Inadequate	▪ Operational work tasks control adequately existed, *e.g.*, operation and maintenance departments were well managed in terms of control and execution of tasks in general. ▪ The construction defects associated with G&C Line project indicate lack of task control and supervision. ▪ Inadequate task control and supervision of projects is due to lack of expertise of team members. ▪ That data accumulation was mostly manual or semi manual led to poor linking mechanism.
Measurement and Monitoring	Exist	▪ Data gathered in shift reports presented indicators for weekly reports. ▪ Many measured parameters but mostly lagging indicators reported.
Control and Reporting	Exist	▪ The submitted reports through different stages of the projects indicated the existence of adequate reporting on indicators and compliance to plans. ▪ Reporting was done manually or semi manually.

Table 6 Mapping the AM System Strategic Relationships Related to Case 1

Elements of Framework (Figure 1)	Status	Indication of Action and/or Resulting Outcome
Identification of Strategy Triggers and Definition of Strategy Event/Change	Inadequate	▪ The analysis and evaluation to identify strategy events and relate them to asset requirement or performance were missing. ▪ Market studies were outsourced to foreign consultants that did not consider local market factors. ▪ Less consideration of local market demand increase than export and improper forecasting of such increase. ▪ Overlooking the priority of local demand increase over export.
Definition of the Required Outcome and Asset Performance to Achieve Strategy	Inadequate	▪ The analysis and evaluation to define the required asset, its performance, business output and requirement were missing. ▪ Definition of required business outcomes focused on export and overlooked local demand. ▪ Inadequate definition of asset requirement to cope with the business outcomes. ▪ Inadequate definition of long run requirement ▪ Inadequate definition of life cycle cost requirement. ▪ The evidence that the requirement for integration with existing assets was overlooked. ▪ Lack of interaction between AM and business management led to a G&C Line project that failed to achieve targets. ▪ Resulting in problems associated with G&C Line's input coils. ▪ The G&C Line contributed negatively toward strategy. ▪ Resulting in high losses, high costs, delays and cancelation of customers' orders, low customer satisfaction, less competitive and consequently damaging the reputation of the company.
Definition and Provision of Assets Solution and Alignment with Required Performance and Resources	Inadequate	▪ Proper activities to contract, acquire, deploy and install assets were missing. ▪ Inadequate provision led to failure to meet the set targets. ▪ Asset requirements were overlooked. ▪ Inadequate contracting terms and clear documentation has resulted in unclear supplier responsibilities. ▪ Implementation of G&C Line project resulted in problems. ▪ Implementation problems of G&C Line project impacted on business outcomes and had negative contribution to strategy. ▪ For the HBI module project, a selection of a familiar supplier with existing assets led to its successful implementation.
Setting Strategies, Policies, Targets and Aggregate Plans	Exist/ Inadequate	▪ No clear policies or strategies for assets acquisition. ▪ Inadequate experience of setting strategies and adopting plans for supervision of projects' implementation. ▪ Adequate operation and maintenance strategies or plans existed.

In summary, the right decision-making to purchase and install the HBI module is ascribed to the followings:

1) The decision was based on the right prediction of the market need or demand.
2) Being a single business unit supplying its output directly to the international market minimised the interfaces and so the need for integration with the rest of the existing facilities.
3) Selecting the same supplier of the two older modules provided familiarity and capability to avoid any problem in design or integration with other facilities.
4) Selecting a project team familiar with the older modules helped to maintain successful implementation and utilization.

For *G&C Line,* the indicators have shown that it was a disaster because it had a negative impact on the organisation's ability to achieve its strategic objectives and affected their reputation with customers. From the interpretation of the decision, provision, and results of the *G&C Line* project, it is concluded that the company lacked those evaluation and analysis activities to establish the right decision relative to alternative investments, indeed most decisions were based on minimum capital cost only, and overlooked the other life cycle costs. Missing expertise and experience and lack of allocating responsibility of the AM activities led to absence or inadequacy of evaluation and analysis activities, and interaction with strategic planning which resulted in an inadequate provision and implementation reflected in terms of:

1) Selecting a supplier based only on low capital cost due to lack of analysis and evaluation.
2) Lack of proper contracting procedure due to lack of experience.
3) Lack of expertise in supervising and coordinating the project.

An overall conclusion regarding the strategic role of AM can be made from the results of Case 1 as follows. The absence or inadequacy of proper AM system activities and relationships conflicts with the strategy and results in an inadequate performance and outcome that cannot fulfil to achieve the organisational strategy or the competitiveness.

5.2 Case 2 – Replacement & repair optimisation of assets

5.2.1 Stage 1 – Establishing the phenomenon

a. Establish the Asset solution in Response to a Strategy Event

Case-2 is a set of asset solutions as responses for continuous improvement strategy. These solutions aimed at optimised performance to enhance customer value and remain competitiveness. The strategy event and asset solutions for Case 2 are summarized in Table 7.

Table 7 Strategy Event and Asset Solutions for Case 2

(1) Strategy Event	(2) Asset solutions
The strategy of optimizing performance to achieve competitive quality, quantity and unit cost of products and sustain profitability.	EAF lining replacement and repair optimization
	Introduction of the ladle furnace.
	Replacement of cooling rolls in continuous casting

b. Establishing Indication of Provision Actions

The resulting asset solution provisions and its indications are summarized in Table 8. These solutions established decision criteria based on analysis and evaluation done by the technical support and development to optimize life cycle cost of specific assets. For example, Figures 5 and 6, show the analysis that determined the criteria for optimising replacement and frequency of hot repair for one lining supplier. This department was able to analyse the alternatives and performance data and conducted cost and benefit analysis to introduce the ladle furnace and replace the external cooling rolls in the continuous casting as evidenced in Table 8. These solutions represent the evaluation and analysis that provided a view on the economics of repair and replacement for decision making.

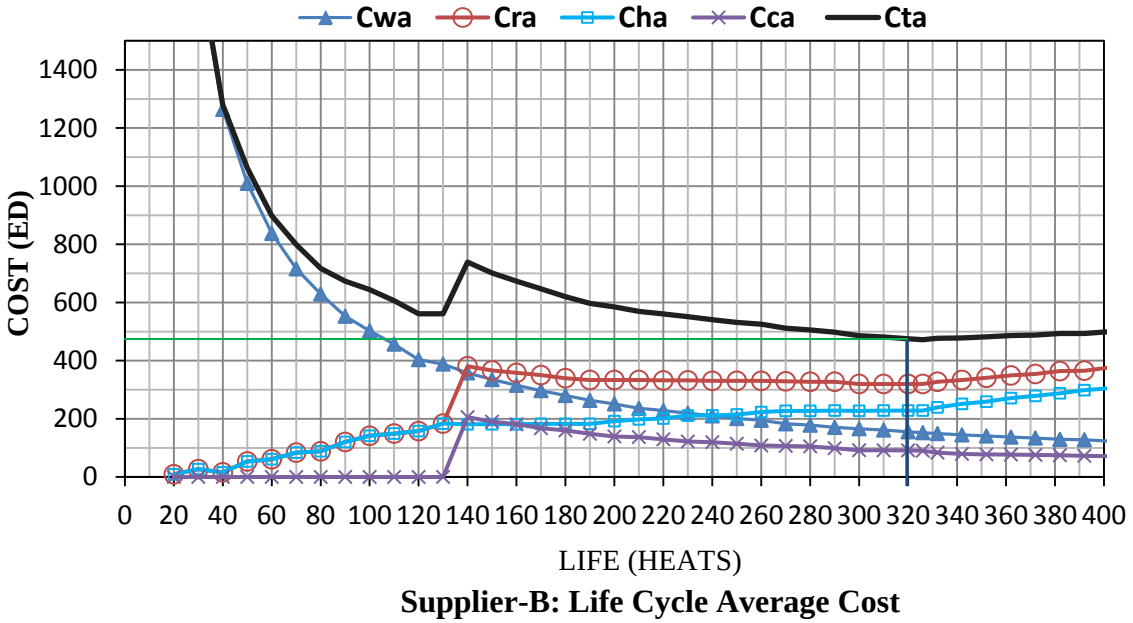

Fig. 5. Determining the Optimum replacement (Technical Support and Development Department Records).

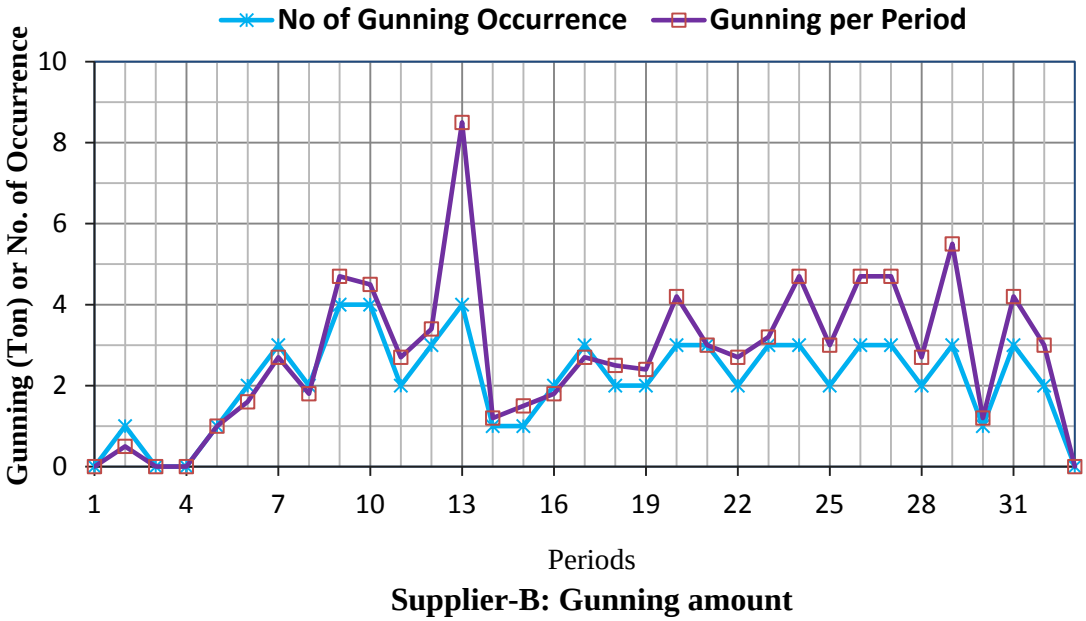

Fig. 6. The Hot Repair Sequence (Technical Support and Development Department Records).

Table 8 Resulting Asset Solution Provision Indicators for Case 2

Asset Solution	Asset Solution Provision Indicators
Replacement and repair optimization modelling of EAF refractory lining	▪ The provision of this solution involved undertaking the research in conjunction with a university to develop the model based on the working lining life cycle cost. ▪ It involved determining optimum working lining replacement time, critical repair sequence and optimum repair limits and optimum material supplier. ▪ It involved determining a clear procedure to follow for the application of models for optimum replacement, repair and supplier lining material selection. ▪ It involved estimating the value lost due to repair or replacement stoppages. ▪ It involved application of the models for achieving optimum performance.
Development in terms of introducing the ladle furnace in 2001	▪ The provision of this solution involved undertaking the study by the technical support and development department in coordination with the Steel Melt Shops departments to decide on the development of the ladle furnace and its acquisition and installation. ▪ The study involved comparing the benefit and cost of introducing the ladle furnace under the existing and expected operation conditions. ▪ The outcome of the study advised introducing the ladle furnace. ▪ The provision also involved selecting supplier, making contract and following up on implementation, commissioning, operation and maintenance.
Development in terms of replacing external cooling rolls by internal cooling rolls in the continuous casting in 2001	▪ The provision of this solution involved undertaking the study by the technical support and development department in coordination with the Steel Melt Shops departments to decide on the replacement. ▪ The study involved comparing the benefit and cost of both types under the existing and expected operation conditions. ▪ The outcome of the study advised replacement of external cooling rolls by internal cooling rolls. ▪ These internal cooling rolls were purchased and installed in place of the external cooling ones.

c. Establishing Indications of Resulting Performance, Outcome and Contribution

These indicators evidence that the introduction and application of these solutions enhanced performance in the following aspects:

1. Increased availability, reliability, and productivity of the EAF, including a reduction in stoppages for replacement and repair by application of the developed lining replacement model. This resulted in savings, values and criteria as presented in Table 9.
2. Eliminated pour-backs leading to a better process yield, reduced delays in casting, energy, time, and utilities, and increased the quality of billets, blooms, and slabs by introducing the ladle furnace.
3. Provided better control and helped produce more precise steel grades/alloys leading to better final products quality by replacing those external cooling rolls by internal cooling ones. Example of the

related benefit is due to improved yield from 85%, 86% to 92%, 95%, respectively, for the two production lines.

Table 9 Optimum Performance Indications (Technical support and development department records) (El-Akruti 1999)

Parameter	**Unit**	Material Suppliers		
		Supplier-A	Supplier-B	Supplier-C
Replacement Cost	$	175,490	161,614	152,613
Cold Repair Cost	$	91,446	91,446	91,446
Maximum Gunning	Ton	5.20	6.0	5.50
Hot Repair Period Length	Heats	10	10	10
Max. Hot Repair Cost per Period	$	13,682	14,007	15,907
Optim. EAF Working Lining Life	Heats	278	319	229
Cold Repair Limit	Heats	120-to-130	110-to-120	80-to-90
Cold Repair Actual Application	---	Not Feasible	Feasible	Feasible
Total Cost per Heat (Cta)	$	1,426	1,544	1,652
Total Cost per Ton of Liquid Steel	$	15.6	16.8	16.8
Expense in Terms of Use	---	Cheapest	Moderate	Most Expensive
Priority for Use	---	First	Second	Third
Optimum Life Achievement	---	Always achieved, or overpassed	Rarely achieved but close to	Never achieved and much less
Priority of Safety Base on Optimum Life Achievement	---	Highly safe since it overpass	Moderately safe since it is close to	Low safety since it never reaches
Total Annual Cost based on use of each suppliers material alone	$	5,436,058	5,887,760	6,298,710

Matrix for Annual Savings or Losses based on Optimum Life Criteria of one EAF			
Material Supplier	Supplier-A	Supplier-B	Supplier-C
Supplier-A	--------	-$451,703	-$862,653
Supplier-B	$862,653	--------	-$410,950
Supplier-C	$862,653	$410,950	--------
Result by Comparing Actual life to Optimum Life	High Savings by not overpassing optimum life	Almost zero losses by being close to achieving optimum life	High losses because optimum life is usually not achieved

The asset performance and its resulting indicators are summarized in Table 10. The business outcome and customer value contribution in this case as summarized in Table 11 is an outcome from asset performance.

Table 10 Asset Performance and its Resulting Indicators for Case 2

Asset solution	Indications of resulting asset performance
Replacement and repair optimization modelling of EAF refractory lining	▪ Improvement in performance of EAF by applying the model. ▪ Increasing EAF availability by minimizing repair and replacement time. ▪ Increasing EAF reliability by determining critical repair sequence. ▪ Increasing productivity as a result of higher availability and reliability. ▪ Reducing cost and stoppages for replacement and repair and increasing the production rate. ▪ Resulting in optimum refractory lining life cycle leading to higher availability and utilization and lowering refractory lining life cycle cost by 10% to15%.
Development in terms of introducing the ladle furnace	▪ Facilitated heating within the ladle to keep temperature of liquid steel as required for continuous casting. ▪ Led to better control of quality and achieving more precise steel grades/alloys. ▪ Provided the ability to sustain the temperature at the suitable level for casting and eliminated pour backs. ▪ Reduced process losses such as energy, time, logistics and yield losses. ▪ Enhanced product quality, increased productivity and reduced process losses and resulting in lower cost.
Development in terms of replacing external cooling rolls by internal cooling rolls in the continuous casting	▪ Helped overcome the formation of scales on slaps in steel melt shop 2 and on billets or blooms in steel melt shop 2. ▪ Eliminated those stoppages due to adjustment of the water cooling rate to keep uniform surface cooling of those external cooling rolls. ▪ Resulted in achieving a smother rolling in the down-stream processes of flat mills or long mills due to scales elimination. ▪ Resulted in enhancing the utilization in the rolling processes leading to higher productivity, better final products quality and less processes stoppage or breakdown.

5.2.2 Stage 2 - Drawing Implications from the Phenomena

a. Mapping and Interpretation of Status of Activities

Evidence of the status of the AM system activities at the strategic level is set out in Table 12. For all three solutions of this case as shown in Table 9, the analysis was coordinated between the technical support and development department and the operation and maintenance departments of the steel melt shops. For all the three solutions, the technical support and development department assisted in the analysis and decision regarding the selection and adoption of these solutions.

It is obvious that the strategic planning and control activities existed as a result of coordination between these departments and provided a means for conducting analysis and evaluation activities that helped make AM decisions related to development, maintenance, and operation practice.

Table 11 Resulting Business Outcome and Value Contribution to Strategy for Case 2

Asset solution	Business Performance and Value Contribution Indicators
Replacement and repair optimization modelling of EAF refractory lining	▪ A better business outcome is achieved as a result of applying this model. ▪ A lower liquid steel unit cost was achieved as a result of: optimum lining life cycle cost while maintaining high availability, reliability and utilization. ▪ The better asset performance contributed to increasing the production, the quantity and quality of final products and lowering cost of all final products. ▪ A 10% to 15% saving in the lining life cycle cost. ▪ Resulted in competitive prices of products and higher profit margin.
Development in terms of introducing the ladle furnace	▪ Introducing a ladle furnace resulted in better business outcomes. ▪ Eliminated pour backs and many other process losses that led to higher productivity, more production and lower product unit cost. ▪ Facilitated better control that enhanced final products quality. ▪ Resulted in a positive contribution by obtaining more precise steel alloys. ▪ Contributed to lowering unit cost of all products and enhancing quality. ▪ Contributed to better products quality and gaining more competitive prices of products or higher profit margin and maintaining a competitive position.
Development in terms of replacing external cooling rolls by internal cooling rolls in the continuous casting	▪ This replacement resulted in better business outcomes. ▪ Resulted in reduced maintenance and replacement cost in steel melt shops. ▪ Enhanced utilisation in the rolling processes leading to better quality. ▪ Resulted in a better quality slabs or billets produced. ▪ Contributed to increasing final products' quality, quantity & lower unit cost. ▪ Contributed to better products quality and gaining more competitive prices of products or higher profit margin and maintaining a competitive position.

It is also evident that analysis and evaluation as part of the AM strategic planning and control activities as proposed by the framework served the organisation strategy. The coordination between the technical support and development department and maintenance, operations and qualitydepartments served the selection and adoption of asset solutions to support many initiatives and resolve operation and maintenance problems.

As set out in Table 12 and 13, the existence of these AM system activities served in maintaining relationships, better suited maintenance and operation strategies, confidence in production and maintenance planning and reporting on those key performance or compliance indicators.

b. **Status of AM System Relationships with Strategy**

From Table 13, it is clear that the relationships in the AM system with the strategic management are enhanced by the analysis and evaluation activity provided through the coordination between the technical support and development department and other departments and that this enhancement contributed to the organisation's success.

Table 12 Mapping AM System Activities Relative to Case 2

Elements of Framework (Figure 1)	Status	Indication of Action and/or Resulting Outcome
Analysis and Evaluation	Exist	▪ The establishment of the technical support and development department one year prior to this event served in providing the required analysis and evaluation for selecting and adopting the proper asset solutions that improved performance to meet strategy.
Decision Making	Adequate	▪ Due to the existence of appropriate analysis and evaluation by the technical support and development department, decisions in this case were adequately taken.
Coordination and Planning	Exist/ Adequate	▪ The coordination and planning activities were adequate among technical support and development, maintenance and operation. ▪ All requirements for analysis and evaluation were. ▪ Operation and maintenance coordination and planning existed in terms of well managed departmental procedures.
Work Task Control	Exist/ Adequate	▪ Operational work tasks control adequately existed. ▪ Operation and maintenance tasks were well managed. ▪ Data accumulation was mostly manual or semi manual.
Measurement and Monitoring	Exist	▪ Data gathered in shifts presented indicators for weekly reports. ▪ Technical performance measurement indicators established. ▪ Many measured Indicators but mostly lagging Indicators. ▪ Condition monitoring was limited to time based inspection.
Control and Reporting	Exist	▪ The performance reports are periodically produced. ▪ There is existence of adequate reporting on compliance to plans. ▪ Reporting is mostly manual and focused on lagging indicators.

With respect to this case, the benchmarking showed that the company had higher production costs than its competitors. This realisation led the company to improving its performance. Objectives were set to reduce unit costs below those of its competitors while sustaining quality leadership. Therefore, the company had to find new methods of minimizing its production costs while maintaining the high quality of its products. The first steps taken to minimise production costs focused on the melting process in steel melt shops because it was thought to be a major cost contributors for all the products. The matter was allocated to the new established technical support and development department, which has done the analysis in coordination with the related departments in the steel melt shops.

It is concluded that two of the three solutions in Case 2, improved performance and contributed positively to the organisation strategy achievement. This confirms that the independent AM control between decision making, solution provision and the resulting performance of asset-related activities has an effect on strategy achievement. The results from these three solutions also imply that the life

cycle cost is essential for AM control in considering the inter-dependence of asset-related activities along the life cycle stages.

Table 13 Mapping the AM System Relationships Related to Case 2

Elements of Framework (Figure 1)	Status	Indication of Action and/or Resulting Outcome
Identification of Strategy Triggers and Definition of Strategy Event/Change	Exist/ Adequate	▪ Benchmarking studies done by the technical support and development department helped identify many triggers. ▪ Benchmarking defined higher than competitors costs. ▪ Reviewing available technology served to identify solutions.
Definition of the Required Outcome and to Achieve Strategy	Exist/ Adequate	▪ Benchmarking analysis helped define required outcomes. ▪ Analysis by the technical support and development department provided the link between AM and business management. ▪ Analysis resulted in defining requirement for appropriate decisions such as the life cycle cost analysis. ▪ The resulting performance improvement indicates that it was as targeted and that it had positive impacts on the strategy. ▪ All three solutions contributed to the strategy by optimization: minimum cost, maximum production & sustainable quality.
Definition and Provision of Assets Solution and Alignment with Required Performance and Resources	Adequate	▪ All three solutions were provided based on coordination between relevant departments and proper analysis. ▪ The EAF model as a solution was developed based on research done in association with a local university. ▪ Implementation of solutions was successful, shared by operation, maintenance and in coordination with technical support and development.
Setting Strategies, Policies, Business Targets and Aggregate Planning	Exist	▪ These solutions changed the operation, maintenance and replacement strategies in steel melt shops. ▪ Implementation strategies of these solutions were coordinated between departments. ▪ These solutions served in coping with business targets. ▪ Annual business, production and maintenance plans were made based on business targets.

6. Overall Findings from the Two Cases

Overall, having the AM activities in place as proposed by the framework and managing the inter-relationships between asset-related activities for decisions related to development, performance, strategic planning are of essential requirements for success. The role of these AM strategic planning

and control activities is critical to achieve any production or quality improvement strategy for the organisation to compete successfully.

Case 1 and 2 show that the existence of proper AM system activities and relationships result in an adequate asset performance and business outcomes to achieve the organisation's strategic goals.

For case 1, the poor results are indications of absence or inadequacy of those proper AM activities proposed by the framework. In this case, handling the implementation of G&C Line by ad hoc teams and the resulted commissioning problems are evident of the absence of those AM activities proposed by the framework. This is reasonable because the company introduced some of these missing activities by establishing new departments later on: a technical support and development department was established a year after implementing these projects and an industrial research centre was established seven years later.

For case 2, it is evident that the introduced technical support and development department took the responsibility for analysis and evaluation in deciding the selection, design and implementation of the three solutions. Specifically, the technical support and development department provided the activities to undertake evaluation and analysis related to research, engineering design, and modelling. The technical support and development manager confirmed that the company established this department to overcome deficiencies experienced in the past as some of them are evident in Case 1.

From these cases, it can be elicited that the absence of technical support activities has led to inadequate strategic planning and control activities of AM system. The role played by the responsible departments was important in the recent development projects studied as part of the overall research. For example, according to records, the introduced technical support department and research centre have guaranteed the technical support for any further expansion in the production facilities and expansion in the upstream facilities and supporting facilities.

It is concluded that the introduction of these departments reflects the recognition of their responsibility of the AM system activities for achieving the organisation's strategic goals by doing the asset development projects.

7. Conclusion

An AM framework is proposed in this paper that described the role of AM system activities in strategic decision-making. Although the linkage between the enterprise strategy and AM activities is suggested to exist previously, this framework is a reflection of the AM system elements required for proper strategy making. It provides a more AM-oriented, systematic and holistic approach to analyse activities, relationships and mechanisms that constitute the linkage between AM and strategy. In this paper, emphasis is directed toward utilizing this framework to provide evidence of the role of AM in strategy making as discussed thoroughly in the analysed case studies. The case studies highlighted that the effect of inadequate or missing elements of the framework can result in negative impacts on cost, productivity and quality and ultimately business outcomes.

AM as defined by the hypothesized framework has a key role to play in strategy development and implementation. This strategic role is maintained based on planning and control of the asset-related activities. This planning and control mechanism is provided as a framework that explains how the AM activities, relationships and mechanism account for the interdependence between the asset-related activities and lead toward successful strategy achievement. The case supports the proposition that in managing the interrelationships between asset-related activities, the adequate existence of AM activities, relationships and mechanism as proposed by the framework is an essential requirement for success. This AM planning and control mechanism is critical to achieving an organization's strategy. In

addition, inadequacies in one activity represented in the framework can result in other AM activities being inadequate and resulting in unsuccessful strategy.

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