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The strategic role of engineering asset management in capital intensive organisations

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The Strategic Role of Engineering Asset Management in Capital Intensive Organisations

by

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THESIS CERTIFICATION

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person except where due acknowledgment is made in this thesis. Any contribution or assistance from others in the project design, conception or in style, presentation and linguistic expression is acknowledged.

Signed ……

Date …….

Thesis Dedication

To my loving mother and beloved father

For guiding me with great wisdom

And

To my wife and children

For their patience and enduring emotional support

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I would like to acknowledge the following contributions:

I am grateful to all individuals from the case study organisation for their contribution and support. The major contribution to this research study has come from the case study organisation and its staff who participated in the field work study. Without their generous support in terms of time, availability and willingness to share their experiences and other information, a study of this nature would have been less exciting and useful.

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ABSTRACT

Engineering Asset Management (AM) in capital intensive industries is argued part of an organisation's management system with a role in competitive strategy development and implementation. While the AM system has an influential impact on the asset life cycle, little has been done in literature on its formation or link to organisational strategy. This thesis aims at further understanding the strategic role of the AM system. It begins by reviewing literature on the nature of this system and the compatible research methodologies associated with such a discipline. The AM system is socio-technical and interdisciplinary by nature so a retroductive case study methodology was adopted because its use of a hypothesised framework allows the development of the understanding of complex relationships. Next, a review of AM models or frameworks, and links to its organisational strategy was carried out and possible existing AM system activities, mechanisms and relationships were also explored.

This thesis proposes a holistic framework for the AM system so that managers in capital intensive organisations can better understand how to manage asset lifecycles and deal with its stages in practice. The framework highlights the role of an AM system during organisational strategy making. The framework adapts and integrates existing frameworks or models used for AM. The approach covers philosophical discussions and comparative studies of others' work and thinking. It covers the main contributors to the development of a framework, explores their different views, and develops a holistic framework that identifies AM system activities, relationships, and mechanisms.

This work establishes a systematic process flow for investigating the strategic role of an AM system within an organisation's management system. Further use of this process will lead to a stronger body of AM knowledge through better contributions from further research. Asset managers in capital intensive organisations can use the proposed framework to examine the applicability of this holistic approach in service and production organisations, and to guide any improvements.

The hypothesised framework has been used to postulate the existence or absence of AM system activities, mechanisms, and relationships, and then the research context and

collaboration which focused on the production industry and involved embedded case studies from the steel industry evidence built from an industrial case study was used to establish the existence or absence of an AM system as proposed by the hypothesised framework. Existence of elements of the hypothesised framework has been shown to be related to the successful implementation of an organisation's strategy. In contrast, some elements' absence or inadequacy results in an inappropriate or insufficient asset performance that does not allow organisational strategy to succeed. The work shows that using the proposed hypothesized framework as a reference can enable organisations to develop organisational structures that facilitate the capture of the intended benefits of their strategy. Finally a holistic view of the AM system in relation to organisational asset-related activities, and strategies is put forward which until now has been missing from the literature.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

DEFINITION OF TERMS

Activity:

An activity is a function: the two terms ‘activity or function’, are used interchangeably as a task to be performed within the organisation.

Asset:

(Physical infrastructure,) plant, machinery, property, building, [vehicles and] other (non-consumable) item[s] and related systems (both hardware and software) that have a distinct and quantifiable business function [or service]

Asset Management System Activities:

A set of activities that facilitate operational task control, aggregate and strategic planning and control over the asset-related activities of the organisation. For example: equipment monitoring; design planning; equipment investment analysis.

Asset-Related Activities:

Activities that are directed at assets. The primary activities are the life cycle activities together with their supporting activities. For example, design, acquisition, operation and maintenance and their supporting activities including procurement, technology development, finance, and information systems.

Asset-Supporting Activities:

Those organisational activities that support the life cycle activities but also support non-asset-related activities e.g. procurement, technical support and development, finance or information management.

Asset Solution:

The response of the AM system to a strategy event. This may include acquiring new assets, modification of assets, changing of asset management strategies such as maintenance or replacement strategy, development or insertion of new technology.

Collaborative Activities:

Activities requiring interaction between a number of departments within an organisation.

Life Cycle Activities:

Those activities that represent the life cycle technical and management processes of the assets e.g. engineering design, maintenance or operation activities.

Management System:

A management system is a set of schemes, arrangements or methods of performing management activities over a set of organisational levels, divisions or departments within an organisation.

Asset Management System:

A management system that plans and controls asset-related activities and their relationships directed at ensuring the achievement of the asset performance that meets the requirement of the intended competitive strategy of the organisation.

Management Activity:

An action, a procedure or a step within a management system, e.g. management activities may include planning, administrating, control, auditing, analysis, decision making.

Strategy Event:

Any external or internal event that results in the need to alter the strategy of the organisation.

1 Introduction

1.1 Purpose statement

The research problem is focused on the concept of ‘engineering’, ‘physical’, or ‘infrastructure’ asset management, AM, and its role in organisational strategy. This discipline and activity within organisations requires definition. This is a basis for determining its strategic significance. It is thought that there are barriers to integrating AM with competitive strategy development and implementation activities. This also includes concept of customer value creation and the contribution of AM relative to achieving or sustaining organisational strategy.

1.2 Key Concepts

1.2.1 Asset Management

The development of the AM discipline seems to have been born out of the idea that the collection of activities it represents is important to organisations. Despite the popular movement surrounding the term AM there is no widely held understanding of its role in organisational strategy, competitiveness and so success.

Asset management varies in interpretation and definition. In the financial division it refers to the management of financial assets. In capital intensive industry, asset management, here termed AM, is used to identify how an industrial organisation manages its physical assets through their life cycle. The output generated with these assets should justify their ownership. The AM Council (Asset Management Council 2009) defined 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 plan and control the Asset-related activities and their relationships to ensure the asset performance that meets the intended competitive strategy of the organisation” (El-Akruti and Dwight 2010).

This definition is largely consistent with the AM Council’s definition while highlighting its link to strategy. Both definitions highlight the central role of asset life cycle management in the context of engineering management.

Any activity of an organisation is only useful if it is directed at assisting in the achievement of its competitive strategy. As such, the concern here is on a concept that helps organisations manage their existing assets throughout their life while they continue to conform to their competitive strategy. From this perspective, AM activity typically begins with an existing organisation that has existing assets. It follows that the starting point and central phase for the AM key activities is their utilization phase. Any decision concerning other stages in the life is built on information accumulated while managing this utilisation phase. The design phase of course precedes utilization, and at any time it may be realized that the current asset configuration are unable to cope with a changed environment and subsequent changed competitive strategy. Concurrently, organisations must identify the need, and make decisions, to launch any change or project to enhance the assets, whether their design, operation, maintenance, or logistic support. This may involve innovation, upgrading, development, expansion or extension, information, insertion of technology, and refurbishment, replacement or retirements of assets. However, the design phase provides the basic information for AM to use and build on to establish AM practice. Conversely, AM must have a strong influence over the performance standards for the acquisition phase of any asset.

1.2.2 Strategic Asset Management

AM is increasingly a focus of attention in various industries to address interrelationships between the life cycle of assets and the risks associated with the performance of asset-related activities. Industries are under increasing pressure to reduce costs, meet tougher performance and production targets, comply with regulatory requirements, and maximize return on assets. A growing number of industry groups, professional societies and research organisations that consider AM as a strategic activity are forming, for example, (IAM 2004; IPWEA 2006; CIEAM 2008; Asset Management Council 2009) . Those organisations are developing new and extended bodies of knowledge and frameworks that incorporate a multi-disciplinary view (Frolov, Megel et al. 2009). Their stated aims are to reduce the cost of maintaining assets, improve their performance. Consequently, these issues have placed a strong emphasis on the area of AM.

In order for industrial organisations to maximize revenue they must utilize their assets in an effective and efficient way, indeed their success often depends on utilising assets efficiently and effectively. AM is now regarded as an essential technical and business process in many organisations, and recognised as contributing to an organisation's objectives.

The links between the organisation's competitive strategy and lower level organisational activities are considered to be complex relationships. They are either considered to require integration across activities and alignment of organisational activities with competitive and corporate strategies (Russel and Taylor 2006), or to require activities that extend across activities (Slack, Chambers et al. 2006). It is suspected that conformance to an enterprise's competitive strategy can be achieved by an integrated decision-making process including AM activities. The link between organisational competitive strategy and organisational activities is more complex than can be represented by a simple top-down hierarchy. For example in studying manufacturing strategy, Kiridena (2009) concludes that:

"The relationships between business strategy, MS and strategic manufacturing decisions and action were far more complex than could be described by simple hierarchical links associated with the organisational structure."

It is suspected that the complexity of the relationship between organisational activities and competitive strategy is endemic to AM and acts as a barrier to integrating it with competitive strategy because it is interdisciplinary in nature and interfaces with many organisational activities.

The life cycle barriers and the activities' integration barriers and hierarchical integration barriers are a major concern in AM. The challenge in effectively managing the entire life of the asset is that costs are isolated and addressed in a fragmented way through the various stages. During acquisition, the emphasis is on implementing a project within the approved budget and prescribed time frame, while ensuring that the facility conforms to the technical specifications. Any identification of need or alternative analysis and project selection are largely dominated by the focus on business management, indeed the decisions are considered to be primarily strategic rather than linked to an engineering perspective. The technical facet of AM is often isolated from an organisation's strategic process. For example, maintenance is typically considered to be a 'necessary evil' that is not involved at

the strategic level as a business issue. Ouertani, Parlikad et al. (2008) argue that, being the longest and most complex life stage, operation and maintenance often deserves additional attention. However, planning and controlling maintenance is only one AM activity, others include choosing the right assets, monitoring their use, and balancing short-term performance against long-term sustainability.

From a life cycle perspective, natural barriers exist between the stages of asset life, but it is reasonable to believe that they occur sequentially. These stages typically require different skills and organisational activities in order to be conducted effectively. Interfaces need to be built through numerous barriers. These may stem from the nature of AM or industry, and include functional, organisational, temporal, cultural, knowledge related, and often commercial barriers.

These barriers can only be overcome by management activity. The effort required and the types of activities and benefits gained from them are specific to the context in which they were devised. These activities in the AM context have been ill-defined or have not been devised or standardised. Many organisations have difficulty in devising and justifying these activities. What is sought are some general rules, based on a specific context.

1.3 Initial Evidence of a Lack of Knowledge

The majority of research publications focus on specific activities or technical activities of AM, particularly maintenance and its management. This technical focus is found in publications on maintenance strategy (Tsang 1998; Tsang 2002; Mather 2005; Pinjala 2008); performance management and performance measurement (Pintelon and Puyvelde 1997; Dekker and Scarf 1998; Liyanage 2005; Garg and Deshmukh 2006; Pintelon, Kumar et al. 2006; Muchiri and Pintelon 2007; Muchiri and Pintelon 2008); replacement (e.g.,El-Akruti 1999; Scarf, Dwight et al. 2007); remaining asset life (Oien 1998), outsourcing (Martin 1997; Buczkowski, Hartman et al. 2005); predictive maintenance (Mckone and Weiss 2002); risk-based aspects (Khan and Haddara 2003); planning, scheduling and information management (Satyanarayana and Prasad 1996; Nagarur and Kaewplang 1999; Tsang, Yeung et al. 2006). This leads to the conclusion that research in AM has often been focused on specific Asset-related activities.

Frolov, Megel et al. (2009) state that historically AM was viewed as a technical activity driven by engineering design that narrowly focused on reliability and maintainability of assets. Charles and Alan (2005) argue that literature is narrowly focused, revealing that the contribution by AM has not been considered from the whole life cycle approach and limited to the primary drivers within the so called utilisation phase. Ouertani, Parlikad et al. (2008) argue that although maintenance has an important role to play it is only one of the 'variables' in managing assets. Others include selecting assets, using them, or trading short term performance against long term sustainability, and managing information. Some of these occur at early stages during acquisition but critically impact the capability and performance of assets.

The need for a holistic system approach to AM has been identified but still not fully developed (Hipkin 1998; Dornan 2002; LoPorto and Udo 2003; Mohseni 2003; Amadi-Echendu 2004; Charles and Alan 2005; Narman, Gammelgard et al. 2006; Stapelberg 2006; CIEAM 2008; Haffejee and Brent 2008; Asset Management Council 2009). This approach has emerged based on the practice of particular organisations. Several frameworks and models have been proposed. Figure1.1 is a particular example.

These are considered to be the result of experience or personal understanding developed personally via anecdotal evidence by their authors. They are typically reported or published by individuals or organisations without reference to the literature or research leading to their development. According to Frolov, Megel et al. (2009), the need to develop this holistic approach to AM has been identified and collaboration between organisations and academic researchers to extend the body of knowledge in this area is under way.

Despite the movement toward this holistic approach to AM, there is a lack of research on the relationship between organisational strategy and AM activities or asset related activities in general. There are too few or insufficient direct studies found in literature on the role of AM in competitive strategy or organisational strategy. A study by Pinjala, Pintelon et al.(2006), for example, reports a lack of studies on the relationship between business and maintenance being one of the important asset-activities.

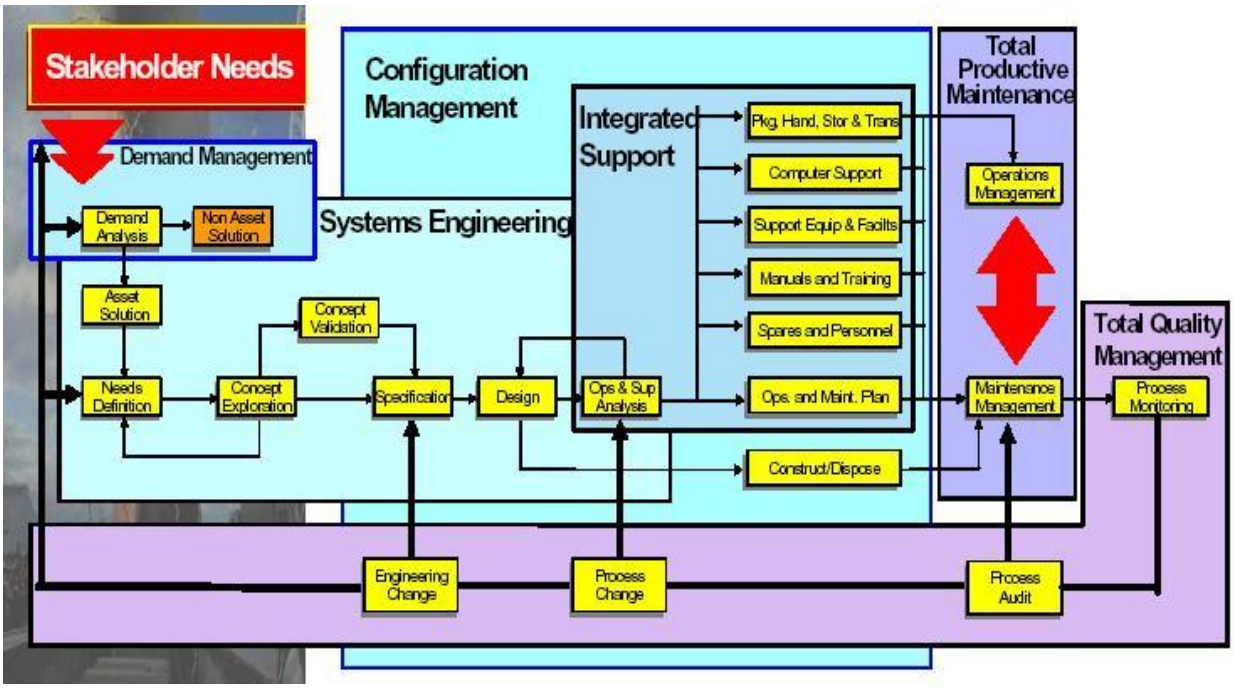

Figure 1.1 : Asset Management Council Technology Model

Source: Asset Management Council

"There are meagre or no direct studies on the relationship between business and maintenance strategies. ..... recent studies like Waeyenbergh and Pintelon (2004) and Al-Najjar and Alsyouf (2004)emphasize the importance of maintenance and its role in contributing to positive business performance."

Alsyouf (2006) and Al-Najjar and Alsyouf (2004) emphasise the lack of relationship between maintenance and quality improvement with an overall neglect of maintenance as a competitive weapon.

A strategic approach to AM is needed, especially in capital intensive industries, but this has only been widely recognised in maintenance (Tsang 2002; Pinjala, Pintelon et al. 2006). In this respect, Ouertani, Parlikad et al. (2008) argue that every stage in the life cycle plays an important role. He states that maintenance deserves additional attention because it occurs during utilization, which is the longest and most complex phase, however, other activities around the asset base during the early stages of acquisition have impact on operation and maintenance and more impact on the capability of assets to achieve strategic objectives.

The impact on organisational success of maintenance may not be well defined because it is hard to quantify. The link between maintenance and competitive strategy, delivery of customer value is usually hidden despite its potential impact on the accomplishment of objectives. Maintenance is typically considered to be a 'cost centre'. For example, 70 per cent of the respondents of a survey conducted on 118 Swedish manufacturing companies considered maintenance as a cost centre (Alsyouf 2006). It is a 'subordinate to operation' or a 'necessary evil'. (Muchiri and Pintelon 2007) suggest that:

"This is due to the traditional attitude by production management towards maintenance as a non-productive support activity and as a necessary evil (Daya, 1995; Pintelon, 1997). It is not until recently has maintenance importance to profitability been recognized"

Dwight showed that it has not been made scientifically credible that there exists a link between the inputs to the maintenance process and the outcomes of the manufacturing process (Dwight 1999). Other recent work of Bamber, Sharp et al. (2004) highlights that both lean and agile manufacture include maintenance as a key to maintaining competitive advantage. Also, as cited by Pinjala and Pintelon et. al. (2006), the cost of maintenance is high and will get higher, and overall effectiveness of the equipment (OEE) is only 45%. They state that:

"..cutting down the costs of maintenance can affect the company's competitive strength equation and its ability to compete in the market (Pinjala, Pintelon et al. 2006), .. maintenance .. should be recognized as an integral part of business strategy or the competitive strength equation(Hora 1987)."

There is evidence that short falls in AM affect an organisation's ability to implement its competitive strategy. The literature is wide ranging in its opinions of the ability to develop new internal capabilities and to re-configure existing physical assets and associated human activities. Some discuss this as agility, arguing that agility stems from flexibility, responsiveness, and adaptive capability (Quinn, Causey et al. 1997; Gunasekaran 1998; Yusuf, Sarhardi et al. 1999; Shaw, Burgess et al. 2005). During development, organisations adjust their internal capabilities or performance in response to changing business drivers. Organisations sometimes fail to meet their strategic goals because they implemented inconsistent or unmatched projects to achieve these intended goals. Projects may not fit

with the existing organisational setting and require adjustment at the implementation stage, which causes extra costs. Miles and Snow (1978) showed how several organisations experienced strategic failures from adopting new strategies that failed because the activities required to manage the new assets, systems or technology were inadequate, so these companies experienced substantial financial losses. Another study suggests that the competitive attributes of business strategy drive the focus and content of project management (Srivannaboon and Milosevic 2005). Morris (2004), studied the integration and interfacing between project management and strategy and showed that the process of a project is an integral element of the business model and a key business process. Donovan(2002) studied procurement in two cases and showed that inadequate feasibility studies and other system engineering activities resulted in an inconsistency between the strategic goals and delivered system. Approximately 195 additional requirements were identified post the award of a contract with high customer value , options in the design were overlooked, and there was a substantial increase in the capital costs, as well as many unexpected adjustment to fit the operation and maintenance requirements (Donovan 2002).

Financial policies may impose constraints that reduce created customer value by affecting assets during their use and disposal stages of their life in particular. This is usually a hidden phenomenon that needs to be presented to decision makers. This issue has been illustrated in practice related to a procurement policy and shown in terms of suppliers comparison based on the cost of life cycles (El-Akruti 1999). Budget constraints based on short term financial performance alone can limit the customer value delivered by assets. For example, Kaplan and Norton (1990; 1992) in particular state that financial measures are misleading and should not be used.

Although AM is an area of immense importance in providing an asset based portfolio and performance capability to achieve strategic business goals, there is little understanding of how it can provide options to alter the strategy to achieve long term competitive advantage.

1.4 Definition of the Problem

The role and suitable design of the AM system relative to the development of competitive strategy and implementation of capital intensive organisations is sought. It is proposed that

capital intensive organisations in production and service industries are not in full control of engineering AM such that it serves the organisational strategy. A fundamental reason for struggling to control the strategic role of AM is because elements of the AM system overlap other systems or activities within the organisation. The nature and inter-relationship of these elements, and their existence as a unified AM system dealing with the whole asset base, has not yet been defined in literature or practice. The focus has mainly been on a specific asset life or specific issues such as reliability or maintenance, whereas the concept of an enterprise AM has only been discussed in literature over the past ten years, so it has not yet been fully developed or understood (Frolov, Megel et al. 2009).

The customer value added activities, relationships, or mechanisms of the AM system, have not been revealed or theoretically developed in literature. This has served to obstruct the positioning of AM at the strategic level of a company. Put differently, AM is not properly linked or integrated into the strategic business planning process, so rather than playing a role in the strategic initiative, AM is generally taken as a technical implementation 'system engineering' part of the business strategy. Although the total life cycle for each specific asset has been considered when implementing any particular strategy, it is not understood how managing the total asset life cycle may assist in achieving the goal. It is not clear how uncovered relationships within the life cycle activities over the total asset base can obstruct any addition of customer value, retard the advantage of capital resources, and destroy a business strategy. Customer value creation can reasonably be assumed to be a function of the quality of the AM system. These system activities and relationships between them and other activities or stakeholders remain to be identified. To properly identify these system design issues an understanding of how AM ensures competitive advantage is required.

It is believed that this requires activities and relationships that simultaneously deal with competitive strategy and barriers between the life cycles of physical assets, and the relationships between life cycle activities and supporting activities. The problem requires interdisciplinary and collaborative activity communication strategies to be directed at designing and managing an organisation's asset base. The objective is to minimise the cost of the life cycle, maximise performance and minimise exposure to risk.

The problem put forward is that organisations are not sufficiently in control of the necessary AM system activities and relationships between activities to prioritise their alignment to competitive strategy.

It is suspected that the AM system plays a supervisory or control role where its activities are inseparable parts of the various activities within an organisation's system and therefore a large number of interrelationships exist that affect the organisation's system as a whole.

These general concepts raise questions such as:

1- Which activities and relationships of the AM system add customer value?
2- How do these create customer value with respect to the competitive strategy?
3- How must they be configured and aligned to sustain competitive strategy?
4- To what extent is this recognized, and if not, then why not, and how can organisations implement the missing concepts?

It is proposed that these are questions have yet to be resolved, but based on them the research hypothesis is stated as:

The research hypothesis may then be stated as: the AM system plays a key role in the development and implementation of organisational strategy. Certain AM activities, relationships, and control mechanism must exist within an organisation for it to attain its strategic goals.

These activities, relationships, and mechanisms can only be devised by appropriate integration of the AM system with other organisational management structures. The effort and types of activities required and the relationships and benefits gained from such configurations are context specific. Organisations do not have a conceptual guide to devise these activities or relationships to justify them.

A comprehensive framework that defines the required activities, relationships and control mechanisms for a specific context is required.

1.5 Research Objective, Scope, Methodology and Approach

This research is expected to provide a framework that establishes the strategic role of AM in capital intensive organisations. Such a framework would provide theory on the form of the AM system activities relationships, and mechanisms. This involves detailing AM

activities with general organisational concepts such as the value chain framework(Porter 1985).

The challenges facing organisations as they manage their industrial assets throughout their life could, through this mechanism, be explored. What is sought is an understanding of the value of the AM system in terms of how it contributes to competitive strategy. Causal relationships between strategic success or failure and the existence or non-existence of particular AM system elements is required. Such knowledge may be constructed initially through analysing the interaction between activities and their impact within specific cases. This can be constructed as a framework that encapsulates an understanding of:

1. How AM creates customer value for competitive strategy and how AM helps achieve and sustain it.
2. The role of the AM system activities and their relationships for all parties involved in developing and implementing strategy.

In this approach, the particular strategy related event or change can be investigated to understand how certain triggers pertaining to the strategy were translated into asset solutions. The management behaviour related to particular AM-related functions and the resulting asset performance can be assessed. The search is for both negative and positive results while referencing the cause to the absence or existence of AM system activities, relationships and control and to the adequacy with which these are performed. The ultimate objective is to determine the extent to which the achievement of an organisation's strategy is dependent on having an adequate AM system in place.

This thesis is composed of six chapters and two appendices. The first chapter is the introduction. The second is Research Methodologies for Asset Management which proposes a research methodology for asset management and justifies it suitability for this particular research. The third is Synthesizing a Framework for the Asset Management System which presents a review of literature on engineering asset management and develops a framework for the asset management system. The fourth is Research Design which set the approach and designs the method the case study analysis. The fifth is Case Study Data Analysis and Findings which present a detailed analysis of the cases included in

the research and draws the overall findings from the analysis. Finally, the sixth is the conclusion which draws the conclusions from findings, present indications for further research and elaborates on the limitations of the research. The thesis also includes two appendices: the Case Study Protocol and Case Study Interviews Transcripts.

2 Research Methodologies for Engineering Asset Management

2.1 Introduction

It is unclear which research methodologies should be utilised for the AM discipline. Research reported on specific activities follows the logic of a relevant discipline such as operation management, industrial engineering or system engineering. Although, these disciplines are dominated by quantitative research and positivist methodologies, they do not help to explore the complexity of AM. Some recognize the role of qualitative approaches in theory building research (Kiridena and Fitzgerald 2006). A broad range of qualitative research approaches may be applicable but their usefulness must be proven.

There are two levels regarding the development of AM theory, discrete contributing activities and the inter-related system activities that constitute AM. As established in Chapter 1, most reported research in the area of AM focuses on specific activities and technical activities such as maintenance. Even in those publications it is either not apparent that a particular research methodology has been used. Several frameworks and models have resulted from experience or a specific personal understanding and reported or published by individuals or organisations.

Given that the objective is to develop knowledge of the AM system to guide organisational strategy, the derived problem is to establish an appropriate methodology requires careful consideration in order to build a credible body of knowledge. The nature of the problem and the proposed solution can then be exposed. Since literature has not dealt with research design in AM it would be beneficial to review the literature on research methodology and provide some guidelines. To provide guidelines for carrying this particular research project and for AM research in general, the necessary aspects of the discipline ‘AM’ must be examined, and the various logics of inquiry and methods available in technical or social science and their suitability for AM research must be considered. In doing so, a fundamental guide to establish the research can be gained.

The adoption of suitable research methods is expected to lead to a stronger body of knowledge through a better contribution from research (El-Akruti and Dwight 2010).

This chapter identifies the nature of AM and the resulting research areas and possible approaches to AM research. It then explores the general guiding principles in research design such as the specific quantitative and qualitative approaches, strategies, and methods suitable to the current methodologies used for AM research. Finally, it establishes the reasons for selecting from existing social science research methodologies.

2.2 The Nature of AM and Resulting Areas for Research

The inter-disciplinary activities nature of AM stems from the fact that it is concerned with the life cycle processes at different stages and through often temporally separated activities. This can be gleaned from the definition of the asset life cycle from a user-organisation viewpoint as stated by Ouertani, Parlikad et al. (2008) as a succession of four stages: acquisition, deployment, utilization and retirement

The strategic success of a capital intensive organisation often depends on its ability to establish and manage and utilize assets efficiently and effectively throughout these stages (Charles and Alan 2005). Concurrently organisations must identify the need, and make decisions, to launch projects that enhance asset design, operation, maintenance, or logistics support (Garg and Deshmukh 2006; Blanchard 2009). This may involve innovation, upgrading, development, expansion or extension, information/technology insertion and refurbishment, replacement or retirements of assets(Garg and Deshmukh 2006; Dwight and El-Akruti 2009). Undertaking any of these may require knowledge from a range of disciplines such as manufacturing, and servicing and process engineering, which integrate with other disciplines such as safety and risk management, finance, accounting, and marketing(Dwight and El-Akruti 2009).

The AM system is either part of or alternatively controls many activities. It is not a single isolated existing entity within an organisation. The boundaries between the Asset-related activities such as production or operation and maintenance management are a matter of definition. Even when the focus is on an activity within AM, its inter-dependence with other asset-related activities and their organisational objectives is evident.

The AM system is socio-technical. Physical assets constitute the focus of concern and purpose on which AM is developed, however, human or social aspects provide the means

by which AM can manage those physical assets. Industrial systems settings include structures and procedures of activities, human or social aspects, flow of information, and knowledge accumulation. The ability to learn is an essential aspect of AM. This is particularly the case where unique physical assets are involved.

AM problems requiring research are often related to the context and may be associated with either the acquisition or utilisation phase of assets(Blanchard 2009; Dwight and El-Akruti 2009). El-Akruti and Dwight (2010) argue that, in the acquisition phase research is likely to require quantitative approaches, experimental and/or mathematical modelling or simulation methods. In the utilisation phase, assets need to be managed as part of a socio-technical system of the user organisation. During this phase research problems may be associated with managing and decision making associated with the life cycle activities. For example, which activities best extend the productive life of assets, minimize their costs, monitor their condition, maintain reliability, utilize their capacity, and result in safe operation and appropriate upgrade initiation. This leads to the underpinning focus of AM, the concept of optimising or managing the asset life cycle (Charles and Alan 2005; Dwight and El-Akruti 2009). In this view AM forms part of a broad area of management. In addition, AM is also concerned with organisational behaviour, work organisation, process management, and work procedures and rules.

This leads to the idea that AM incorporates collaborative activities within an organisation. This means that research must consider holistic approaches for exploring the AM system and building theory across traditional disciplines. Research needs to account for problems in their context in order to deliver a real contribution to decision making processes in practice.

2.3 Approach to AM Research

Since problems in AM are related to their context, they will require fieldwork in an industrial environment and an applied approach to research. This means that both the researcher and practitioner must define the problem in its industrial context and understand how a solution might benefit a particular organisation. Theory can be developed, tested, and validated for the intended benefit of that particular organisation. This coincides with the

situation sometimes confronted and approaches to strategic management. For example, Freeman and McVea (2001) argue that:

"*A pragmatic approach to strategic management would focus academic research on the detailed study of concrete situations. Over time general theories might emerge through frameworks that describe different approaches and different aspects".*

In this context the value of a theory will depend on its ability to help managers 'make sense of their world', rather than any other theoretical agenda and any research issues would depend on the circumstances under consideration. The drivers for research are part of the world of practice and the business environment around it, but the real interest is to gain insights into decision making. Managers need effective analysis, planning and control of the acquisition and utilisation of assets to guide their organisation. Dwight, Martin et al. (2007) point out that there are challenges for academic and industrial communities to 'close the gap between research and practice'.

"*... Applied research is by nature much more problem oriented and could potentially alleviate the problem to value the applicability of envisioned research output" (Dwight, Martin et al. 2007).*

Starkey and Madan (2001) argue that the key to management research should be its applied nature. A new form of research and knowledge development, as opposed to the traditional approach, was identified by Starkey and Madan (2001) and Gibbons, Limoges et al. (1994). According to them, this approach is less concerned with a discipline agenda and more with knowledge related to the nature of problems arising from practice.

2.4 The General Guiding Principles of Research Methodology

There is extensive literature on the principles of research methodology. The methodology used in this research builds on some of these methodology principles (Platt 1976; Mitchell 1983; Majchrzak 1984; Miles 1984; Pettigrew 1985; Hakim 1987; Eisenhardt 1989; Gummesson 1991; Gay 1992; Platt 1992; Ragin and Becker 1992; Sekaran 1992; Walton 1992; White 1992; Guba 1994; Blaikie 2000; Creswell 2003; Saunders 2003; Yin 2003; Cooper 2006). The interpretation of terms is often ambiguous, e.g. methods and methodologies are used interchangeably, Yin(2003) considers a case study as a research strategy while Blaikie (2000) considers a case study as a means of selecting data, and then presents four types of research strategies. To avoid confusion the key principles used for

this research are highlighted, including both quantitative and qualitative approaches, research strategies, and research methods.

2.4.1 Qualitative Versus Quantitative Research

The commonly used typology of research in literature is separated into quantitative and qualitative research, and is further classified using other criteria, e.g. exploratory or explanatory, basic or applied. Although the distinction between quantitative and qualitative approaches relates to the nature of the data used, differences incorporate the assumptions made, sources of data, methods or procedures of data collection, and philosophical paradigms assumed. As expressed by Kiridena and Fitzgerald (2006), quantitative research relies on a variety of assumptions that include a closed system, constrained conditions, manipulation of variables and isolation from context, and ideal and rational decisions. These characteristics imply that some aspects of AM are fit for investigation but they may be inadequate for research into the holistic system of AM. In contrast, qualitative research has some characteristics that overcome some of these limitations. Case studies, field studies, historical studies, and others, allow for an exploration of possible theory and insight relevant to the context (Ragin and Becker 1992; Walton 1992; White 1992; Platt 1996; Yin 2003).

2.4.2 Research Strategies and Methods

Research strategy and method may be defined as:

- The logic of enquiry applied throughout the research. This includes an approach to answering the question, assumptions concerned with what is believed to constitute reality, and the claim or assumption about possible ways of gaining knowledge of reality. Most literature on research methodology identifies three types of strategy, inductive, deductive, and abductive. Blaikie (2000) adds retroductive to this list.
- The procedures and techniques of data selection, collection, and analysis, e.g. qualitative, quantitative, case-study, experiment, survey, mathematical modelling, and simulation.

Any strategy and method, or group of strategies and methods, constitutes a particular research methodology. The various strategies and methods are not mutually exclusive but it is better to select one, pair or group of strategies and/or methods for a particular research

question. An appropriate selection connects the research objective/questions, data, and findings, or the contribution the research makes to knowledge and the extent to which it can be generalized.

2.4.3 The Choice of Strategies: Reasoning the Logic of Inquiry

To facilitate the selection of a research methodology for an AM problem, the possible routes that can be followed have been mapped in Figure 2.1. It includes strategies based on the description by Blaikie (2000) or derived from common use in literature, e.g. Hakim(1987); Sekaran (1992), Blaikie(2000), Saunders(2003). These routes can guide the selection of a specific methodology based on the intended contribution from research. Rather than establishing boundaries between research strategies, it facilitates understanding their logic and establishes a conceptual map linking strategies to the research question. It merely suggests that different research strategies are suited to different research puzzles. The vertical structure represents the common use of these strategies, as identified by Blaikie (2000), singly, or in combination. He indicates that they are not mutually exclusive and their use depends on the researcher's choice. The superiority of one or more strategy over others to handle a particular research problem depends on the nature and circumstances of the problem, and the research objective. The focus here is to select one or more strategy to handle the identified nature of AM and provide the basis for a holistic approach to its system.

Chapman(2006a) used a 'theoretical framework' to guide his methodological approach to study causes of socio-technical failure resulting in accidents or disasters. Although the strategy is not identified, the methodology used is consistent with a retroductive strategy. In building on the 'contextualist' methodology introduced by Pettigrew(1985): Chapman concludes that:

"*... data collection and analysis needs to be guided by a clearly articulated 'theoretical framework' .... and an action or time-based flow of events .... Ultimately, the finding can be generalized to other settings with similar parameters" (Chapman 2006a).*

The findings were focused on social settings 'human choice making' and were generalised to other similar cases. His 'theoretical framework' is related to human settings, not the design or existence of a system that controls or guides human choice.

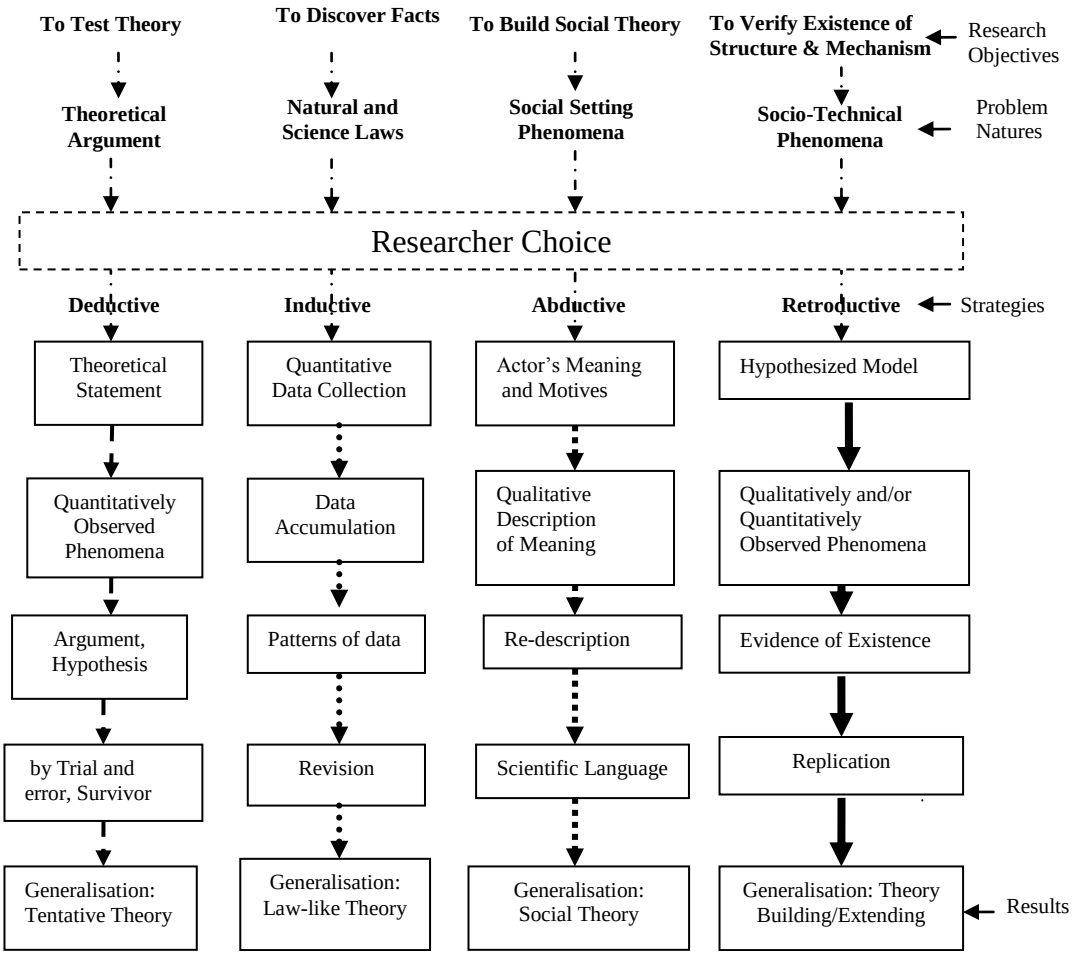

Figure 2.1: Conceptual Map for Selecting Research Strategies (El-Akruti and Dwight 2010)

This raises the possibility that a retroductive strategy may be applicable to AM research if it is associated with appropriate methods. The retroductive research strategy allows for a hypothesized model as an instrument for describing socio-technical systems proposed. Such a hypothesized model then provides a basis for the observation and collection of qualitative and quantitative data. Other strategies may be used to measure this data as output or input parameters, however, all measurements have to be directed and interpreted using a proposed model. As cited in (Yin 2003):

"*Logical inference is the process by which the analyst draws conclusion about the essential linkage between two or more characteristics in terms of some systematic explanatory schema – some set of theoretical propositions (Mitchell 1983)".*

The development of knowledge by this type of research is related to providing a model for the proper design of an AM system and its embodiment in an organisation. As Flynn, Sakakibara et al. (1990) suggest: "*Theory building study is not a hypothesis, but rather, some assumptions, frameworks, a perceived problem or perhaps, very tentative hypothesis".* The cause and effect relationship can be verified by observing consequences as outcomes and then arguing that the evidence and hypothesized model propositions are somehow connected.

It is proposed that the retroductive strategy can enhance research considering the holistic AM system. It utilises models that are capable of describing the complexity and open nature of a system.

2.4.4 The Choice of Research Methods: Reasoning the Use of Methods

There are many factors involved in selecting a particular method of research. As established previously, the nature of the AM problem being researched influences the choice of research methods. For example, the use of a 'controlled experiment' may be limited to technical aspects. Research methods already used for AM include case studies and surveys. Reporting on a case study, Iravani and Duenyas (2002) indicated that making maintenance and production decisions separately can be rather costly and there are significant benefits for making these decisions in an integrated fashion. The same principle was demonstrated for a make-to-stock production system consisting of a single deteriorating machine which produces a single item. Based on survey responses, Muchiri, Pintelon et al.(2010) analysed the manufacturing environment and maintenance objectives on the choice of key performance indicator and their role in supporting and improving decision making. The integration of activities within a holistic AM system is argued to be a central issue. Jonsson (1999) argued that integrating maintenance with other activities produced better results. Data gathered and analysed from 293 Swedish maintenance managers in manufacturing firms showed that integration and long-term planning of maintenance affected prevention, quality improvement, and manufacturing capabilities. Integration of activities such as maintenance, operation and procurement by information systems can be a major factor for improvement(Garg and Deshmukh 2006).

The nature of AM tends to focus research on the longitudinal effects of actions on the organisation. The research difficulty here is trying to predict future conditions. In designing research for this situation, problems result from inter-dependence with other actions and unclear boundaries, i.e. AM must be studied as an open system. This makes it hard to assign variables to causal relationships and limits the use of formulation and prediction. Surveys are mostly used to prove a theoretical point, such as evidence of a relationship between parameters. Jonsson (1999) established that integrating maintenance produces better results. How that relationship takes place, or how it can be managed is not elaborated. In contrast, case studies can allow the exploration of the complex relationships of the AM system.

Context influences the selection of a research method. Research in AM requires applied research where the findings may be unique for each organisation. Appropriate management of similar assets may vary even within organisations, depending on contextual parameters such as the operating environment, market characteristics, location, and local legislative requirements (El-Akruti 1999). This is consistent with contingency theory, e.g. Herbert, Roitblat et al.(1995) explain this theory by integrated systems in standard cognitive science. Context is an essential consideration for AM research, not just for obtaining data, but for setting the research question and the intended contribution from research. The researcher has no control over context and cannot construct a controlled experiment. Rather the researcher must choose a context.

These factors indicate the need for comprehensive methods to research the open system 'contingent' nature of the AM system. As shown earlier in this chapter, research methods used in AM so far, vary but typically, conducting case studies or surveys are commonly used.

2.4.5 The Case studies Choice

Case studies can develop new insights into the relationship between activities and the control and decision making process for those activities. This coincides with the typical AM research problem identified previously. As Blaike (2000) states, case studies allow the holistic and meaningful characteristics of real life events: such as individual, organisational

and managerial processes, to be investigated as well as changing environmental events, external relationships, and the maturation of industries. Case studies can be used to analyse an event, an entity, a decision, program, implementation process, organisational change, strategy, policy, or the trade or capital flow between two entities(Yin 2003). Case studies have been used for exploratory, descriptive and explanatory research purposes, and to generate theory and initiate change (Ragin and Becker 1992; Blaxter 2001; Yin 2003). There are many different purposes for applying case studies: to develop theory; to explain the causal links in real life intervention that are too complex for survey or experiment; to describe an intervention and the real life context in which it occurred; to explore those situations where the intervention being evaluated has no clear single set of outcomes (Platt 1992; Ragin 1992; Walton 1992; White 1992; Yin 2003). According to Sloan (2005), Andrews (1987) stresses the importance of case study research in the development of organisational strategy. Yin(2003) argues that case studies can be used to investigate a contemporary phenomenon within its real-life context, when boundaries between phenomenon and context are not clearly evident, and when multiple sources of evidence are needed.

Positivists question the credibility of case studies for generalization. Mitchell(1983) and Yin (2003) for example raised this issue. They argue that critics of case studies were operating from a position of statistical inference appropriate to sample surveys. On the other hand, a different kind of logic is required to test a proposition or answer the research question. Mitchell(1983) called it 'logical inference'; Yin(2003) called it 'analytical generalisation' or replication logic. Mitchill(1983) made a very clear distinction between logical inference from statistical inference that generalized to some wider population, from some sample of that population to which the observer had access.

"*Logical inference is the process by which the analyst draws conclusion about the essential linkage between two or more characteristic in terms of some systematic explanatory schema – some set of theoretical proposition"(Mitchill 1983).*

Yin's argument stems from the analogy to laboratory experiments in distinguishing 'analytical inference' from statistical inference. Knowledge cannot be developed from a single experiment. He identified the analogy of replication of holistic cases and sub-cases

within an embedded case. The embedded case study is relevant to studying the relationship between changes in organisational strategy and collaborative activities making the AM actions. In an embedded case, a cause and effect relationship can be uncovered. For example, an action may result in changes within activities and relationships between activities, but they still translate into changes in an organisation's strategy. The aim is to build theory that coveys reality relative to the socio-technical phenomena and that can be generalized to a similar context, or cases with similar parameters(Chapman 2006a).

As shown earlier, the use of case studies for AM research has been for description rather than for building theory. However, Walton(1992), demonstrates that generalisations in social science were developed based on case studies. He identifies progression from a limited to more a general interpretation of casual processes by developing theories from cases for further application. He argues that if cases are provocative and invite models for further application, then they lead to conceptual and methodological modification. Walton(1992), Ragin and Becker (1992), Platt(1992) and White(1992) considered that case studies were methods for building theory, preferring to use models and frameworks to construct a theoretical case. This is consistent with the underpinning principles of a hypothesized model in retroductive strategy. Walton demonstrates how cases can be reformulated into a theoretical form by demonstrating its causal connection to a hypothesized general process:

".....case reformulation adapts available models or fashion new ones to address distinct substantive problems. The old do not fit, because the new phenomenon is either a different kind of case or one that cuts across conventional boundaries"(Walton 1992).

The reformulation of case studies through a causal connection to a hypothesized model can then lead to the development of theory. Platt considers the role of cases in changing theory. White points to a use of theoretically reformulated case studies " *…to account for why events unfold in one way and not another, with the idea that such knowledge can be used to control situation or fix them in some way".* This is relevant to controlling the AM system with the idea that such knowledge can be used to achieve strategic objectives and avoid future risk or exploit perceived opportunities..

2.5 A Retroductive Case Study Methodology

It has been realized earlier that research in AM needs to consider approaches to build theory associated with the holistic system and establish ways to manage its multi-disciplinary nature. Furthermore, the situations that may be confronting AM may threaten to require individual solutions and therefore research methodologies that provide some promise of general theory building must be found.

It is proposed here that combining retroductive strategy with case study methods would yield a suitable research methodology. To follow a retroductive research strategy, a hypothesised model must be developed. For AM research, it is suggested that system theory comprising the system design approach e.g. Hunger (1995) and Al Marsomi (1997) may be used to build useful models. The hypothesised model should reflect the role of the AM system in terms of structure and mechanism and the logic of control within an organisation. If the model structure and mechanism exist and act as proposed, then their presence, absence or quality of implementation will explain the performance of the assets and their impact on an organisation's strategy.

The relevance of the hypothesised model (Blaikie 2000) can be tested through embedded case study method(Yin 2003) where the reaction to particular events, the rationale for particular actions, and reviewing the causes of particular outcomes can be studied. These reactions, rationale, and causes are developed through reference to the hypothesised model. With the AM system this may involve testing the value delivered relative to the expected value if the hypothesised model were in place. This value may be defined in terms of the performance of the asset life cycle in achieving the organisation's strategic objectives. This combination of retroductive strategy and case study methods are useful in building a model that reflects the appropriate AM system structures and underlying mechanisms. This hypothesised model can be verified by applying it to other organisations using the embedded case study method. This methodology may lead to a general representation that can be generalized to a broader range of organisations. In contrast, findings from descriptive case studies may only be applicable to identical contexts or to an organisation with similar parameters. The aim is to generalize to 'what could be' to account for how organisations succeed or fail in achieving their goals or ideals while using an AM system to

control practice. This can be verified by the performance or outcomes that reflect the existence or absence of the AM system, based on insights provided by case study methods.

2.6 Conclusion on Appropriate Asset Management Research Methodology

AM research has been challenged to provide new insights into the decision making process that concerns the design and management of the AM system. Research in AM needs to build on currently applied qualitative approaches to research methodology in order to explore this new discipline and contribute better solutions based on evidence. The main concern of research in AM is control and decision making processes involving interfaces between and integration of discrete activities. The current status of AM as a discipline is such that sound theory utilizing appropriate research techniques must be developed. Research in AM often lacks theoretical credibility and practical validation. New methodologies need to be added to handle the challenge.

Qualitative methodologies, retroductive research strategies and case study methodologies are candidates which could complement and strengthen AM research and improve its contribution. Qualitative methodologies could explore the holistic AM system, as an interdisciplinary and strategic activity of capital-intensive organisations, while combining retroductive strategy with appropriate case study methods results in a credible methodology capable of generating a general conceptual framework. This is in contrast to the findings of descriptive case studies that may only be generalized to organisation with similar parameters. Therefore, the retroductive strategy and embedded case study method is used in this research to study the strategic role of AM in capital intensive organisations.

3 Synthesizing a Framework for the Asset Management System

3.1 Introduction

Chapter 2 established the retroductive research strategy and case study method as a suitable methodology for AM in general and for the research problem sought here in particular. Such a methodology uses a hypothesized model. Such a model must therefore be developed by exploring the literature on related aspects including AM, system theory, and strategy or strategic management. The activities and also the embodiment of the AM system in an organisation must be defined before its role in organisational strategy can be studied. Asset-related activities require definition and placement within a framework of inter-relationships between them. This can then be developed further into a framework of activities, relationships and control mechanisms. The resulting framework should include the relationship between the AM system and strategic management system to represent its potential role in organisational strategy. This can lead to a system model of the whole structure, relationships, and mechanisms of the AM system as part of the enterprise system.

3.2 The Asset Management Discipline and Its Aspects

Relevant literature may be categorised in terms of four key terms: asset; asset life cycle; the process of management of assets' life; and, available AM frameworks. The concepts under these terms are reviewed to direct the research toward deriving a framework for the formation of an AM system in organisational strategy.

3.2.1 Assets

The term 'asset' is used differently by various disciplines so a meaning from an AM perspective must be found. An amalgam of definitions altered by Dwight and El-Akruti (2008) covers the breadth of terminology:

"(Physical infrastructure,) plant, machinery, property, building, [vehicles and] other (non-consumable) item[s] and related systems (both hardware and software) that have a distinct and quantifiable business function [or service]" (British Standards 2004).

Therefore, assets are the engineered physical entities or technical systems within an organisation. The concept that an asset has a value is highlighted in many publication such as (Snitkin 2003 ; Bdkarada and Gao 2006 ; Koronios, Nastasie et al. 2007; Ouertani,

Parlikad et al. 2008). It was also argued that it is essential to identify the asset that play key role in generating customer value (Eyre-Jackson and Winstone 1999).

Those views emphasise that assets need to be linked to their contribution to an organisation's capability and competitive strategy but this can only be realized if they are properly managed. Therefore, these definitions tend to mix the term 'asset' with management aspects. The presentation by PAS 55-1and2 (2008) in Figure 3.1, is in line with this idea. It shows relationships between various categories of assets, but focuses on physical assets as the core. The essence of reviewing this representation is not to identify relevant categories other than physical assets, but to identify the challenges in managing physical assets through these interfaces involving many different management activities.

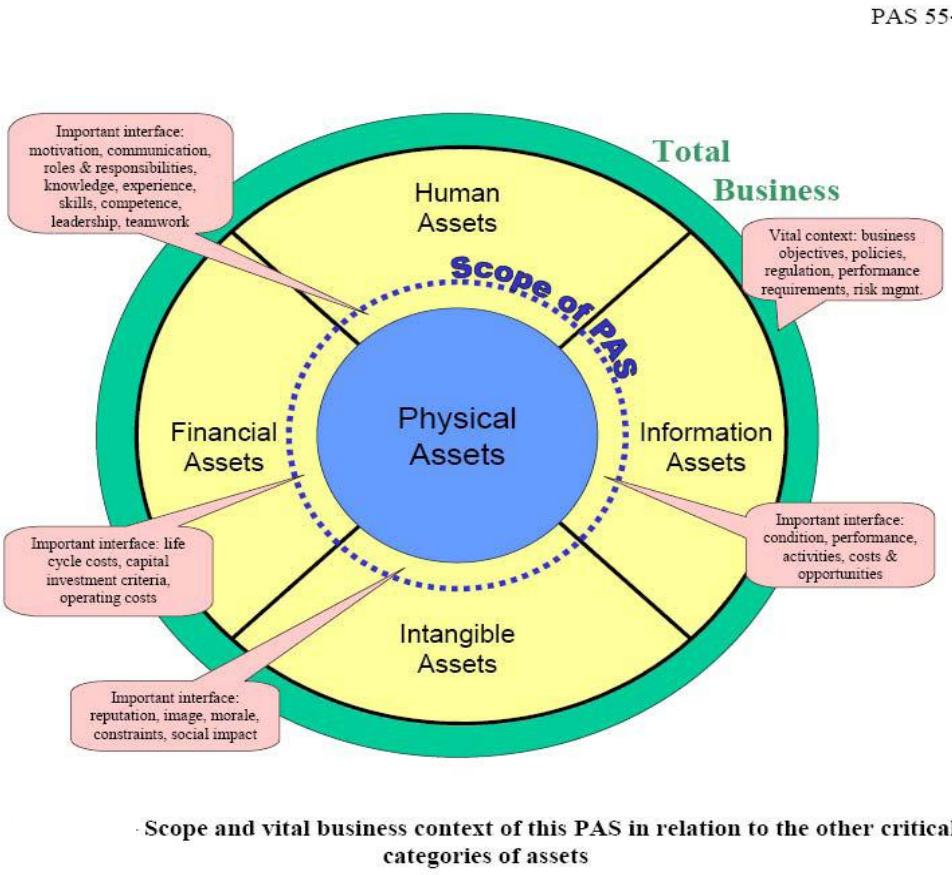

Figure 3.1: Scope of Asset Management

AM complexity arises from the numerous interactions with its surroundings. For example, information management complexity results in difficulty with the capture, storage,

retrieval, and use/analyse asset information(Evan 2008). Maintenance or operational complexity is related to the different equipment in operation and how they are maintained. Some examples are aircraft, heavy load vehicles, machines, rolling mills, steel making furnaces, and railway systems. These are all owned by organisations to generate revenue via services or products, but they require a considerable amount of effort and cost to ensure effective utilization.

It is useful then to consider an asset as a physical system purposefully performing an activity or set of activities within an organisation. Overall, AM management is concerned with assets as part of an organisation's system including their ownership and contribution.

3.2.2 Asset Management

The key aspects of AM can be extracted from exploring the various definitions and concepts in literature. While it is not the purpose of this research to review or adjudicate on the range of published definitions of AM, its definition does provide the context for the research.

Most definitions emphasize the life cycle. They not only focus on a specific asset's life but tend to reveal what AM is responsible for rather than saying what it is. For example:

"The process of guiding the acquisition, use and disposal of assets to make the most of their future economic benefit and manage the related risks and costs over their entire life" (Asset Management Series: Principles Nov 1995.).

Similar definitions are found in (Koronios, Nastasie et al. 2007; CIEAM 2008; Asset Management Council 2009; NSW Government November, 1993). The essence of these definitions is the implication that AM deals with the whole set of system engineering processes throughout the life cycle of the asset. This reveals that activities of concern to AM are directly responsible for activities associated with the life cycle: such as asset technical support and development and design, construction and installation, operation, maintenance, security and safety and those activities that indirectly support them: procurement or purchasing; finance and accounting; and human resource management.

Other definitions tend to reveal what AM does as opposed to what it is. For example:

"The optimum way of managing assets to achieve a desired and sustained outcome, ... systematic and coordinated activities and practices through which an organisation optimally manages its assets, and their associated performance, risks and expenditures over their life for the purpose of achieving its organisational strategic plan" (British Standards 2004; PAS 55-1&2 2008).

A similar definition is found in (Mitchill 2007). The essence of these definitions is that they point to the activities responsible for the life of the asset and highlight the strategic dimension of AM and its link to organisational strategy.

Other definitions of AM identify it as a set of activities within an organisation and identify the nature of these activities. For example: integrated or provide the tools or engineered means without specifically defining these activities. For example:

"Those activities that together provide the tools, or engineered means by which organisations satisfy their customers with reference to the competitive strategy of that organisation" (Dwight 2006).

Similar definitions are found in (Mitchill and Carlson 2001; Charles and Alan 2005; Schuman and Brent 2005). The essence of these is the view of AM as part of an organisation linked to the long term objectives, return from assets, and competitive strategy.

From the preceding review a comprehensive view of AM can be summarised as follows:

1. AM is concerned about the system engineering processes of the entire assets' lives.
2. The concern of AM is all those technical activities that directly manage assets, and those activities that support the primary activities for managing these assets.
3. AM may involve a combination of technical and management activities and engineered tools such as standards, programs, or information systems.
4. The strategic challenge for AM is more towards coordinating, integrating and optimizing the entire life cycle of assets for long term business profitability.
5. AM is linked to competitive strategy and may have an important role to play in attaining and sustaining competitive advantage.

This specific indication of the link between AM and organisational or competitive strategy is related to the focus of this research, but exactly what this link needs to be and how it

should be enactive depends on identifying the value activities (Porter 1985) and their relationships to AM, a matter which has not been revealed by these definitions. However, there is an indication that these activities deal with the assets life from needs statement to disposal and are, by necessity integrated within an organisation's system.

3.2.3 Asset Life Cycle Management and Organisational Activities

Although, literature focuses on tackling a particular asset life, it reveals that AM is not considered from the whole life cycle approach, but is limited to the primary drivers of the utilization phase (Charles and Alan 2005).

Industry often focuses on technical aspects such as maintenance where certain available management tools are used, 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 only applying these models is that a large percentage of the life cycle costs are fixed during the design phase (Barringer 1997; Waeyenbergh and Pintelon 2002). The acquisition phase is taken to encompass need identification, alternative exploration, and selection and synthesis decisions. Overall life cycle costs are sometimes inadequately considered (Charles and Alan 2005). Blanchard (2009) highlighted the importance of considering future activities in the life cycle as part of a the system engineering approach. Some suggest a deficiency in approach to acquisition based on life cycle cost by industry requires a paradigm shift beyond the normal focus on cost principles of maintenance (Amadi-Echendu 2004; Frolov, Megel et al. 2009). This leads to the assumption that there is a need to include proper synthesis, analysis, and evaluation to make decisions related to early stages of asset life such as selecting, developing, and deploying of assets.

Ouertani, Parlikad et al. (2008) indicate that coordinating between the life cycle stages is vital to effective AM. The traditional life cycle system approach considers the acquirer, and the supplier (Blanchard 1990, pp. 19-29; ISO/IEC 15288 2003). However, managing the asset portfolio from the user organisation viewpoint is still ambiguous.

From a user's perspective, with specific reference to a set of assets, management responsibility changes hands from one phase to the next. A technical support and development, design, project management, or technical department will take full

responsibility for acquisition but will hand over to an operation, maintenance, and other departments for utilization. The question is how AM deals with these temporary and structural barriers to serve the strategic intent? The form of AM system and process in order to adequately deal with these issues is required. Dwight (2007) argues that:

"The focus of AM, as a business process, is assets. One consideration for existing assets is the need that gave rise to their acquisition. Note that in this context, existing asset means an asset that is currently owned or operated by the organisation for which the AM process is being considered, i.e. the prime relationship is with the value derived from the asset, which can only be related to its current use in satisfying the need of a business or a business's customer" (Dwight 2007).

AM typically begins with the utilization of some existing assets within an organisation, i.e. the organisation needs AM to derive customer value from its total system which comprises different classifications of complex engineered assets. The challenge is to deal with an existing context constrained by many conditions and limits from inside and outside the organisation. It is suggested that AM must deal with the life cycle of many inter-related and inter-dependent assets and is not only associated with a particular asset. Dwight's statement and the PAS 55-1and2 guide definition of the asset lifecycle are similar:

"It seems that AM is a process that might have objectives associated with directing activities through all the life cycle stages and relevant to all the organisation-owned assets, towards an 'optimum' and towards a 'desired outcome'"(Dwight 2007).

"The time interval that commences with the identification of the need for an asset and terminates with the decommissioning of the asset or any liabilities thereafter"(PAS 55-1&2 2008).

This definition corresponds to the asset life cycle from an asset owner and user viewpoint but how the decision was made, the need identified, alternatives selected, or the project defined is still ambiguous. Ouertani, Parlikad et al. (2008) argues that:

"The definition of the asset life cycle from a user-viewpoint can be stated as the succession of five phases;

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

2. *Deploy- all activities associated with the installation, testing, and commissioning.*
3. *Operate/Maintain - all activities involved in most effectively maintaining asset availability (health), longevity, and capability (quality, performance).*
4. *Retire - all activities involved in disposal of assets."*

The above illustration fits the user-viewpoint in an industrial context but does not show how the life stages should be related or integrated.

For AM to contribute towards strategic objectives, means managing the entire life cycle of the assets. The challenge is that cost and system effectiveness control activities are isolated and addressed in a fragmented way through the various stages. The emphasis during acquisition is on implementing a project (e.g. development, expansion, technology, etc.) within the boundaries of the approved investment, budget, and prescribed time frame, while ensuring that the facility conforms to the technical specifications. Somehow, the need identification, alternative analysis, and project selection are dominated by a focus on business management where the decision is considered strategic and not properly linked to the technical engineering perspective within the organisation. This is how the technical perspective of AM is isolated from the organisation's strategic process. For example, focus is usually directed to minimise costs relative to operation and maintenance, it is not driven toward investment in their innovation from a strategic investment viewpoint. Maintenance is typically considered to be a necessary evil because it is only considered at the operation level as a technical activity, not at the strategic or business level. In this respect, Ouertani, Parlikad et al. (2008) argue that AM requires a total life cycle approach to succeed. They add that being the longest and most complex life cycle stage, the operation and maintenance activities often require significant attention. However, it should be noted that although the maintenance activity itself has an important role to play it is only one of the 'variables' in managing assets, others include, for instance, choosing the right assets, using them appropriately, or trading short-term performance against long-term sustainability.

Accordingly, the measurement, monitoring, analysis, and evaluation activities during utilization are crucial for decision making regarding the stages of asset life. These activities provide the basis for decision making between life cycle processes. They facilitate parameters, indicators, constraints, limits and the like for decision making. Furthermore,

these activities explore how the life cycles of specific assets impact on the life cycle of other assets. They illustrate the inter-dependence of the life cycle management of the entire system. For example, measuring and monitoring the performance and condition serves operations, maintenance, and replacement decisions, and enhance feasibility studies, acquisition, and deployment of new assets. They are in fact tools to manage the life cycle of organisational assets. Furthermore, these activities can provide information and a basis for future prospects such as:

- Improving asset reliability through efficient prediction of asset failures.
- Planning and scheduling of repairs, replacement, innovation, and redeployment.
- Maximizing asset performance and throughput.
- Improving asset selection, acquisition, and deployment
- Indicating opportunity for improvement or the risk involved.

However, information must be managed and put into the right form for decision making as Ouertani, Parlikad et al. (2008) indicate that:

"Monitoring information could be captured through an array of sensors, filed devices and/or manual inspection systems, which is then collated and analysed to see how the asset behaves over a period of time".

Therefore, to better understand how AM may deal with needs relative to the life of various assets there should be continuous measurement or monitoring, and analysis and evaluation throughout the different stages of life. Examples are identifying the need, analysing the feasibility, and evaluating the current status or future requirements that take place between the processes of asset life. These processes are not limited to current lagging indicators, but they include prediction indicators and other operations, including business and risk indicators.

In order to optimise the complex industrial system of any organisation, the concept of AM should include those developing measurement/monitoring, analysis and evaluation activities because they deal with many activities of the organisation at the utilization phase and are central to identifying the need and decision making between stages.

3.2.4 Asset Management Related Frameworks and Standards

It is argued that the published frameworks relevant to at least some aspects of AM do not cover all of the relevant aspects in a manner suitable for application. Some, e.g. UK terotechnology framework cited in (Bamber, Sharp et al. 2004); and the system engineering or life cycle framework shown in Figure 3.2 (Blanchard 1990; 2009), tend to present AM relevant activities that follow the sequential life cycle stages of an asset's life.

Figure 3.2: The Life Cycle Framework, Source: Blanchard, B. S. (2009)

The focus of the life cycle framework is limited to a particular asset. It presents the life cycle processes that are needed for a particular asset. It shows the sequence of these processes along the life cycle stages and the interfaces and feedback between these processes but does not extend to show the organisational aspects of managing the life of that asset as part of many assets in an organisation. Although, it is a sequential set of system processes that are the core focus of asset management, it does not reflect asset management as a total system. With relation to this research, the life cycle framework exposes the sequential and temporal pattern of the life cycle processes. Others concentrate on developing frameworks for maintenance and its relationship to the life phases and associated processes. Figures (3.3 and 3.4) are particular examples (Geraerds 1992; Dwight 1999). As these focus on maintenance, decisions related to disposing assets, introducing new assets, and considering their replacement are not part of the maintenance activity.These require investments which can be handled by established methods for replacement and any requirements for other assets. Similarly these frameworks do not cover procurement (selection or specification of asset design) which may impact on the reliability of assets and influence the specification or undertaking of maintenance activities. Although, these models bring in the perspective of the organisational activities, they have maintenance-specific focus and do not cover all the management aspects of the life cycle activities.

These frameworks are predominantly developed to highlight a specific problem as perceived by their authors. For example they may be used to emphasise the need for an organisation to have a significant level of resources directed at the maintenance acquisition process and following a systems engineering approach to that activity. These frameworks describe independent maintenance activities that impact on the organisation's objectives and cover a diversity of individual situations. However, these frameworks help to understand the relationships between a diversity of activities; particularly where an enterprise AM system is part of an organisation but it is not explicitly apparent in literature.

There is no currently available and accepted standard setting out the requirements for an AM system. Some organisations have tried to utilize some of the standards or guides (ISO/IEC 15288: 2008; PAS 55-1&2 2008) to enhance AM. The Institute of Asset

Management has produced guidelines for AM and called it (PAS 55-1&2 2008). At the Asset Management Council Conference held in 2010, the need to cooperate in developing a standard for AM based on the PAS-55-1and2 guidelines and (ISO/IEC 15288: 2008) was discussed (Kennedy 2010).

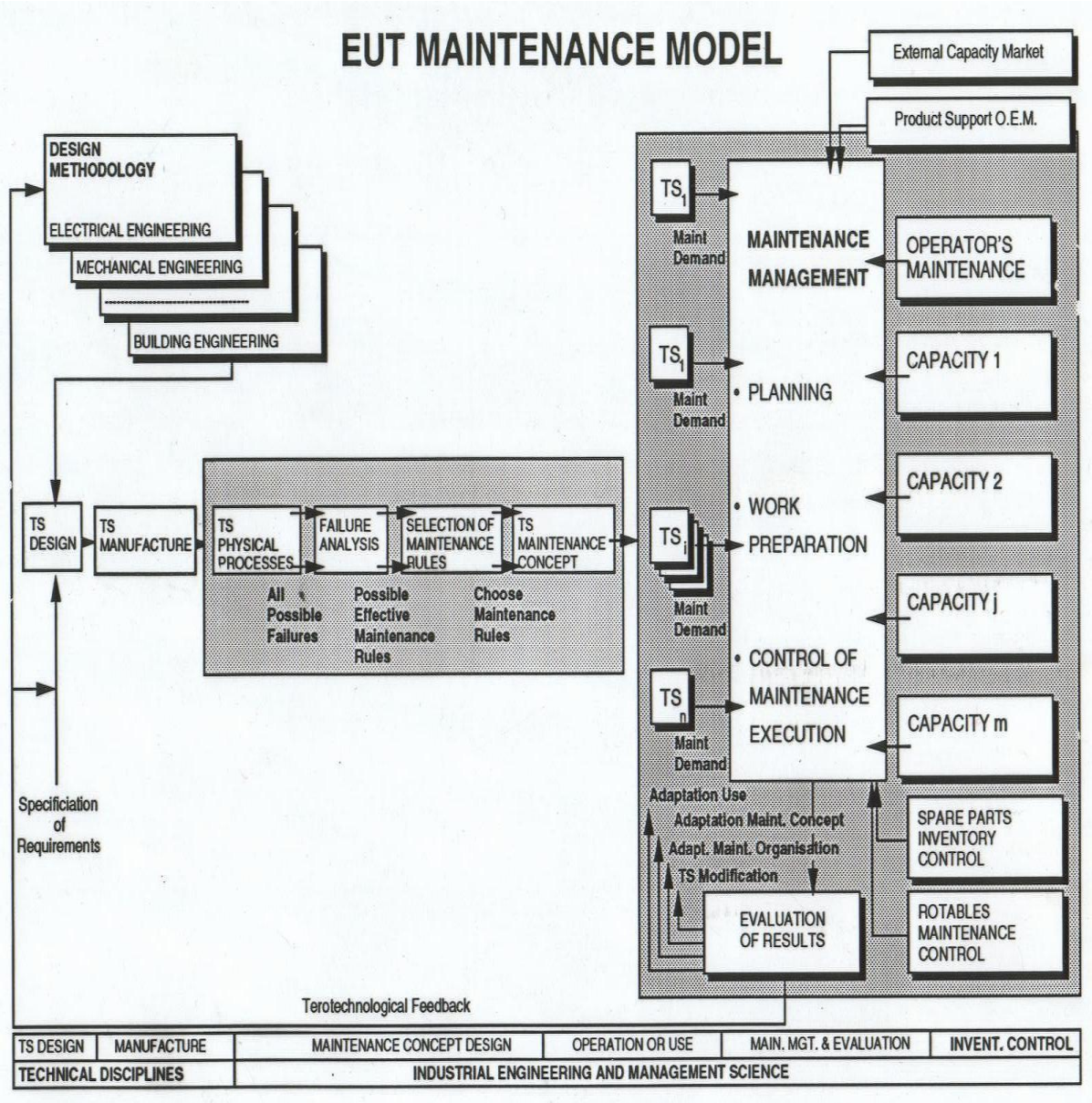

Figure 3.3 The EUT maintenance model, Source: Geraerds, W. M. J. (1992)

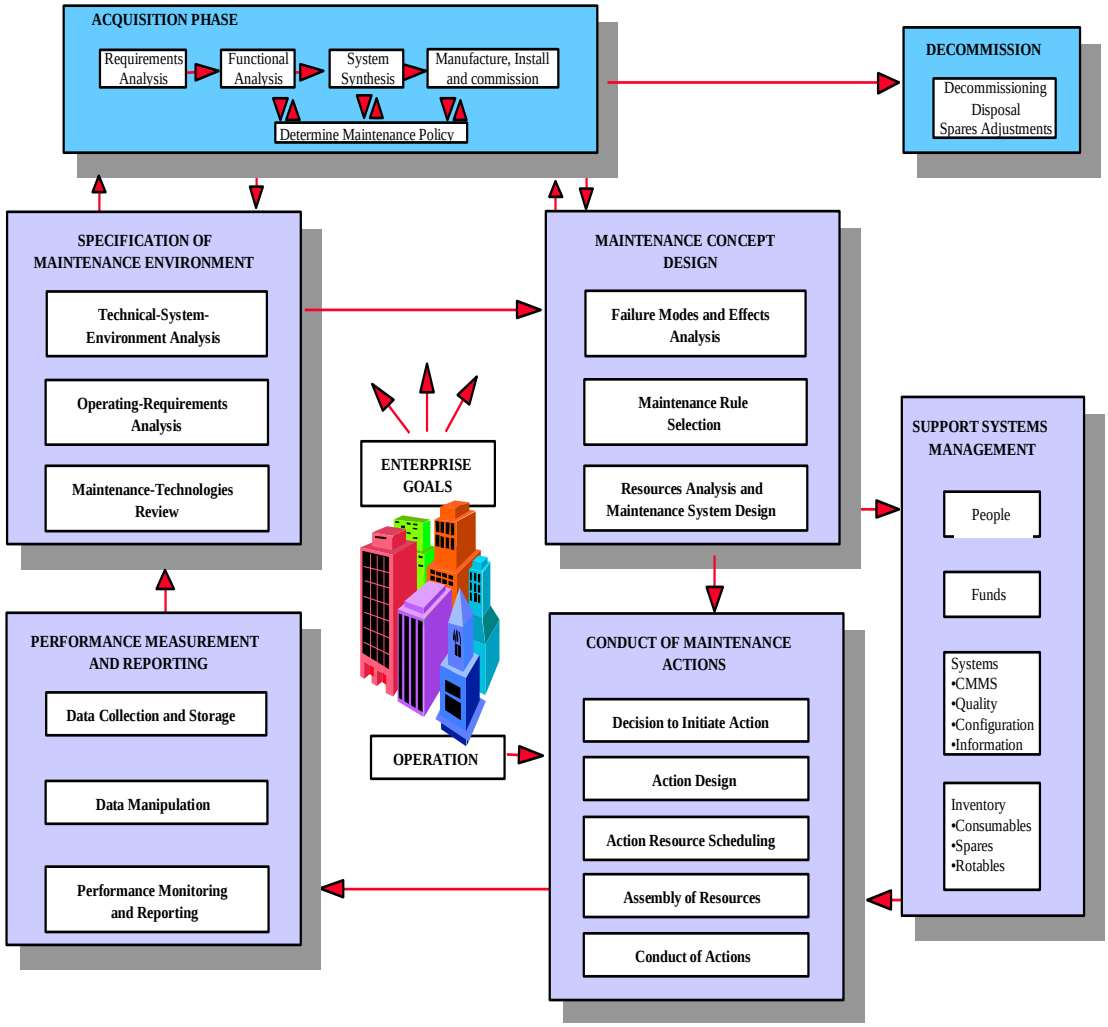

Figure 3.4: Framework for Measuring the Performance of the Maintenance System in a Capital Intensive Organisation, Source: Dwight, R. (1999).

The PAS 55-1and2 guidelines indicate that there is a link between AM system elements and organisational strategy, but how such a link is maintained was not explained. According to the typical elements of the AM system in the PAS 55 guidelines the element that connects the AM system to organisational strategy is AM policy. However, the AM policy presented in the PAS 55-2 guidelines is just several 'shall' statements that do not show how the AM system plays a role in organisation strategy. It states that AM policy shall be derived and be consistent with the strategic plan but no guidelines are provided regarding how is that to be done, what activities are to be taken, which departments are relevant, or managers are responsible, and how control can be maintained. It may be argued that these are context

specific issues and publically available specifications should not perspective. However, without having guidelines set out to tailor the use of these standards, their application becomes difficult and limits their ability to link AM with organisational activities.

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, ISO/IEC 15288: 2008 standard provides support for both technical and non-technical systems and a paradigm to orchestrate the life cycle of systems in their sphere of operation*"*(Arnold and Lawson 2004,230).*

In this mode the international standard is used to assess conformance of a declared, static environment where in reality the external and internal environment of an organisation are dynamic. Furthermore, the standard uses a pictorial representation of the life cycle that depends on sequential stages to link and manage the life cycle, whereas in many instances parallel paths will exist due to changes in strategy, iteration, and concurrency. Following this standard makes it difficult to manage incremental and evolutionary strategies through the life cycle. Moreover there is no procedure for measuring past performance or predicting the future; following the standard's processes is the ultimate goal, but how this guarantees future strategic performance is not explained. For example, to set processes that aim at maximum levels of reliability, may not just be costly but out of proportion and the resulting unit costs and in the extreme may drive the organisation to bankruptcy.

Although the ISO/IEC 15288 standard and PAS 55 guidelines are relevant they do not reasonably fit the task of linking AM to the competitive strategy of an organisation. This is because the strategic role of AM deals more with these changing environments by predicting possible changes, defining the requirements or needs of asset life and adjusting the practice to achieve the organisational strategy. Neither standard details the life cycle processes in terms of activities, methods, or procedures required ensuring the outcomes of a strategy, nor do they detail documentation in terms of format, explicit content, and performance measurement. They give no directions on how to select or modify the processes to a strategic need or make any provision to establish technical activities to be appropriate for organisational strategy.

What is missing here regarding the research problem statement is that action should stem from an underlying set of concepts that imply how management should be conducted, an organisation be structured, and the mechanism displayed to achieve the possible strategic objectives. In turn, the ISO/IEC 15288 standard or PAS 55 guidelines give no design of activities, relationships, and control mechanisms within an appropriate organisational responsibility and resource structure. This makes their application difficult and limits their ability to link AM with organisational strategy or managing appropriate changes in strategy.

This research takes a different approach in tackling AM. Rather than follow a set policy or general processes that may be static and may not react to the needs of the organisation it is assumed that there is a requirement for an appropriate structure and mechanism of activities, relationships, and control process that are linked to organisational strategy. With this structure and mechanism in place the required management cycle can be formulated and acted on as the strategic direction unfolds. This approach stems from the view that an enterprise is a system where changes require consideration of their effects on the system as a whole. This means that coordination is necessary to support the overall organisation objective. Achieving this objective requires synergy between the management activities within the organisation's system (Geraerds 1972). What is unclear is what AM activities and relationships constitute such a synergy in managing assets and which of them are strategic or linked to strategy.

3.3 Competitive Strategy and Asset Management

3.3.1 Strategy and Asset Management

The current theory on strategic management does not explicitly include factors relating to AM or asset life cycle management directed at achieving the strategic goals of a capital intensive enterprise. While this research focuses on physical assets, the strategic management process considers a wide range of tangible and intangible assets that drive the emphasis away from the role of engineering or physical AM, e.g. Hafeez, Zhang et al. (2002) tabulated a set of the various types of assets including physical assets but their analysis seems to emphasise the role of intangible assets in strategic management.

However, in this context it is necessary to explore the link between the management of physical assets and strategy making.

Strategy has been variously defined as:
"The determination of basic long term goals and objectives of an enterprise, and adoption of courses of action and the allocation of resources necessary for carrying out these goals." (Chandler 1962). And,
"... a coherent, unifying and integrative pattern of decisions; determines and reveals the organisational purpose; selects the businesses the organisation is in or is to be in; attempts to achieve a long term sustainable advantage in each of its businesses, engages all the hierarchical levels (corporate, business and functional) of the firm and; defines the nature of the economic and noneconomic contributions it intends to make.''(Hax and Majluf 1991).
These definitions imply that strategy is the overall plan for deploying resources (including physical assets) to establish a favourable position. Strategic development is an ongoing process to develop and revise future strategies that allow an organisation to implement it in order to achieve its objectives, consider its capabilities and constraints, and the environment in which it operates (Robert 1984). This includes an ongoing analysis of the changing business situation, selecting a generic strategy such as Porter's (1985) cost leadership or differentiation, and managing assets and/or resources to produce a sustainable competitive advantage.

The traditional approach to strategy is a top-down "cascade" approach (Thompson and Strickland 1989). However, many bottom-up initiatives can trigger a need to change strategy and define the feasibility for such a change. The development of strategy depends on the interaction between corporate, business strategies and activities. The corporate level decides the type of business to be in. The business level decides how each unit approaches its competitive position and how to achieve and sustain its competitive advantage, while the activities attempt to find ways to fulfil the elements of the business 'competitive' strategy.

Therefore, the management of every individual activity builds its strategy and structure following the business strategy. The operating staffs execute the strategy and give

management feedback on achievement. The sequence begins by selecting the competitive priority e.g. cost leadership, differentiation or focus, then a manufacturing or operational strategy is selected to fit the competitive priority and then assets or resources are allocated sequentially to fit with the other activity.

It is the competitive strategy at the business unit that drives the strategy formulation at the corporate level to change the emphasis on business units leading to change at the lower level in terms of activities and their strategies. The aim is to always contribute to the organisation. It is also reasonable to say that the role of any of the organisational activities is to achieve a long term sustainable competitive advantage for the organisation.

Strategic development and implementation are concurrent processes. Development is driven by external and internal factors but feedback from internal management constitutes most of the information for the decision makers regarding any change of these external or internal factors. Changing strategy at any level stems from realizing a future gap or some expectation of a gap in response to changing factors that impact on an organisation's competitive position.

Organisational behaviour is a significant factor in the strategy making process. In this area, Mintzberg (1979), for example, presented the 'Organigram' to visually describe the key elements of an organisation that focuses on the hierarchical inter-relationships. Mintzberg argues that the 'Organigram' can be used to assess whether the balance of these elements is appropriate for a particular business. It starts with the strategic apex of senior managers, from which the strategic direction of the organisation is set. This top down direction is converted into tasks which are overseen by so called middle line managers. The staffs under the middle line managers are defined in the 'Organigram' as the operating core, producing the goods and/or services. Around the flow from strategic apex to middle line managers, the 'Organigram' presents two elements: the support staff and the techno-structure. The support staff includes supporting activities e.g., finance, HR or asset investment that assist in the conversion of strategic directions into operating tasks. The techno-structure strives for standardization e.g. compliance to specifications relative for example to quality or asset management control.

Research into strategic management revealed the notion that organisational 'actors' at all levels contribute to the strategy making process (Floyd and Wooldridge 1992; 1994; 1997), however, they stated that how this process takes place is less well known. The strategic literature seems to use the term 'actors' rather than managers in certain area to highlight the idea that all persons involved in action may contribute to advising the strategy making process. Research suggested that strategy making should be considered as an organisational capability that, if developed at multiple levels across the organisational hierarchy, leads to sustainable competitive advantage(Gordon 1998). How this process varies within different industrial contexts is unknown. Moreover, 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 strategic management system and plays a role in decision making to achieve long term competitive advantage. The specific nature of this role is yet to be uncovered.

3.3.2 Competitive Advantage and Asset Management Activities

The logic of competitive advantage can best be understood through the value chain framework proposed by Porter (1985). It is proposed that AM helped to achieve competitive advantage but this area has not been the focus of research in literature. The concept of competitive advantage is based on Porter's three generic strategies (Porter 1985). His value chain framework provided the fundamental choices for performing activities differently than rivals to deliver value for the customer and gain a margin for the enterprise.

"Competitive strategy is about being different. It means deliberately choosing to perform activities differently or to perform different activities than rivals to deliver a unique mix of value".(Porter 1985).

Porter (1985) in his value chain suggests the identification of the value adding activities but he does not distinguish those management activities from operational or technical Activities. Even asset--related activities such as maintenance are not dealt with directly by Porter's value chain concept. No research has yet distinguished the role of these asset-related activities in the value chain separately. For example, Porter includes maintenance as a sub-activity of the operation activity: i.e. as a primary activity, while asset acquisition is treated as a sub-activity of the procurement activity: i.e. as a supporting activity. But

neither Porter nor others have focused research on these AM activities within the value chain. Pinjala, Pintelon et al. (2006), suggest for example that maintenance should be managed as a separate activity of the value chain so management can visualize its costs on the value added chain and business strategy. There is no effort made to link maintenance management or any other asset-related activity to the value chain or business strategy.

The use of a value chain is based on viewing the organisation as a series of activities but in literature the focus was concentrated on direct activities to customer value creation such as operations or marketing (Porter 1985).

"The value system of an enterprise is a concept that capture the idea that an organisation is a series of activities and that analysing how each is performed relative to competitiveness can provide useful insight. It aims at disaggregating activities into activities and showing how activities are interrelated and linked to the competitive advantage or the scope of competitive strategy. Competitive advantage can be derived from managing these relationships just as it can be derived from activities themselves."(Porter 1985).

Although the value chain illustrates the important role of relationships for competitive advantage, it does not show how these relationships can be managed by the organisation directed at its competitive strategy. The degree to which activities should be disaggregated is not clearly defined, and depends on the impact of cost or differentiation to perform other activities.

3.3.3 Synthesizing the Asset Management Related Activities and Interrelationships

With reference to the Porter value chain (1985), a typical representation of the main asset-related activities in an organisation is shown in Figure 3.5. The activities in Figure 3.5 represent those that directly deal with assets or their life cycle processes. While the supporting activities partly support direct activities, they also support non-asset-related activities.

The relationships of the asset-related activities exist among the asset life cycle activities and with supporting activities. Building on Porter's value chain framework (1985), the relationships in Figure 3.5 are assumed to include:

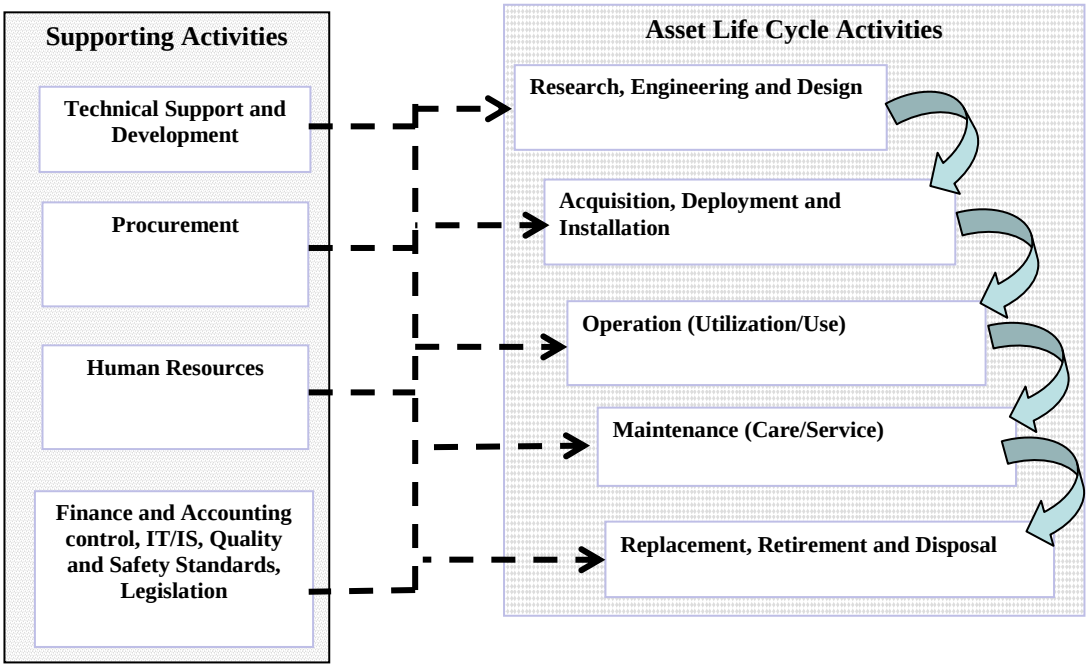

Figure 3.5: A Typical representation of Asset-Related Activities

1. The relationships between life cycle activities such as production, operations, or maintenance. Such relationships usually require coordination through planning and control. They may also involve temporal barriers as a result of the different life cycle stages.
2. The relationship between life cycle activities and supporting activities such as procurement. These may involve:
    a. Those relationships between maintenance or acquisition, and finance or accounting. These are important for establishing the requirements to enable investment, funding and budgeting, cost analysis, and decision making.
    b. The relationship maintained by the IS/ IT to establish the required information flow, information systems and/or its developments to facilitate relationships and integrate information across all asset-related activities, and create a data base for planning, control, and analysis. 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. Those relationships with purchasing for establishing a basis for analysis to evaluate suppliers and maintain value added relationships with them.
d. Those relationships with manufacturers of assets to establish their involvement in managing the asset through its life cycle stages.
e. Those relationships with outsourcers to establish a basis for analysis to make outsource verses in-house decisions and maintain beneficial relationship with both sides.
f. Those relationships with inventory for establishing a suitable supply of requirements for the assets and their life cycle processes at an optimum cost.
g. Those relationships with technical support and development to establish any necessary development in assets or related processes, and suitable technology or any new developments in technology to enhance performance.
h. Those relationships with human resources for training and recruitment of expertise.

Based on the value chain idea of links, Figure 3.5 result in the overall assumption that the AM system needs to encompass all of these asset-related activities.. AM is assumed to be a key to manage integration through these relationships mentioned. This is the theme of AM but how these activities manage relationships is a question this research is trying to answer. The representation in Figure 3.5 assumes that AM cannot be isolated from other organisational activities. It is a set of activities related to many activities within the organisation. Accordingly, every capital intensive organisation must somehow perform all the asset-related activities but may not have a system in place to undertake the AM system activities associated with them. In which case the organisation may be:

1. Missing all or part of the collaborative activities (activities that make the link between asset-related activities).
2. Missing all or part of the AM system activities within one or more asset-related activities.
3. Missing the links/inter-relationships between the AM system activities.
4. Carrying out the AM system activities improperly.
5. Lacking the means to carry out AM system activities such as knowledge, expertise, technology, (IT) or skill.

Managing the asset base as a unified system to optimise its output for the organisation is a question that remains unresolved or hidden. Exactly who resolves such a matter does not fall under a specific activity that can be distinguished as "AM" dealing with assets, it requires a management system for the coordination, integration/alignment, or trade-off among many asset-related activities. AM activities are probably part of the organisational management system and need to be identified. However, reviewing literature on the contribution of AM is essential to explore the nature of those activities.

3.3.4 Asset Management Contribution to Competitive Strategy

Many management concepts encompass creative processes such as, total quality management, Just-in-time manufacturing, total productive maintenance, and total employee involvement. The underlying reason for these concepts is the need to enhance the customer value of a product or service and provide it at a competitive cost (Omar, El-Akruti et al. 1996). The customer value delivered by a product or service together with its cost of production must be the focus for any organisation. Customer value has been defined and expressed as the ratio of many performance attributes to the cost of production. For example, product value is a consumer utility function expressing their relative satisfaction with the quality and price of a product (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; Kiridena 2009). Value has also been defined in special areas of performance that are critical to both the long and short term position to gain capital (Liyanage and Kumar 2003). From Porter's work (1996), customer value stems from offering lower prices than competitors, premium products or services, or providing unique benefits that more than offset a higher price.

Although these concepts set the basis for the relationship between operation and organisational strategy, how they interact with AM is not clear because AM unlike operations management, has an indirect impact on delivered customer value.

Determination of the impact of AM on operations and their management allows AM's contribution to customer value to be built into Porter's (1985) value chain framework. The value chain represents a firm's value added activities in relation to the structure in place

that results in its current competitive position. A competitive position can be defined in terms of performance or the capability of a firm to sustainably create a margin between the cost and revenue of its offerings. Customer value is perceived by potential customers in the price they are willing to pay for these offerings. The customer value generation by AM is embedded in providing 'the physical assets and their life management,' and 'the means of production or service delivery' that allow an organisation to fulfil its strategic intent.

The link between outcomes delivered by the AM system and the customer value that the organisation creates depends on its activities and resources that underpin it. Some deficiencies of the value chain concept are identified in handling the value of service firms or even departments within production firms. Such criteria hold true for service firms and have been adapted by Stabell and Fjeldstad (1998) by transforming the value chain into the concept of a 'value shop'. The value shop identifies the same supporting activities as the value chain but adopts a generic form for the primary activities. In the value shop it is stated that:

"Selection, combination, and order of application of resources and activities vary according to the requirements of the problem at hand".(Stabell and D. Fjeldstad 1998).

Stabell and Fjeldstad showed how the value shop can be used not just for a service organisation but for an engineering development department within a production organisation. Therefore, the value shop can be taken as part of the value chain of an organisation. From this perspective, how a service activity such as maintenance can be part of a primary or supporting activity in the value chain becomes ambiguous and is probably unfit. The value shop (Stabell and D. Fjeldstad 1998) is presented as a further development of the value chain to handle this weakness, but does not distinguish management activities from technical activities.

It is suspected that the customer value creation can be detected in terms of performance through the value chain. Output depends on the performance of production or operations, which depend on the capability of the assets and the performance of the utilization processes. The capability and performance of assets during utilization also depend on the capability and performance of the design during the design phase. Therefore, customer value creation is a function of the performance of all the life cycle processes.

Porter's value chain framework (1985) illustrates the value chain as a stream of value systems shown in Figure 3.6.

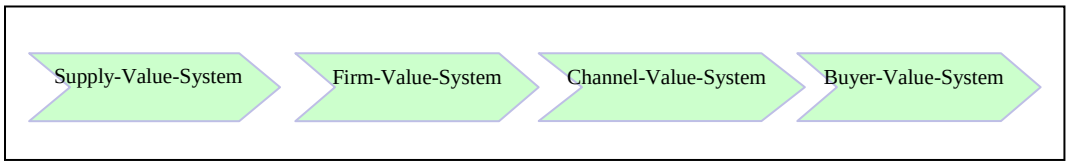

Figure 3.6: Value systems of the Value Chain, Source :(Porter 1985)

The value chain framework suggests that the links in the chain can be maintained by focusing on each value system and its links to other value systems. However, it relates customer value creation to identifying and performing value added activities, which implies that doing activities that add customer value and doing them the right way will guarantee the delivery of value to the next value system in the chain. In this value chain, performance is the link from one part to the next. AM value creation is apparently related to the ***supply-value-system*** and the ***firm-value*-system** portion of the systems in the value chain.

It is assumed that if value is expressed as a ratio of performance parameters and in terms of the value chain, then it may be defined as:

1 At the customer-value-system, customer value is customer utility and can be defined as a ratio of output attributes to price for the customer or market perspective. Its expression can be put as:

   Customer value = Output Attributes / Price

2 At the firm-value-system, firm value can be defined as a ratio of performance parameters relative to several perspectives.

   a) For the shareholders, finance and accounting perspectives can be put as:
      Shareholder value = Price / Unit Cost, or Revenue/ Cost
   b) For the production or service operation, process perspectives can be put as:
      Process value = (Effectiveness, Efficiency, Quality) / Cost
   c) For manpower perspectives it can be put as:
      Manpower value = (Skill, Motivation, Knowledge) /Cost
   d) For the asset perspectives it can be put as:

Asset value = (Asset Performance: e.g. Reliability, availability, Capability, safety)/Cost

3 The supply-value-system, supply value can also be defined as a ratio of performance parameters put as:

Supply value = Return/Investment, and/or Risk/Investment

From these expressions, enhancing the value can be captured through the contribution of any of the value systems of the value chain. At any value system it can be realized either by increasing the numerators (which usually are unquantifiable) or reducing the denominator (cost). However, there are constraints on cost reduction because all the numerator terms (e.g. quality or reliability) have a direct and sensitive function of cost, and therefore, unwise cost reductions would have a negative effect on contribution and would lower the customer value rather than increasing it. On the other hand, increasing the numerators always enhances value contribution but each term in the numerators cannot be increased without incurring some expenditure (cost).

The values expressed by the performance parameters reveal an inverse relationship between value and cost. Within the value chain this relationship can be visualized as inverse where the value originated as the 'customer' revealing its existence and importance at the strategic organisational level from the top down, while the cost is incurred and realized at the lowest organisational level from the bottom up.

The value/cost relationship might be mathematically useless but its conceptual realization in relation to a trade-off analysis between cost and performance is very important in measuring the AM contribution. Such a trade-off is very hard to quantify and may involve trading between long or short term benefits, opportunity or risk, growth or cash return, and what costs can be considered as a future investment. The relationship between cost and performance is usually influenced by decisions regarding what to do and how. This leads to Porter's idea of doing the right value-added activities and doing them such that they achieve the required customer value (Porter 1985). He also presented two criteria for the relationship between activities, trade-off and reinforcing integration. The contribution of the management activities associated with these criteria need to be represented by performance parameters. However these management activities are not elicited or

distinguished from operational or technical activities in Porter's value chain(1985). These activities may be a part of the organisation's management system and the AM activities are part of them. It is proposed that understanding these AM activities will allow organisations to be more capable of creating customer value consistent with the competitive strategy.

3.4 The Role of Asset Management in the Strategy Formulation

As stated in chapter 1, it is proposed that AM within an organisation is often not properly positioned at the strategic planning level. It is suspected that this is because it is considered to be a service technical support to operations, and is not in contact with customers. However, changes in strategy usually require changes in the asset base that provide the output (product or service) and the performance of assets impacts on organisation output. For strategy development and implementation, decision makers are focused on competitive issues and communicate their strategic decisions via the next lower level of management. Proper interaction or coordination between management disciplines in the organisation is vital for success, for example:

"The value chain is only as strong as its weakest link; poor coordination between parts of the business could lead to costly mistakes and loss of customers"(Porter 1985).

In studying the AM system and its role in the development of strategy, the relationship between the AM system and business management system should be explored. In real situations, strategy deals with changes in missions, expected changes or events in the external or internal environment, and set the means to adapt to such changes or events.

"Strategy, as a planning activity, is performed to coordinate the organisation's activities to guarantee that the future is being taken into account and to design the control mechanism which ensures achieving such plans"(Mintzberg 1990).

As Gordon (1998) observes, the development of strategy apparently requires an ongoing understanding of the interplay between objectives at corporate, the business unit, activities levels, and strategies and budgets. Further, strategy implementation implies task, monitoring or measuring, and feedback. In reality it is suspected that the strategy process is not necessarily sequential or linear, nor does it necessarily cascade in a top down approach. It is likely to be iterative and ongoing. Changing circumstances will always make corrections desirable and long term plans may need to be altered. Performance objectives may flow up in a cumulative fashion or in response to viability problems. Performance may

be raised or lowered in the light of operational and technical capabilities or experience, and influences such as environmental changes. Further, Gordon observes that implementing strategy is not just a one way task, it is a trial and error process. In addition, management tasks involved in strategy making overlap, they are not cleanly divided or sequenced. There is a constant interplay between elements.

To confirm this argument, the tasks of a formal cascaded approach to managing intended strategy formulation were examined (Thompson and Strickland 1989):"

1. *Develop the concept of the organisation and forming a vision.*
2. *Translating the mission into specific long and short range performance objectives.*
3. *Crafting plans that fit the situation and should produce the targeted performance.*
4. *Implementing and executing the chosen strategy efficiently and effectively.*
5. *Evaluating performance, reviewing the situation and initiating corrective adjustment."*

By analysing this approach the AM system in strategy development could be synthesized but steps 2 and 3 above are not clear. The problem can be clarified by asking; what if the long and short range performance objectives set in step 2 cannot be practically or technologically achieved and what are the asset requirements to fit the plans for producing the performance targeted in step 3? These questions highlight the possible role of AM in strategy development because both performance and requirement are related to the required asset performance and capability. The technical capabilities, e.g. asset performance and capability may act as barriers to implementing the strategy or achieving the objectives. It is proposed that the capability of assets or expected performance of the life cycles should stimulate the development of strategy and give rise to a bottom-up loop in the strategy making process. As reviewed in strategic management literature earlier, strategy may need to be modified but this should assist with decisions on the performance and capability of assets, including their allocation and actual requirement. Technical decisions such as replacement, maintenance or upgrading of assets should be analysed at a lower level to fit the strategy and flow up the hierarchy to fit business objectives and possible investment or budget allocation.

Having developed a framework of AM related activities an alignment between the AM system and business management may be developed to represent the role of AM in the process of formulating strategy. This process requires linking or aligning the technical and

business decisions. It is suspected that such integration of decisions requires that the AM system be structured to link top management teams with those managers dealing with the management of assets at lower activity levels in a well managed way. The middle management perspective on the strategy development process e.g. Wooldridge, Schmid et al.(2008) argue that the lower managers have a key role in decision making by providing both feedback and planning to implement decisions. This view requires maintaining initiatives and feedback in a bottom-up approach while setting business objectives and approval in a top-down approach. In this way top management teams can formulate concrete positions relative to markets or stakeholders and translate them into business objectives or targets related to technical performance or capability(Dwight and El-Akruti 2009). On the other hand asset managers can evaluate asset performance and capability; and define the assets required for the strategy to succeed. During implementation it is suggested that asset managers need to obtain progress reports and feedback.

The strategy making process may be viewed as process that depends on two sets of management activities:

1. The business management system activities that control business performance or output objectives.
2. The AM system activities that set the strategy in terms of the resulting asset performance and requirement to ensure that the objectives of the business are met.

In this manner strategy making is suggested to be a cyclic process that involves top down business decision making and bottom up AM decision making.

Although the link between the business management system and AM system is required, the AM activities that comprise this link are still undefined. It is still unclear what these AM system activities are or how they play a role in formulating strategy, therefore they should be defined and their management process synthesized.

3.5 The New Paradigm of Asset Management System Activities

Asset-related activities have been established as presented in Figure 3.5, but AM system activities are not clearly established yet. AM system activities are part of the asset-related activities. Activities or sub-activities that are considered related to assets are numerous. Examples of AM activities among asset-related activities are, repair analysis, condition

monitoring, replacement analysis, refurbishment analysis, outage scheduling, maintaining asset information records, measuring asset performance, design and procurement of assets and spares, deployment of assets, life cycle costing or prediction, maintaining the availability, reliability, and maintainability of assets, and so on. These examples show the complexity of AM because those activities can be dealing with the technical, managerial, or business aspects of dealing with assets. The difficulty is not in realizing all these activities but from defining them as a linking process or mechanism for the strategic purposes of an organisation.

Defining the levels of management at which these asset related activities exist distinguishes the AM activities as decision making and control activities from the technical or operational activities. Organisational levels are also important because they highlight the different roles that each AM activity may play in the development of strategy.

As revealed in the literature, AM activities may be classified under some organisational categories. Those presented by Kostic(2003) as "*asset-oriented, network-oriented and enterprise-oriented*" are relevant to this research. The activities under each category are the responsibility of many asset-related activities in an organisation and vary relative to context, stage of life and type of organisation. Organisations have always carried out these activities. Performance measurement, analysis, decision, plan or adjustment, and task control are always done in carrying out operation, maintenance, disposal, development, modification, or any investment project of assets. Budgets are always specified, resources allocated, and information about the condition and performance of the assets are usually obtained in some format. These activities are part of various asset-related activities in the organisation but they may not be integrated to serve the strategic purpose of the organisation. This paradigm can be verified from industry.

In some industries, AM is plant maintenance, while in others it is used as a synonym for plant management or even enterprise management, e.g. in the energy or transportation industry. The power generation industry is an example where the form 'plant management' fits nicely because technically, 'generators' are plants, and financially, generators produce power, which is distributed for financial revenue. However, in the power transmission and

distribution industry, the interpretations of what AM is are many, as shown by answers from some Swiss utilities (Kostic 2003):

"It is mastering the state of the equipment...what shape ... equipment is [in]. ... identification of assets through ... GIS (Geographic Information System). ...support for computing the ROI (return on investments) and the value of the assets. ....what equipment to buy... whether to buy shares in a generating unit. ....he legal issues related to asset life cycle"

Certainly the essence of an AM system can be drawn out of an amalgam of these responses because it deals with organisation wide management. In support of this view, Sinha, Lahiri et al.(2007), stated that:

"The enterprise AM (EAM) system forms an integral part of the management process in utility businesses AM system is a key component of business performance. Making existing assets work to deliver improved performance allows investment plans to be targeted where need really exists…"

From this perspective, a good AM system may be considered to be about these key principles: proper design and management to maximise capability, reliability, availability and utilization and minimise the cost of the life cycle (capital, operating, maintenance, support and disposal cost). This involves the concept of enterprise AM that manages the life cycle of assets and the risks involved (from needs definition to retirement) in integration with the organisation supporting activities such as finance, accounting, procurement and personnel.

Put another way, an organisation management system can be looked at from two views, the operations management discipline (procure-operate-deliver output or service), and the assets management discipline (identify need-acquire assets-maintain- keep, develop or replace). While these two disciplines are inter-dependent in action, the former is directly related to business and easily governed by finance budgeting for short-term cost and profitability. However, the latter contains the strategic relationship with customer value which is hard to quantify due to the uncertainty or risk involved in investment decisions and the intangible relationship with business or stakeholders.

What distinguishes the AM system in an industrial engineering discipline from operations management is the conscious life cycle consideration of:

1. Optimizing performance and minimizing costs.
2. Justifying the budget and investment by a long term return on spending or ROI,
3. Justifying improvement of assets, and their management systems for long term need.
4. Minimizing and mitigating risk to quantify and prevent failures.

3.5.1 Synthesizing the Asset Management System Activities

The new paradigm of the previous section reveals that there is a whole set of technical and managerial activities, not just a single one. It is a set of different activities performed to optimise the trade off between effectiveness and life cycle cost of assets or reliability, and costs for the organisation and its customers.

But these technical and managerial activities are part of many asset-related activities of the organisation, so how is AM accounted for in all of these? Or, how does AM exist as a system with a set of activities, relationships, and inputs and output? This has not yet been revealed by literature.

From a practical view in utility industry, an analysis of responses form workers results in a set of activities under the three categories presented by Kostic(2003) :

1. Enterprise-oriented activities involve strategic decision taking about investments, overall reliability and policies set up. They are managerial activities, and rely on the results of the other two groups.
2. Network-oriented (or system) activities deal with the outage scheduling (for maintenance), with respect to system constraints, such as maximum load and required network reliability. Organisationally, they are usually the responsibility of operations, but need some coordination with Maintenance.
3. Asset-oriented activities focus on an asset as a component (e.g., transformer “xyz”), or on the population of assets of similar type (e.g., all 500 MVA transformers). These activities are closely related to one specific instance or one specific type of physical asset. Organisationally, they are usually the responsibility of the Maintenance department.

These activities are specific to their context, but how they fit together has not yet been shown, however, they are consistent with the concept of AM as an 'enterprise' system and not a single activity. But technical and managerial activities within such a system already exist in various asset-related activities at different hierarchical levels, so these categories could be used to arrange activities for an AM system framework or model. This can be reorganized from the levels of assets and their management 'typical priorities and concerns' as presented in (PAS 55-1&2 2008):

1. Asset portfolio activities to manage capital investment, optimization and sustainability.
2. Asset systems activities to manage performance, cost, and risk.
3. Assets Activities manage life cycle processes.

From an industrial management system theory, the levels of management can be defined as strategic planning, aggregate planning, and operational tasks (Anthony, Dearden et al. 1989; Anthony and Govindarajan 1995; Al Marsomi 1997). But how can these AM activities be related to these levels?

For example, Anthony and Govindarajan (1995), showed that in an organisation, management control is facilitated by planning and control activities that take place at three organisational levels. They identify them as:

1. Strategy formulation activities: involving planning and control activities to decide on goals, strategies, and policies.
2. Management control activities: involving planning and control activities to implement the strategy.
3. Task control activities: involving maintaining an efficient and effective performance of individual tasks.

As discussed before, these categories of AM activities presented by PAS 55-1and2(2008) guidelines and Kostic (2003) are consistent with the planning and control activities at the management control levels presented by Anthony, Dearden et al. (1989), Anthony and Govindarajan (1995) and Al Marsomi (1997). Accordingly, it is argued here that the AM system is a management control system where its activities are planning and control activities that exist at these three levels. Consequently, the planning and control activities of

the AM system exist at the strategic, tactical or aggregate, and operational levels of the organisation.

The synthesis of the new form of activities is based on the ideas highlighted in the literature review. This builds up on the levels of the organisational management control systems and these categories of AM activities as discussed in the previous section; (Anthony, Dearden et al. 1989; Anthony and Govindarajan 1995; Al Marsomi 1997; Kostic 2003; PAS 55-1&2 2008).

Therefore, based on the concluding argument of the previous section regarding the nature of AM system activities, this research defines the organisational levels and AM system activities at each level as:

1. AM-Strategic Planning and Control Activities at the strategic management level.
2. AM-Aggregate Planning and Control Activities at the aggregate management level.
3. AM-Operational Task Control Activities at the operational management level.

The AM system may be viewed in terms of these three management levels as distinct parts or elements of the management system but noting that they are inseparable parts of other organisational activities. These management levels classify activities according to the span of control over them and how they are inter-linked to form an overall AM system acting as an integral part of the organisation. The classification defines the type of activities: planning and or control, activities. The activities under this classification are not meant to reflect the life cycle of an asset but they constitute the overall set of management activities within the AM system. The activities at each level are meant to control the asset life cycle and associated supporting activities, depending on the problem at hand or strategy to be achieved.

Considering that this research deals with the development and implementation of strategy for an organisation with existing assets, the AM system activities, simultaneously control the asset- related activities to fit the strategy. Therefore, the AM activities span across assets and along their life cycle by managing:

- The needs of existing assets that are at the utilization stage (operation and maintenance) while proactively dealing with the expected future change in the needs of these assets

- The remaining life/technological outage of these existing assets while deciding on their replacement/disposal or development.
- The need to identify, research, design, and acquire new assets in response to changes in current and future requirements.

Management of the asset-related activities is maintained by a cycle of AM system activities along the management levels where each asset-related activity can be considered to have a control process acting on it, that may be iterative, i.e. a cycle of itself. An effective control process or cycle is essential to the successful AM system in developing and achieving organisational strategy.

Further, as illustrated in Figure 3.7, the control cycle involves levels of activities in the organisation. As defined earlier, these levels of management control are strategic, aggregate or tactical, and operational. Each level has its own control activities designed to meet the objective set at the higher level. While the 3rd and 2nd levels of activities meet the objectives at the higher level, the 1st level of activities develops the asset solution and/or sets the decisions to achieve the resulting asset performance that ensures customer value to the business objectives. The 1st level of activities links the AM system with the business management system and presents the relationship with strategy development.

The AM control cycle framework in Figure 3.7 identifies those AM activities at management levels and acting on the asset-related activities. It also defines the relationships between those AM control activities. It also demonstrates the input from one control activity to the next and connects the management levels into one rigorous management system.

The concept of this proposed framework requires some detailed explanation as it is put forward as a possible structure for an AM system. This hypothesised framework may then provide a focus for research to explore the nature of AM systems found in organisations. The various components and the details with each component of this proposed framework have been derived from the idea of a control management cycle similar to the Plan-Do-Check-Act (PDCA) process (Tague 1995; Gupta 2006; Moen and Norman 2011) and the control management cycle for continuous improvement(ISO 9001 2008; Anderson 2011). Others, including the AM council (Asset Management Council 2007) derived an AM model based on the same idea. In this model, the process is argued to be applied to any number of

sub areas of the business or operation. According to the AM Council Model, the four component plans must be clearly driven by the business needs and not just the existence of the assets. This implies that this four-component process is linked to the business strategy of the organisation.

The AM framework proposed here comprises an extended cycle for process management which is building on the PDCA idea but expanded in steps, details and used different terminology. The proposed framework in Figure 3.7 comprises three levels of activities that emerge into a 6 steps' cycle. The strategic planning and control activities consist of: analysis and evaluation and decision making; the aggregate planning and control activities consist of: coordination and planning and control and reporting; the operational task control activities consist of: work task control and measurement and monitoring.

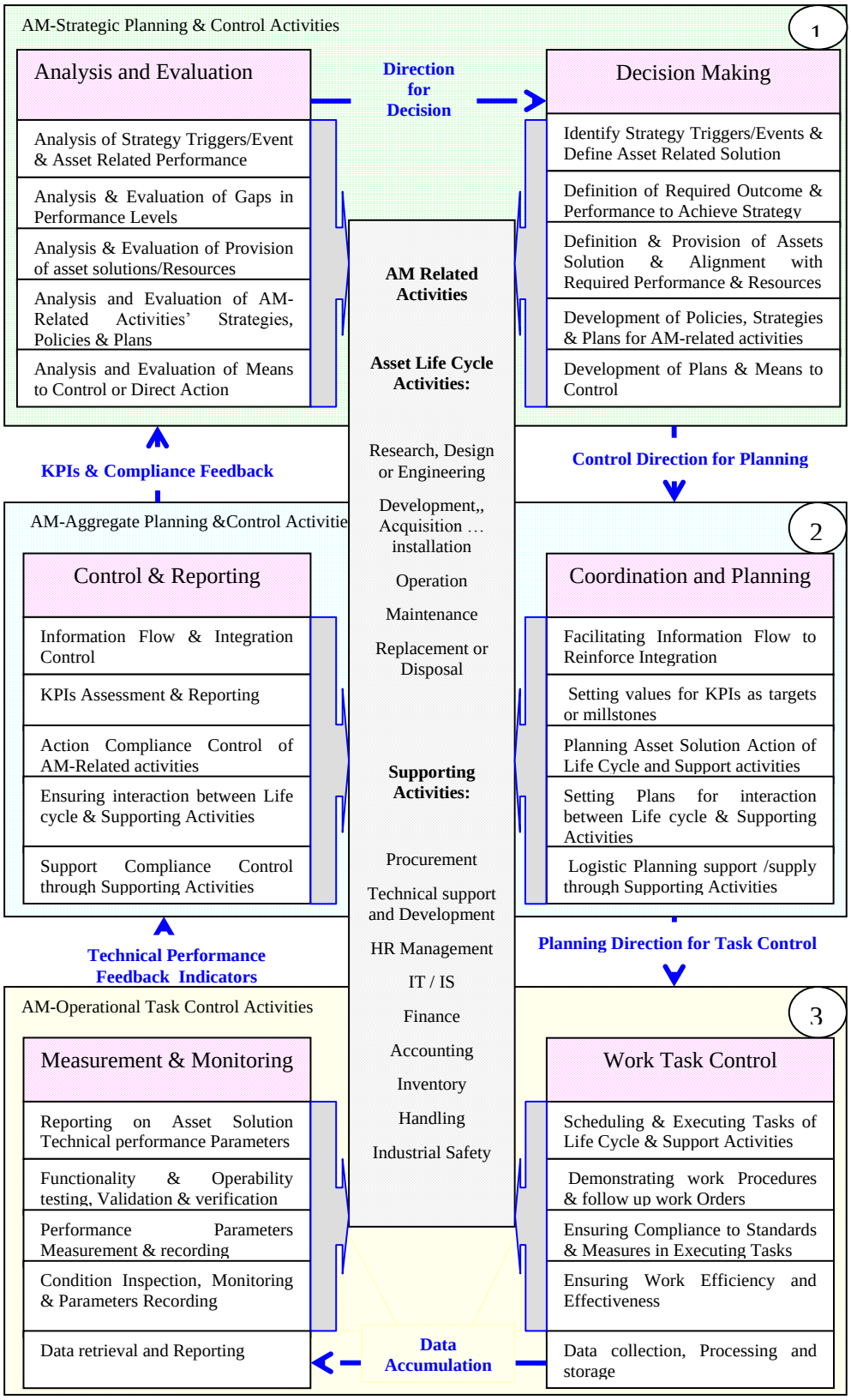

Figure 3.7: The AM System Framework: Activities, Relationships and Mechanisms

Strategic Level (1): Strategic Planning and Control Activities

As indicated earlier, the AM-Strategic Planning and Control Activities consist of two steps:

1. Analysis and evaluation
2. Decision making.

These may be expanded in details as:

a. Identify Strategy Triggers/Events and Define Related Factors. This involves analysis and evaluation to identify and define which factors of the business strategy may be impacted by the resulting asset performance. These factors reflect the need to identify the change to meet long and short term goals in relation to the status and performance of the assets. These factors may be derived from the business strategy statement or from the need or constraints of external stakeholders such as customers, suppliers, contractors, technology advancement, environmental safety, and legal or government regulation. Solutions may be derived by identifying the related life cycle activities, supporting activities or relationship with suppliers or outsourcers.

b. Definition of the Required Outcome and Performance to Achieve Strategy. This involves analysis and evaluation to determine the required performance of assets and then respond to the strategy or triggers/events. This may involve determining gaps in the assets' design, capability, flexibility, reliability, availability, maintainability, life cycle costs, and associated risk and safety aspects.

c. Definition of Provision of Asset Solution and Alignment with Resources. This involves analysis and evaluation to determine whether the assets are performing to their specifications. This means determining whether new assets are needed or the current ones need further development, expansion, upgrade or extension. It also includes defining the utilisation of the assets, their use, maintenance, support, information and/or replacement or disposal. Provision of the asset solution also involves analysis, evaluation, and trade-off to match requirement with the appropriate form, timing, and amount of available resources such as funding, budget, investment, know-how, manpower, training, and inventory and information resources, including provision of suitable information systems, hardware and software or other tools to carry out asset-related activities.

d. Development of Policies and Strategies for Asset-Related Activities. This involves analysis and evaluation to set or choose strategies or policies for the AM life cycle or supporting activities. This includes policies and strategies for design, Technical support and development, acquisition, procurement (contracting, purchasing and inventory), project management, maintenance, use and replacement, disposal of assets, and associated limits or restrictions. These strategies or policies are developed to ensure the assets serve the business objective and strategies while considering the available resources.
e. Development of Plans, Means or Direction to Control Action. This involves analysis and evaluation to translate polices and strategies into means to direct aggregate planning and operational tasks. These may include the establishment or decision to adopt standards, models, control limits, techniques, specifications, procedures, and key performance indicators (KPIs).

With the business activities, these strategic planning and control activities establish the decision to select the correct assets and or define its performance for the strategy. They are viewed as analysis, evaluation, and decision making activities. They establish the basis for deciding on the life of the assets or any adjustment required at the design or utilization stage in the way they are managed, operated, maintained or disposed. On one hand they consider the related triggers/events to determine the performance of the asset while on the other they consider the leading and lagging performance indicators to determine any gap between current performance and the targeted performance.

These strategic planning and control activities also facilitate approval for directing the lower AM activities by establishing input to them at the lower level which assists decision making on aggregate planning and control activities. These strategic planning and control activities control the activities at the other two levels and demand feedback from them to establish analysis, evaluation, and decision making.

At level 1 of Figure 3.7: strategic planning and control activities, the analysis, evaluation, and decisions are based on either reinforcing or trading off alternatives involving criteria such as, cost and benefit, effectiveness, risk and safety, and long and short term objectives. Reinforcing involves adding up the positive impact of activities for a total result that

supports the overall objective or strategy of the organisation(Porter 1985). Trade off, on the other hand is an analysis to provide the optimum cumulative contribution of activities to the overall objective(Porter 1985). This is done to provide a basis for analysing the inter-dependence or impact between activities. This facilitates the selection of alternative actions of doing activities or alternative ways to connect asset-related activities. For example high design costs may reduce the cost of maintenance, new advanced technology or projects verses current assets and high maintenance costs, preventive maintenance verses current maintenance, operating the assets at certain environmental conditions or stopping the operation, or outsourcing verses in-house activities.

In order to maintain such a trade off at level 1 shown in Figure 3.7, various techniques may be involved such as life cycle cost analysis, risk analysis, criticality analysis, financial analysis, and critical factors analysis:

- Life cycle cost analysis involves every activity in the life cycle of assets to determine the costs and their cumulative result for investment, budget, and replacement. And it may also serve as a basis for setting strategies or policies of procurement and technical support and development.
- Risk analysis can be used for identifying, minimizing, and mitigating the risks that may be involved in all the stages or processes associated with assets.
- Criticality analysis can be used to prioritise assets according to their effect or impact on overall performance and prioritise any action.
- Financial analysis is usually used to decide on investment alternatives.
- Critical factors analysis can be used to define critical factors in relation to strategy triggers/events.

In conclusion, these strategic planning and control activities form the way in terms of decision as outputs to strategic management or direction to control activities at the lower levels. However, they depend on input from activities at the other two levels of the process: aggregate planning and operational task control. They facilitate how asset-related activities should perform with asset-supporting activities to achieve the overall objective of the organisation. It is expected that the effectiveness of these strategic planning and control activities depend on a team's knowledge and information connected across the organisation. The extent to which organisations have such activities, structures, expertise,

tools, as an integrated AM system may explain their performance. The hypothesised framework incorporating all of these elements and proposed relationships must be tested to determine its efficacy, as is proposed for this research.

Aggregate Level (2): Aggregate Planning and Control Activities

The AM-Aggregate Planning and Control Activities comprise two steps:

1. Coordination and planning
2. Control and reporting.

These take place as:

a. Coordination and Planning translate decisions regarding strategies, policies, requirements, resources, standards and adopted models or tools into operational plans and procedures, i.e. translating input from higher level activities into an output to the lower level activities. This task involves coordination between activities, integration of efforts, planning of actions and tailoring procedures or standards to the needs. It includes planning the use of assets in operation and maintenance (action and time), planning the implementation of asset-related projects such as replacement and disposal and integrating/coordinating life cycle activities with supporting activities or systems. These planning control activities provide the means to translate strategic and directions into operational action.

b. Control and reporting: supervisory steps provide feedback for analysis and evaluation at the strategic level by translating operational actions and parameters into KPIs and compliance indicators. This is done by assessing operational parameters and following up plans/procedures or verification with reference to standards. These supervisory activities also involve supervising and reporting on the interaction between asset-related activities. The supervision covers all life cycle processes and is provided through testing, validation, verification or compliance verification.

Aggregate planning and control activities require an adequate information system and information management to translate the top-down flow of directions into actions and provide the bottom-up flow of indicators that provide a basis for analysis. These activities and their information systems also facilitate interaction between life cycle and supporting activities.

These aggregate activities are tactical in nature and carried in coordination or integration between asset-related activities to deliver the requirements, but they may exist as separate activities or part of these life cycle or supporting activities. It is suspected that these activities are overlooked as an AM responsibility or the full extent of their impact is not recognized. They can play a central role in integrating actions of activities for efficiency and effectiveness, and identifying causes of conflicts, deficiencies, and unwanted costs. They can help control activities for the purposes highlighted by strategic events.

Operational Level (3): Operational Task Control Activities

The AM-Operational Task Control Activities constitute task control and measurement and monitoring steps. They are operational and done separately by the various asset-related activities. They may be divided into task control and measurement/monitoring of operational parameters:

1. The task control steps involve supervising the action directed by the higher level to ensure that it is executed according to plans, procedures, standards, limits, and the like. This means carrying out the proper technical action of the asset-related activities at the various stages of the life cycle, materializing the design, implementation of projects, using the assets to operate and to restore them by maintenance or retiring them by replacement/disposal.
2. The measurement/monitoring steps involve measuring the technical performance parameters (TPP) and inspecting or monitoring to measure the condition parameters (CP). They also involve collecting data, processing and retrieving, and reporting quantitative values of these parameters. It is really a feedback on the operational actions by reporting on parameters to the higher level activities. These activities generate the data base for these technical parameters. Such data is generated by inspecting, monitoring, or measuring the condition, performance, and safety of assets. They also include testing, validating and verifying the design, functionality, and operability of assets through maintenance, operation, design, and project management. These activities generate quantitative figures of technical performance parameters at any stage of their life cycle.

3.5.2 Existence of the Control Mechanism of the AM System Activities

The AM control mechanism may be considered to take the form presented in Figure 3.7. In an organisation this process provides direction on how asset-related activities should be performed relative to the various assets and their life cycle processes. Therefore this notion highlights that the AM system manages these life cycle activities by planning and controlling them to establish the outcomes that match the intended strategy.

By accepting this notion, the mechanism for AM system activities can be further synthesized as a set of planning and control activities that facilitate operational, tactical, and strategic decision making. This mechanism emphasises the monitoring of current action and interaction to define the future requirement for assets and their life cycle processes and match the achievement or sustainability of performance with the business strategy. It also identifies the means for inter-relationships between asset-related activities. This mechanism facilitates coordination between the asset-related activities and proper flow of feed-forward and feedback information.

It is suspected that if AM mechanism existed it would control and direct the way life cycle activities should perform in coordination with other asset-supporting activities for the overall objective of the organisation. This should result in an overall asset performance that accounts for all the changes required for responding to strategy triggers/events.

3.6 Asset Performance and Contribution to Customer value

Asset performance results from the integration of the performance of the asset-related activities. Such performance reflects the inter-dependent performance of all the life cycle activities. Therefore asset performance is the resulting performance relative to competitive strategy. The parameters of this asset performance include:

1. Those capability parameters such as productivity, load, quality, precision, or flexibility, and functionality parameters.
2. Those utilization parameters such as availability, reliability, safety and effectiveness.
3. The life cycle cost parameters (e.g. investment, budget, production or operation cost and disposal cost) and risk parameters

The parameters of the resulting asset performance are then linked to the customer value creation logic for competitive advantage (delivering value to the customer and a margin for the organisation) and not just focusing on minimizing the cost of the life cycle.

The customer value creation process in an enterprise involves striking a compromise between external and internal factors that drive value generation or constrain resources. The factors involved in this compromise can be summarized as follows:

1. The relative business determinants of the competitive position in industry.
2. The targeted products or services and operational plans for achieving a favoured competitive position, and the factors that determine them.
3. The attractiveness of investing in assets in a particular industry to achieve and sustain a competitive position, and the factors that determine it.
4. The alternatives of design, utilization, maintenance, and disposal of assets to perform over their life cycle in order to create customer value and maintain a competitive advantage, and factors that determine them.

Only the factors in points 3 and 4 are related to the strategic role of AM, but are definitely linked to 1 and 2. Therefore, the customer value created is determined in part by factors generated outside the enterprise that are favoured competitive position. However, long term industrial profitability as a function of competitive price, premium products, or services and response to customers, depends on the performance of these assets that create customer value. These can be divided into financial and technical performance parameters:

1. Financial parameters include asset related investment, life cycle costs and the associated risk involved.
2. Technical performance parameters include various areas such as capability, productivity, capacity, load, quality, precision, flexibility, availability, reliability, safety, effectiveness and efficiency.

Measurement of these performance parameters expose the customer value created.

Since customer value is partly created inside the enterprise, competitive strategy must take account of the likely performance of the assets that drive customer value. Actual performance depends on how the various asset-related activities and management activities are performed. However, it is difficult if not impossible to separate asset performance from

operational or production performance or overall organisational performance. Isolating the customer value contribution by AM cannot easily be achieved. Some aspects of organisational performance that are impacted on by the AM system for customer value creation include:

1. Optimizing asset performance and its life cycle cost.
2. The justification as ratios to return on spending as investment in assets, and as an associated budget of asset-related activities.
3. Predicting the condition of assets, quantifying the risks and preventing failure, accident, or catastrophe.
4. The selection of alternative strategies for asset-related activities to improve the performance of assets, including developing or innovating assets and enhancing their life.

Reflecting this challenge in measuring performance, AM may involve reconciling conflicting demands such as:

1. Providing and maintaining the right assets, the right technology or innovating assets to establish their performance that achieves competitive products or services
2. Maintaining the required levels of performance in terms of maintainability, reliability and availability of assets that can deliver premium products or services with higher levels of satisfaction than competitors.
3. Maximizing utilization, efficiency, or effectiveness of the assets for a superior price to the customer.
4. Minimizing the life cycle cost of assets to maximise returns, profitability and satisfy shareholders.
5. Minimizing risk and maintaining a safe environment, complementary with society, and conform to legal and government regulations to sustain competitiveness.

These must be reconciled while facing constraints such as:

1. Conforming to some stakeholders needs may be limited by high costs.
2. Innovation requires investment that may be constrained by budget or funding.
3. Conformance to safety or regulation may impose very high costs.
4. Maximizing asset utilization and minimizing the life cycle cost is a hard trade-off.

5. High reliability and availability are costly and need to be matched to future business demand, which is usually a function of uncertainty.

In the context of this research, AM system activities are those activities within an organisation directed at ensuring the performance intended of the assets. The challenge raised by the value chain framework (Porter 1985), is to identify and disaggregate activities to know by which sub-activities customer value is really created. It is argued here that the levels of resulting asset performance reflect indications of the customer value created and highlight the link to these sub-activities and the associated management activities.

In conclusion it is proposed that AM activities, mechanisms and relationships determine the extent to which the asset-related activities outcomes result in the required asset performance. This performance must be measured against the strategy. In any organisation an AM system and business management system must exist but there has been little distinction between the activities, mechanisms and relationships that plan and control of the asset-related activities to establish appropriate asset performance. It is expected that these AM and business management systems play an important role in establishing the expected asset performance against the intended strategy, but how they are linked in this process is not clear.

As such the integration of the AM system within the organisation system needs to be defined and synthesized to explore the role of AM for competitive strategy.

3.7 Integration of the AM System within an Organisation System

Having accepted the notion that activities of the AM system are a set of planning and control activities existing over the organisational levels, the AM system can now be defined.

3.7.1 System Functional Model for Asset Management

To establish how an AM system may fit in an enterprise for strategy development and implementation a view of the basic functional flows is imperative to understand the relationships. A system functional model that offers a better view of the integration of the AM system is developed in Figure 3.8. This system functional model is of a general format

but offers a way to show asset-related activities, control activities, relationships, and the boundary between a system and its external environment.

This system functional model builds on the production model devised by (Al Marsomi 1997) and the widely recognized models in system theory and functional analysis, e.g. (Hunger 1995,71). Such models are based on the functional flow; input, activities, output, and feedback control. However, the system functional model developed here also includes the supporting activities as found in the value chain framework (Porter 1985), and the life cycle activities as found in the life cycle framework (Blanchard 1990; ISO/IEC 15288 2008; 2009).

To understand the logic of this system functional model, a comparison with the value chain helps illustrate what this system functional model adds:

1. While in the value chain only the conversion flow is shown and denoted by the primary activities, in this system functional model Figure 3.8, the life cycle activities are included as well.
2. In addition to the primary and supporting activities this system functional model shows the AM activities, relationships and mechanisms of control.
3. The value chain concentrates on a configuration of value activities to derive value from them and illustrates the important role of linkages for competitive advantage. It does not show allocation of management responsibility or linkages to manage strategy development and implementation.
4. In this system functional model Figure 3.8 the AM system is presented separately with three different levels of activities, and control elements over the asset-related activities and their relationships. A control mechanism is shown in terms feed-forward; solution, strategies, policies, plans, control direction and feedback; KPIs, compliance and technical performance indicators. This mechanism provides an iterative process for controlling the asset-related activities to analyse and evaluate maintained information before taking decisions to control their actions. This system functional configures the responsibilities, rules and re-assign rules to maintain a chain of control to link with organisational strategy. Such an alignment highlights

that any deficiency can be declared as a priority, at any time, if that will help the businesses or competitive position.

The AM system as labelled in Figure 3.8 is considered to be usefully viewed as being integrated within the enterprise system as shown by this system functional model in Figure 3.5. It shows the control elements over the various organisational levels and across activities. In one way or another, these interact to cope with the strategy events or requirement to achieve a performance that contributes to customer value.

The framework developed in Figure 3.7 and the system functional model in Figure 3.8, are proposed as guides to AM practice to realise the structure and mechanism required by an AM system in order to play its role in the organisational strategy. As proposed by these, the existence of the AM activities, relationships and mechanisms depicted may result in the required management actions that allow achieving the required performance. Such actions can be extracted based on the AM framework and the system functional model and should be reflected in these steps:

1. Identifying the strategy event/ change and the associated business performance requirement.
2. Determining the performance of the asset to achieve the performance needed to cope with the strategy event/change.
3. Selecting or designing a suitable solution to achieve, ensure, or maintain the required asset performance.
4. Determine the asset solution, the requirement of asset-related activities (life cycle and supporting activities) to establish and implement the solution.
5. Translating the asset solution into strategies, policies, plans, and control action to perform asset-related activities in order to achieve this performance.
6. Maintaining approval for adoption and implementation of the solution and implementing it.
7. Review strategy by maintaining feedback on compliance to targets in terms of performance indicators or measures, defining the gap, and adjusting accordingly.

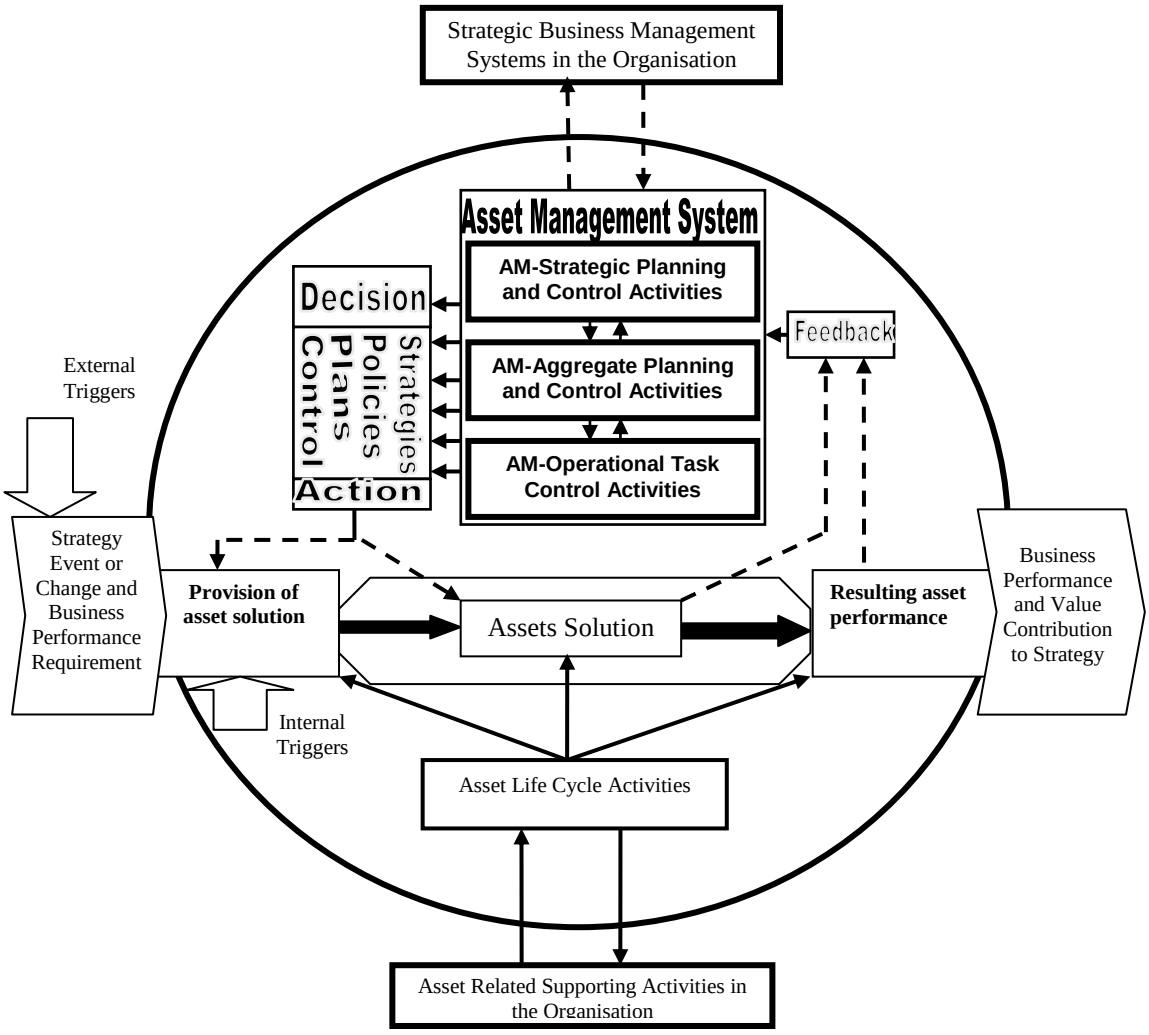

Figure 3.8: The Asset Management System Functional Model

However, it is argued here that such steps can only take place if the structure and mechanism of the AM system proposed by the developed framework actually exists in the organisation. Furthermore, the effectiveness of such management procedure also depends on factors that facilitate the proper existence of activities, relationships, and mechanisms. These factors may include information system and technology, knowledge and experience, culture and incentives. Hence, these factors are accounted for in defining the proper existence of activities, relationships and mechanisms.

3.8 Research Hypothesis and Proposition

A framework for the AM system is developed and a system functional model is established to accommodate its integration within the organisation system. It is proposed that the AM

framework and system functional model adequately represent the role of the AM system in the strategy development and implementation. Utilising the combination of the AM framework and its system functional model should constitute a guide to design a methodological approach to undertake this research.

The overall hypothesis to be tested is that: the AM system can be viewed as having a key role in developing and implementing organisational strategy. Certain AM system activities, relationships, and mechanisms must exist within an organisation for this to occur effectively.

These activities, relationships, and mechanisms are proposed as a hypothesized framework shown in Figure 3.7. This framework is integrated in the organisation by a hypothesized system functional model shown in Figure 3.8.

In serving the objective of this research, the structure of the AM system is proposed in a AM system framework reflecting activities, relationships and mechanisms and integrated in the organisation system in the form of an AM system functional model. This is proposed in terms of:

1. A configuration of the asset-related activities, including life cycle and supporting activities, Figure 3.5;
2. An AM system framework comprising activities, mechanisms and relationships of the AM system over the asset-related activities, Figure 3.7; and,
3. An AM system functional model that is an assemblage of the above figures in one model integrating the AM system framework into the organisation system model, Figure 3.8.

4 The Research Design

4.1 Overall Research Process

This chapter is considered critical to the connection between defining the problem and validating the findings for generalization. The main concern here is how to organize data to answer the research question. A presentation of the research process is shown in Figure 4.1.

In chapter 2 the retroductive research strategy and the embedded case study method were identified as an appropriate combination that establishes the methodology for undertaking this study. Chapter 3 dealt with developing a framework that fits the appropriate structure and mechanism of the AM system. The developed framework was fitted into a system functional model to establish its integration within an organisation system. This chapter establishes how the system functional model developed in chapter 3 can be used as a hypothesized model within a retroductive methodology and how it can be verified by the use of the embedded case study method. The remainder of this chapter is devoted to the retroductive case study design by detailing all the methodological procedures to be followed to guide data collection, sorting, and analysis, relative to the specific context of the case study.

4.2 The Retroductive Case Study Design and Methodological Procedure

4.2.1 Case Study Design

The research design is considered critical to achieving validated results and if the objective is to generalise the findings. The main concern in this chapter is to put forward a design that identifies how to implement the retroductive methodology for this specific research question? This will include collecting data and organizing it to answer research questions that are relevant to AM. Research is judged by the ability to produce valid knowledge (Silverman 2001; Kiridena 2009). While validity and generalization concepts for case study were discussed in chapter 2, construct and internal validity are essential for validating case study design. For case studies, Yin(2003), interpreted construct validity as the ability to establish correct operational measures of the concept being studied, while he interpreted internal validity as the ability to conclusively establish cause-and-effect relationships.

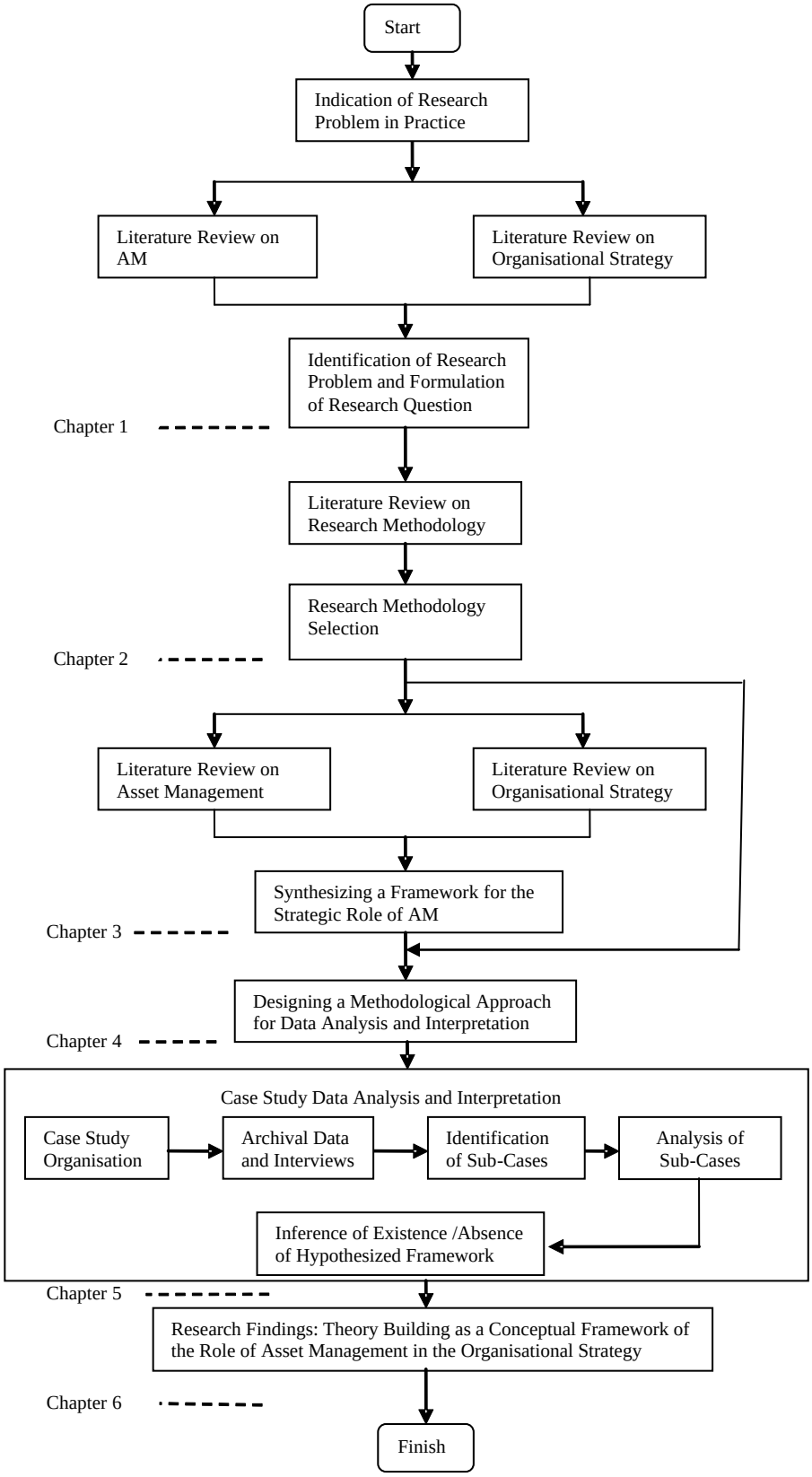

Figure 4.1: The Research Process used

The details of the proposed methodology require definition. This involves setting the details of all procedures to be followed based on the retroductive case study design. This design is based on a combination of the hypothesized model of the retroductive research strategy (Blaikie 2000) and the concept of 'embedded case study'(Yin 2003). This case study approach involves the investigation of sub-cases while the organisation remains as the main case study. The research should incorporate a sequence of events in a historical and longitudinal data collection to establish the causal relationships between these events. A sequence for the purposes of AM may follow the flow illustrated by the system functional model in Figure 3.8: i.e. the progression from strategy change to asset solution and eventual asset performance. The study of each strategy change and resulting sequence of events constitutes one embedded case-study. Each sub-case can be analysed to determine the effects on the change in the organisation's strategy. This allows for having sub-cases while still treating the organisation as a single case-study.

Clear and detailed approaches to case studies have not normally been made explicit. According to Yin(2003):

"The analysis of case study evidence is one of the least developed and….Unlike statistical analysis, there are few fixed formulas or cookbook recipes to guide the novice. Instead much depends on the investigator's own style of rigorous thinking, along with the sufficient presentation of evidence and careful presentation of alternative interpretations."

This matter is lacking in most qualitative published studies. Kiridena (2009) stated that exposition of methodological approaches is sparse in qualitative research publications. In addition the retroductive research strategy is not fully developed. Blaikie(2000) stated that:

"The retroductive strategy still relatively undeveloped ….When the researcher uses the retroductive strategy… all measurements have to be directed and interpreted using the constructed (hypothesized) model. In the end, the degree to which any model is a valid representation of reality will be a matter of judgment".

One of the well established case study design approaches is based on socio-technical theory and termed the contextualist case study approach proposed by Pettigrew (1985). The strength of this approach lies in the necessity to describe phenomena in detail and in the context within which the case study is embedded. This contextualist approach has been

widely used in research to investigate the strategic decision making process and the dynamics of organisational change as a process or sequence of events over time e.g. (Pettigrew 1985a; Dawson 1996a; Nelson and Dowling 1998; Siti-Nabiha and Scapens 2005; Chapman 2006b).

Pettigrew(1985) argues that relative to collection, sorting and analysis of data, a contextualist has three general basic elements to use:

1. The context component; including external and internal context.
2. The process component; including events and management actions unfolding over time.
3. The outcome component of the process under investigation; including decisions undertaken and process performance.

He states that: *"…the key to the analysis lies in positioning and establishing relationships among context, process and outcome."(Pettigrew 1985).* He emphasized this notion as 'embeddedness' and interconnection of process and action across systems.

Drawing on this view, Chapman (2006a) developed an application of this contextualist methodology to study socio-technical phenomena related to asset failure phenomena. In his new application to work with a specific case, Chapman(2006a) used several theoretical elements representing data categories for data collection, sorting and analysis. These categories were: immediate cause; triggering events; signal events and conditions present for some time. Based on these he further structured them into pre-specified design procedures for data collection, sorting and analysis.

With reference to research into organisational change, Dawson (1994; 1996; 1996a; 2003) argues that a useful way of tackling the problem of analysing complex change data is to construct data categories either around themes or around various activities and tasks associated with organisational change. He emphasized that: *"…appropriate data categories….should … fit particular case examples and the characteristics of different change programs" (Dawson 2003).* He advocates three general categories:

1. The initial conception of a need to change; in response to external or internal pressure (reactive) or through a belief to meet future competitive demands (proactive).

2. The process of organisational change; during which complex non-linear actions occur comprising a number of different tasks, activities and decisions for individuals and groups both within and outside the organisation.
3. Operation of new work practice and procedures; emerging outcomes including new organisational arrangement and systems of practice.

Whilst the work on AM systems does not focus on organisational change, it is proposed that AM related activities and decisions may be investigated using similar approaches. Both the retroductive and contextualist approaches investigate a sequence of phenomena over time. They both use the same ontological approach: a model or framework for data collection sorting and analysis. However, they differ in their epistemological approaches in the sense that the contextualist approach seeks a descriptive account of the phenomena studied over time while the retroductive approach is directed at determining whether the underlying structure and mechanism proposed by the hypothesized model explains the phenomena.

4.2.2 Tailored Retroductive Case Study Design

The ideas of the retroductive approach and the issues around the method of data collection and analysis may be related to the specific problem of AM system research. This is best done by considering a representation of an organisation and the interfaces with AM as illustrated in chapter 3 by the AM system functional model in Figure 3.8. As such, the existence or adequacy; or the absence or inadequacy of the underlying structure and mechanism of such a hypothesized model can be verified by a two-stage process. Stage 1 involves establishing the sequence of an observed phenomenon: the strategy event; the asset solution choice; asset provision; and, resulting asset performance. In this case, these are represented within the hypothesised model devised. Stage 2 involves drawing implications for the nature of the asset management system from the phenomenon defined in Stage 1.

Both stages involve analysis of elements of the system functional model. These elements are presented as specific parts of the hypothesized AM system functional model as identified in Figure 4.2. Elements 1 to 4 belong to Stage 1 and follow the contextualist

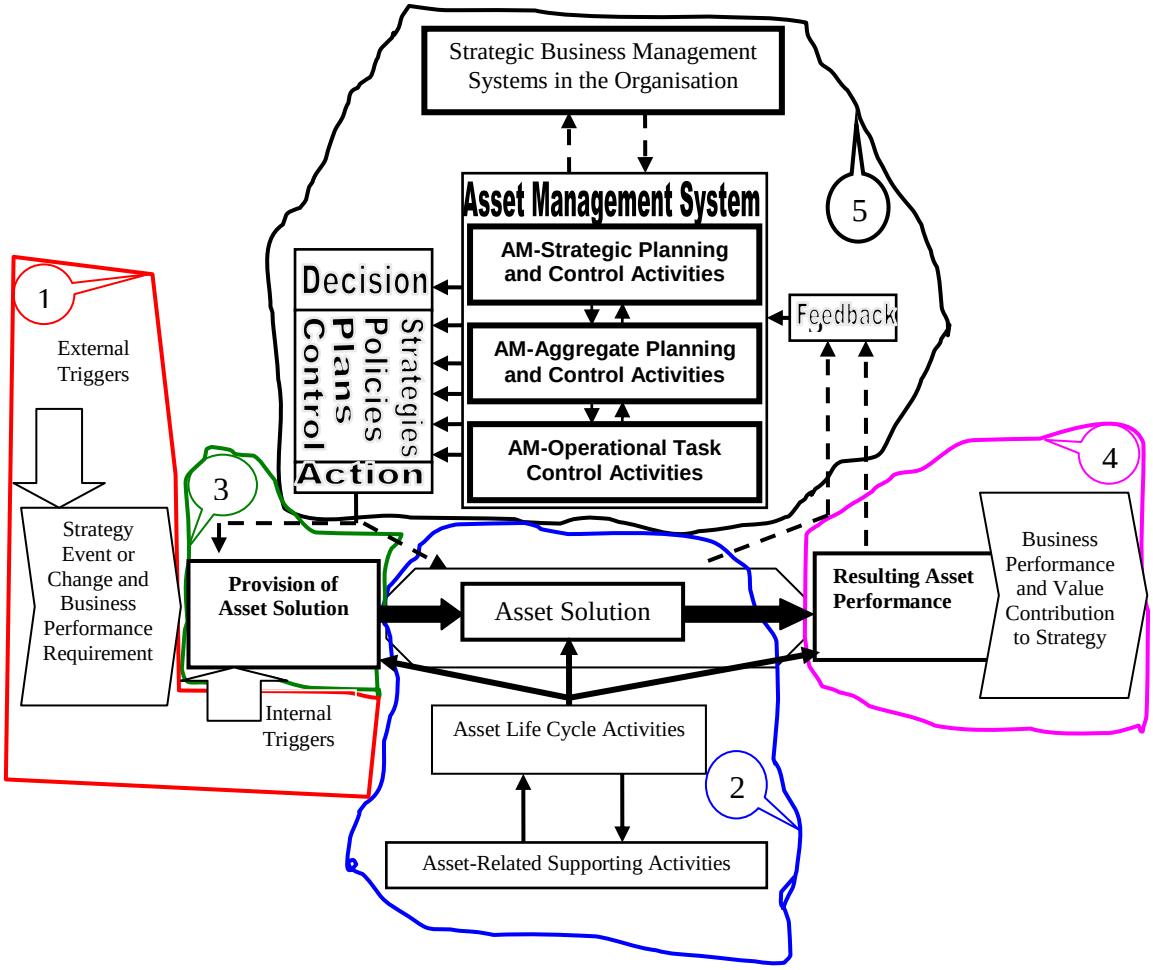

Figure 4.2: Elements of a possible hypothesised AM Model to use in a retroductive methodology

design and require a descriptive account to convey sequence of occurrence of phenomena. Element 5 belongs to Stage 2 and follows the retroductive design which focuses on the existence of these underlying activities, mechanism and relationships of the AM system to explain the underlying reality for action to take place in certain ways. The 5 elements are identified as:

1. The strategy event or change: this may include triggers of external or internal environment
2. The asset solution: this involves the action in response to this strategy event which may include the change in assets, life cycle activities, asset-related supporting activities or the relationship between them.

3. Provision of the asset solution: this involves the provision of the requirements of assets, their life cycle activities or supporting activities.
4. The resulting asset performance: this involves the results which may include the resulting technical performance relative to assets or the asset-related activities and the resulting business performance.
5. AM system 'control': this constitutes activities, mechanism and relationship to direct actions for the provision of the solution and achievement of the asset performance and business outcomes. This may include planning, feedback control, decision making and managing technical tasks.

4.2.3 Structuring the Procedure

The object of analysis in this case is the AM system. This is represented as element 5 of a AM system functional model as set out in Figure 4.2. The process of 'data collection, sorting, analysis and interpretation' can be structured to match with the five elements of the hypothesized model. Data collection and sorting involves: identification of the strategy event, definition of the asset solution, provision of asset solution and establishing the outcomes. Analysis and interpretation involves: establishing and interpreting the AM control action. These steps comprise the analysis and interpretation of a sub-case.

Stage 1: Establishing the phenomenon

Stage 1 involves 4 steps referenced to the asset management system functional model and provides the data required to evaluate the asset management system in place:

1. Identification of a Strategy Event or Change: This involves identifying a strategy event/change that took place as a consequence of some external or internal triggers.
2. Definition of the Asset Solution: This involves identifying the particular asset solution(s) adopted in response to the change in strategy. Definition involves determining if the response was an asset solution and what resulted from that response. This occurrence of an asset solution in response to a change in strategy defines the sub-case to study as proposed by the model.
3. Provision of the Asset Solution: This requires the recording of how the asset solution was provided. This includes details of designs, plans, testing, resources used, budgets and procedures of implementing the solution for example.

4. Establishing the Outcomes: This involves the resulting performance and value contribution and requires three steps:
    a. Establishing the resulting asset performance associated with the selected asset solution. This involves defining whether these resulted asset performance indicators are in compliance with the designed or targeted performance.
    b. Establishing how the resulting asset performance is translated into business outcomes. The resulting business outcome is an indication of the outcome of the AM system.
    c. Establishing whether the resulting asset performance has resulted in positive or negative value contribution. This involves indications/indicators of the value contribution or destruction as delivered by the AM system. Positive contribution is an indication of the existence and adequacy of the AM system and negative contribution is an indication of absence or inadequacy of the AM system.

Stage 2: Drawing Implications from the Phenomena

This involves establishing and interpreting the AM control action relative to a hypothesized framework utilising the data resulting from stage 1.

Establishing and interpreting the AM system in place involves verifying the existence or absence of the activities, relationships and mechanisms of AM system as postulated by the framework. Establishing the existence (adequacy) or absence (inadequacy) of these involves the following four steps:

1. Establishing how the organisation decided that a certain strategy event or change required an asset solution. This will provide some indication as to the existence or absence of the relationship between AM and the organisational strategic development process. This will indicate how the AM-strategic planning and control activities handle the relationship with the strategic management system and the interface-relationships with external environment such as supplier, contractors, outsourcers, manufacturers, regulators or environmentalists for example.
2. Establishing how the AM system established the possible solutions and how the particular adopted solution was selected over others as the most suitable to achieve the strategic objectives. This will provide an indication of the existence or absence of the

AM-strategic planning and control activities their interrelationships and control cycle as proposed by the model's control mechanism. These include analysis, evaluation of the gap in the resulting asset performance to achieve the business performance for the strategic objectives. They also include the decision activities based on the feed-forward flow from the strategic business management and the feedback from the other two levels of activities in the model's control and feedback cycle.

3. Establishing how the AM system dealt with the provision of the asset solution to achieve the resulting asset performance. This will indicate the existence or absence of the AM-strategic planning and control activities their interrelationships and control cycle as proposed by the model's planning and control mechanism. This includes analysis, evaluation of requirements of the asset-related activities to cope with the resulting asset performance. It also includes the decision activities based on the feedback from the other two levels of activities, aggregate and operational.

4. Establishing how the AM system dealt with implementation of the asset solution. This will give an indication to the existence or absence of the AM-aggregate planning and control activities and the AM-operational task control activities. It also provides an indication to the interrelationships existing between these two lower levels of AM system activities with the AM-strategic planning and control activities. These interrelationships include on one hand, a feed-forward flow in a top-down direction for the solution implementation in terms of strategies, policies, plans and task control of the asset-related activities. On the other hand, they include a feedback in a bottom-up direction as basis for carrying analysis, evaluation and decision making support for selection and formulation of the asset solution for the strategy.

As a result of analysing a specific sub-case, a conclusion on the value contribution toward the customer value resulting from the associated asset performance can be established and then related to the existence or absence of the AM system as proposed by the framework adopted and integrated by the AM system functional model. This resulting customer value provided by the AM system can be translated into contribution to the achievement of the organisational strategy. Therefore, in a sub-case, explanation of how the structure and

mechanism of the AM system plays a role in the organisational strategy can be established. If the investigation of several sub-cases is undertaken on the proposed framework and integrated by the AM system functional model, then the process may begin to establish theory on the role of AM in the organisational strategy and the importance of such a role.

In this type of case study investigation the AM-related solutions or actions are examined to determine how they caused performance outcomes and indicate if other causes may be involved.

Interpretation requires a detailed search for causes and resulting effects. For each sub-case the particular strategy event or change can be investigated to understand how such an event was responded to with an asset solution. The management behaviour of the asset-related-organisational activities and the resulting asset performance can be assessed. The search is for both negative and positive results while referencing the cause to absence or existence of AM system activities, relationships and mechanisms. Such existence or adequacy or absence or inadequacy may be associated with duties and responsibility related to the asset-related activities. Negative results may be associated with missing or poorly executed AM system activities. Positive results may be associated with appropriate AM system activities. Activities may not exist at all or may not exist to the extent that serve the strategic purpose and may exist with conflicting objectives or with negative impact on each other. The ultimate conclusion is to demonstrate that the achievement of the strategy is due to having adequate AM system in place or its poor achievement is due to inadequate AM system in place. However, results may also be influenced by non-AM factors such as a particular individual's approach to the organisational environment. In such cases these factors should be identified and their associated impact illustrated.

4.3 The Choice of Organisation and Data Collection Method

In this research it is important to use an industrial organisation where the framework may be verified by existence. In the context of this research, the organisation should be capital intensive with its success being contingent on its asset performance. The capability of conducting a detailed investigation of a capital intensive organisation is a key. It is required that the researcher become familiar with the organisation so that the context can be

adequately understood. According to Lawler III, Mohrman et al. (1985) research findings may not be useful to theorists and practitioners because they do not describe the actual behaviour of an organisation. Familiarity with the organisation makes the researcher capable of understanding the context of that organisation and interpreting the participants' responses or narratives. It is preferable to find organisations that may be interested in the outcomes of the research because it will facilitate obtaining data and encourage participation by employees.

As the design procedures indicate, the case study approach to be employed follows the 'embedded case study' method. Sub-cases are investigated while the organisation remains the main case study. Each sub-case comprises a sequence of events in a historical and longitudinal collection of data aimed at establishing causal relationships between events. In the case of asset performance only long term performance can explain the extent to which organisational strategy achieved change.

As indicated earlier the unit of analysis will be a strategy event that requires an asset solution or solutions resulting in achievement to some extent of the organisational strategy. Each unit or analysis or sub-case and each unit can be analysed relative to its change, effects or impact on the organisation's strategy. This allows for having sub-cases while still treating the organisation as a single case-study.

Data Sources and Collection Methods

The strength of the research findings is somewhat dependent on the number of independent data sources used. All case studies rely on multiple sources of evidence. In addition they benefit from the prior development of theoretical propositions (Verner, Sampson et al. 2009) which then guides the data collection. The interviewing technique is widely used in literature for in-depth investigation (Blaikie 2000; Blaikie 2003; Yin 2003), so they will be used here as the main source of data. Records of interview is one source of data, but other sources are used such as publication, documentation, archival records, physical artefacts, organisational charts, company website, company's newsletter clippings, asset life histories, reports, manuals, service, personnel or financial records, performance and consumption record, user manuals, contracts, letters, meeting minutes, proposals, progress

reports, formal studies and observation, will be used as corroboration, as suggested by (Verner, Sampson et al. 2009).

Starting with archival data or other text based sources rather than interviews may enhance understanding and guide the first stage interviewing process. It may also help to identify strategies and their triggers, and define changes in strategy, missions, and objectives of the organisation. Observation of physical artefacts such as the layout of assets and processes helps build a view of the actual technical system and define relevant departments to be targeted for investigation. Through this understanding, individuals that should be targeted as participants in the study and the possibility for interviewing them can be identified.

The advantages of interviews are that they allow a direct focus on the case study topic and can provide causal inferences by those participants who were closely involved with the context of the research problem. Responses of the participants to interview questions explain the specific issues targeted by the investigation and confirm certain facts that may be presented by other sources of data and also help to avoid irrelevant data.
Interview questions need to be constructed to identify the sub-cases and establish the existence of activities for the strategic purpose and the extent of their application. As presented in the case study protocol in Apendix-8.1, the questions can be open ended so the respondent can recount a sequence of events through past, present, and future expectation and add any information they consider pertinent. This approach is particularly important to the exploratory nature of the research and can help identify areas that may have been overlooked by other participants. Information extracted from Interviews will be validated by comparing it to other sources of data and between different interviewees to maintain a good chain of evidence.

When conducting interviews certain measures essential to consider are:

1) Participants should be drawn from those with experience delivering most asset-related activities and across the 3 organisational levels.
2) The relevance and application of the hypothesized framework to the function under investigation.

3) To allow interviewees to express their view and opinion widely about certain events and relate to dates of events and make recommendations for other relevant source of evidence.
4) To ensure interviewees' perceptions are extracted.
5) Ensuring alternative sources are available for confirmation of evidence.

To achieve these requirements the aim will be to have two meetings with each interviewee or be broken into two parts. The first is to introduce and answer questions related to identifying the sub-cases, i.e. the AM-related solutions, actions, or involvement in decisions in response to strategy events. The second part or meeting will be a detailed investigation with interviewees with information on who were involved with the sub-case or sub-cases identified.

Both qualitative and quantitative data should be collected. Based on the approach and steps indicated earlier, data collected in this investigation can be classified into four categories:

1- Strategy event identification data, including those related to the external and internal strategy triggers, and any change in business strategy and corporate mission/goals.
2- Data related to the asset solution, including data related to the acquisition or utilization phase and compatible to the strategy.
3- Performance measurement data, including business performance and resulting asset performance data.
4- Data related to management behaviour, action, or decision, i.e. data related to activities, relationships, or control of the AM system.

Data on strategy events is by nature qualitative and can be identified from any indication of change in corporate mission, goals, or business strategy and external or internal triggers. Asset solution and performance data may be either quantitative or qualitative. The asset solution data can be collected from what has been done through the life cycle phases. The business performance data can be collected as organisational output indicators. The resulting asset performance data can be collected as indicators relative to asset 'technical system' performance or relative to the performance of any activity. These indicators may be associated with single assets or technical systems, or with output or outcomes pertaining to each separate organisational activity.

The overall asset performance depends on performance of those asset-related activities but cannot be measured by quantitative data as a single parameter. The action data indicating management behaviour, structure, and mechanism is qualitative and can be determined by investigating what took place in practice. For this research, these three categories of data must be collected as they occurred relative to the strategy event, asset solution, resulting performance, and the action related to management behaviour, structure, and mechanism.

5 Case Study Data Analysis and Findings

5.1 Introduction

The research design, including the approach, protocol, and data selection and collection procedures have been established in line with the research methodology. Using this design the research methodology can be used to investigate the workings of the phenomena. It begins by describing the case study with a narrative based on archive data and interview records to identify several sub-cases for analysis. Then, an analysis of each selected sub-case is presented using a uniform structure to demonstrate the existence or absence of AM system activities, relationships, and mechanisms relative to the strategic events proposed by the hypothesized framework. In this chapter the narratives and analysis are guided by an analytical approach and procedure for collecting data, and an analysis in research design from the previous chapter.

5.2 General Conduct of the Case Study Process

5.2.1 Organisation Selection

The organisation selected for this case study is one of the world's largest steel producers, and the researcher has experience in this organisation. A framework was proposed to study the role of AM in the organisational strategy; the company was interested in the outcome of the research so it was selected. Moreover the company is relatively new and concerned that its assets should be totally utilised. The production facility consists of a large number of complex plants involving various types of equipment (e.g. rolling mills, furnaces, treatment plants, utility equipment, associated instruments or IT systems, control systems with associated operational or business systems, and safety systems). Furthermore, the organisation is constructed of production units that are organised into line production of several business units. Each unit is committed to supply a portion of its products to the domestic marked and compete in the international market with the rest of its production. The organisation was and which were suspected to have experienced changes to its strategy. These, and the particular interest of the company in the outcome of the research, and the familiarity of the researcher with the type of industry, supported this selection.

The organisation is a complex setting of assets and systems whose management is suspected to have an influential impact on its strategic success. For confidentiality, the name of the company is called (A-Steel) and other companies dealing with it were not named. Participants are mentioned by their roles and not by names and their interviews were coded (e.g. interview-1). Also, the titles of magazines that provided information were coded (e.g. regional trade magazine).

5.2.2 Arrangements

On 1st of June, 2008, the researcher sent an email to the company and an approval from the chief executive of A-Steel was obtained to conduct the research. In the same year, an approval from the ethics committee was also obtained. In October 2008, the researcher travelled to the company and started field work. Upon arrival, the chief executive issued a letter authorising employees to participate in the research process was sent to all departments. The field work took about four months from October, 2008 to the end of February, 2009. During this time many visits were conducted to the various plants to observe the organisation's system and collect documentation such as charts, quality manuals, sales manuals, safety manuals, various production or maintenance reports, cost reports, project documentation, annual planning reports, and company newsletters. Based on these visits the researcher selected various plant 'technical systems' to be studied, those departments targeted as sources of evidence, and identified potential interviewees.

50 interviews were held at 2-stages with 25 managers from different levels of the organisational hierarchy (managers of sections in departments, department managers, general managers, directors and the assistant to the chief executive). Those interviewees were selected from departments belonging to the four divisions, in the organisation chart. The selection for interviews was based on including managers from those asset-related department such as maintenance, operation and project management or support departments but favoured those who had long experience and in particular those that were team members or attended the early commissioning of projects long time ago. It was decided to include the directors of divisions and general managers when ever is possible and the managers of relevant departments. These divisions are the technical division (AM), production division, commercial division and human resources division. The management

hierarchy of the company is illustrated in Figure 5.1 as extracted from the organisational chart. Information was gathered from these managers through interviews. Each interview ranged from 30-to-90 minutes. Interviews were audio-taped with permission. Some notes were taken but most were recorded. The data was collected following the prescribed procedures in section 4.2.

The emphasis was on the main production assets and therefore the technical systems investigated were: DR Modules, Steel Melt Shops 1and2, Rod and Bar Mills and Flat mills; Hot Rolling Mill and Cold Rolling Mill. The managers, heads of sections, or engineers of

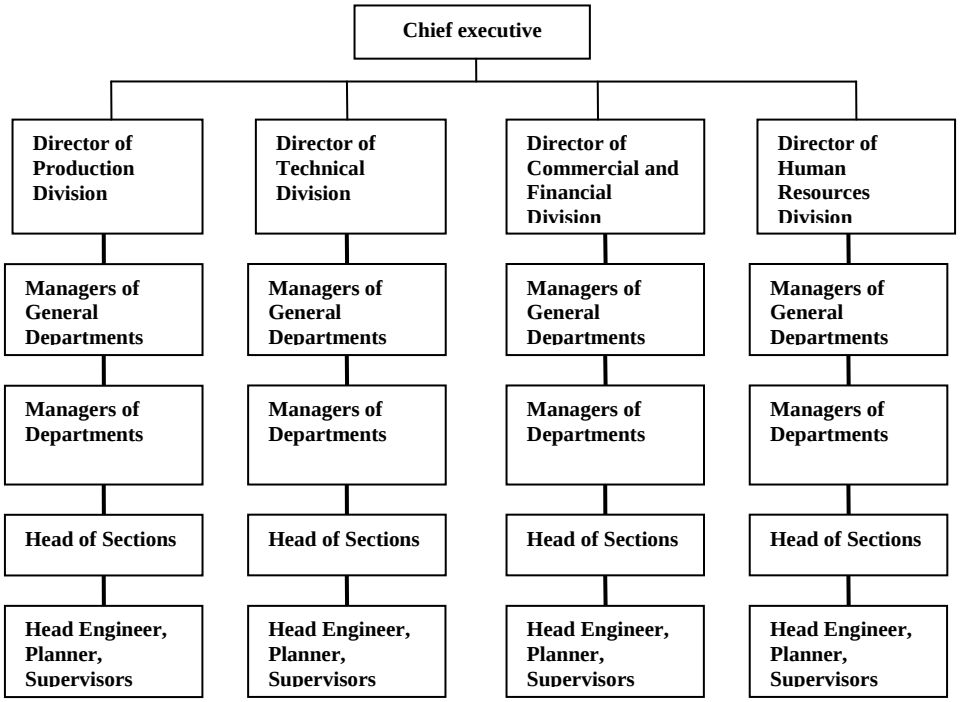

Figure 5.1: The management Hierarchy of the Case Study Organisation

AM-related departments relevant to these technical systems were interviewed. Those interviewees and data collected were from these areas shown in Table 5.1. The interview process was based on the response to questions in the interview guide from the case study protocol in Appendix 1.

5.3 Description of Case Study Organisation

After reviewing several publications, websites, and company records, including a site visit, a description of A-Steel was obtained.

Table 5.1: Data Collection Areas or Departments

Production	**Technical**	**Commercial and Financial**	**Human Resources**
Director:	Director:	Director:	Director:
Steel making	Maintenance	Finance	Personnel
Flat mill	Technical Division		
DRI and handling			
Production planning and control	Quality control	Asset account	Training
Maintenance planning and control	Safety	Cost control	
Steel melt shop 1 operation	Technical support and development	Purchasing	
Steel melt shop 2 operation	Computers/systems	Marketing	
Steel melt shops maintenance	Civil maintenance		
Refractory maintenance			
Bar and rod mill operation			
Section mill operation			
Bar and rod mill maintenance			
Hot rolling operation			
Cold rolling operation			
Flat rolling mill maintenance			

These sources included en.wikipedia.org/wiki; an online regional trade magazine, company newsletters, company website, and company establishment and development records.

A-Steel is an overseas iron and steel producing company with a large number of manufacturing plants, a wide range of products, and a working capital of about 1.3 billion US dollars. In 2004, an online Regional trade magazine ranked it third largest iron and steel companies in its region. The company is Government owned and originally a small plant.

The Government's strategic plan in the late 1970's had launched projects to transform the company into one of the largest steel producing companies in its region and in the world (company website). Most design activities from need analysis to commissioning of projects were outsourced to foreign consultants (project development and commissioning records). The organisation formed teams to work alongside the consultants to implement the projects. A program to prepare manpower (education and training records) for operation and maintenance was undertaken at the same time, as shown in the training records. Table 5.2 illustrates the progressive development of facilities and so also of capacity and capability.

Table 5.2: A-Steel's Facilities (Source: A-Steel website)

Facility	Capacity(Tonnes)	Established
DR Modules (2 off)	2 x 550,000	1989
DR Module	650,000	1997
Steel Melt Shop (1)	630,000	1989
Steel Melt Shop (2)	611,000	1989
Bar and Rod Mill	600,000	1989
Rod mill	200,000	1997
Light and Medium Section Mill	120,000	1989
Hot Strip Mill	580,000	1989
Cold Rolling Mill	140,000	1989
Galvanizing and Coating Line (G&C Line)	80,000 Galvanized	1997
	40,000 Coated	

Annual capacity of 1.3 million tonnes of liquid steel was achieved on a 1,200 hectare site, with about seven thousand employees. The company began production in 1989. Over the

past few years, the company has improved the quality of its management and therefore there should be evidence of events/changes that illustrate these improvements.

5.4 Analysis to Identify Sub-Cases

A first stage investigation of the case study can be conducted to identify suitable sub-cases. As indicated in section 4.2, these embedded sub-cases must be identified as strategic events that required an asset solution and result that did not achieve the organisational strategy. Interviews were conducted using questions 1 to 3 in the guide for case study protocol in Appendix-1. This part of the investigation and analysis is based on archival records and interviews. Appendix-2 contains most of the interview transcripts.

In order to start with an overall view that can direct the investigation to identify relevant sub-cases, one of the members of the strategic chief executive's committee, was interviewed. When he was introduced to the research project, he stated that he was not familiar with the concept of AM and that A-Steel has a quality policy, but nothing related to AM. He indicated that:

"*If asset management is about strategic investment in assets then, perhaps that is why A-Steel lacked a formal procedure relative to asset related development projects" (interview-1).*

He referred the researcher to the quality manual when asked about strategic events. That manual was subsequently analysed relative to the company's strategies. It revealed that for many years the aim of the company was to achieve quality leadership among its competitors. To quote from its quality manual:

"A-Steel quality policy is provided to comply with relevant quality requirements to its products and customers' requirements, needs and expectations to secure its leading position among iron and steel producing companies. A-Steel endeavours to use best equipment and technology, methodology, training, awareness, competence,...investment in technical support and development ……and reviewing periodically its objectives" (A-Steel Quality Manual, 2001).

From the same document, the mission and objectives of A-Steel were stated as:

"The general orientation in iron and steel industry is within the integral and development cooperation whether regionally or internationally. A-Steel endeavours within this to build

an integral industrial basis which will enable it to stand confidently to assure the achievement of its following objectives:

- *Insisting the importance of-especially the strategic-industry in supporting the economic development; considering it as being an alternative of petroleum for varying income sources.*
- *Breaking up the international monopolies by increasing the product and improving its quality on local consumption and exports.*
- *Expanding in projects for varying the products to fulfil the needs of the local market and entering equivalent competition in international markets.*
- *Focussing on the importance of human resources by adopting training plans and availing chances for qualifying and improving personal efficiency in the company".*

The director of technical division in the company, (interview-2), explained that strategic events and AM actions were consistent with these documented missions and objectives. He stated that:

"We follow the mission set in the quality manual but our company as one of the steel industry producers its strategy depends on three major factors: product quality, price and demand in the market."

Further investigation of documents and through interviews showed that these factors were the major triggers that shaped the competitive strategy of the organisation. These were a major driver for competitiveness, for example it was stated by director of technical division that:

"Quality is very important for us and we cannot compete without having high quality standard…. Cost reduction is very important for us and we cannot be competitive or get a reasonable profit without keeping our cost as low as or lower than competitors. …. demand in the market affects our profitability and annual return and will be reflected on development and growth… our company is operating in a developing country but we are competing in the international market, so a huge effort is required to survive." (Interview-2).

A chief executive's committee member, (interview-1), mentioned that A-Steel had many projects and actions in response to changes in strategy. He added that information about

these and their relevance to the research project can be obtained from archival records and other available documents.

To select several sub-cases to study based on a connection between strategic events and projects or actions undertaken, the company's documents and archival records should be reviewed. Based on the review of development records, newsletter issues and an online-regional trade magazine for the period from 1990 to 2008, it was realized that A-Steel had undergone many developments since it commenced operation in 1989. With a number of production projects and supporting assets acquired, the company had undergone a significant transformation. As stated in the A-Steel quality manual, the company aimed to satisfy the local market and break the international monopolies. Some of the projects that entered operation in 1997, as shown in Table 5.1 in the previous section, were a response to this strategy. These were the DR Module for producing HBI and G&C Line for producing galvanized and coated coils and sheets. However, the Rod mill for producing wire rods was opened in response to an increase in demand by local market for certain products. According to the company newsletter (December, 1994) and records of the Long Rolling Mill general department, A-Steel had developed the Long Rolling Mill in early 1993 by modifying one of its production lines from single rolling mill to slit-rolling. This modification was meant to increase production in response to local market demand.

According to the company newsletter (July, 2008), the unprecedented demand for steel products in domestic and overseas markets necessitated continuous expansion and development of its production assets. For example, an article from the company newsletter (July, 2008) related how the company had expanded and developed projects to the change made since it commissioned the Industrial Research Centre (IRC) in 2004, which was established to prepare the techno economic studies to expand and develop the company. For example, in 2004 this included expanding its plants to a capacity of 3 million tonnes of liquid steel per year, and the implementation of Phase 1 of the scheme in steel melt shop-1 (SMS 1) to boost capacity from 674 thousand tonnes of liquid steel per year to 1.14 million tonnes. In the following years, a number of new projects were commissioned and entered operation. In 2005, the strip pickling line was expanded and a new AR station was built, and in 2007 new wire drawing plant was built. In 2006 A-Steel contracted with an expert

foreign consultant to upgrade the previous study and prepare a new master plan to achieve an annual capacity of 4.168 million tonnes of liquid steel. This plan was approved in August 2007 by the A-Steel General Board and completion is expected by 2012. The main expansion projects are presented in Appendix-2. Additionally, these projects need a great many supporting assets to cope with services. For example, some major supporting facilities developed include setting up a new (LBSS-4) 10 – 30 KVA sub-station, a plant to separate gases and compressed air (16000 m3/H), and extend the port quay to 1092 metres to accommodate three ships.

Records on research, training, and development projects and records from the technical support and development department showed that many research projects were undertaken to optimise operations and maintenance practices. In 1995, the company signed a contract with several local universities to undertake research to improve management and technical operations and maintenance practices. Those that were thought to relate to AM included: developing a maintenance cost control system; optimizing the replacement of the electric arc furnace lining; replacement of skid pipes in flat mill furnace; adopt a best practice inventory control system; re-use the refractory; develop an information system to better integrate the inventory; and purchasing;. Furthermore, in 2001 the government supported a $20 million modification of the company's electric arc furnace as well as construction and installation of a $17 million ladle furnace. According to the newsletter (January, 2002), the development of Electrical Arc Furnace (EAF) and introduction of the ladle furnace was to eliminate pour backs to save time and resources, and therefore reduce losses that contribute to the cost of production.

Many of the projects or actions revealed by the archival records seem to respond to strategic events. However, only those projects or actions with enough time elapsed to see the outcomes and impact on the organisation were considered as potential candidate to study in detail as sub-cases. From this analysis three sub-cases were selected for study based on their relationship to strategy change or triggers or their connection to the strategic objectives or missions of the organisation. The three sub-cases were selected as three different sets of responses to three different strategy triggers:

1. Sub-Case 1: is a progressive response to increased demand. Local demand to increase certain sizes of bar and rod products triggered two consequent projects in this bar and rod mill: modifications in 1993 to slit rolling and development in 1997 of the rod mill, as AM responses.
2. Sub-Case 2: is a set of responses to a new mission of the company to compete in the international market. Diversifying products to compete in international markets triggered two parallel projects: establishment of an HBI module and G&C Line in 1997, as a response to this strategy.
3. Sub-Case 3: is a set of responses for the continuous improvement strategy of the company. This strategy caters for improving performance in terms of achieving competitive quality, unit cost of products, and sustaining profitability. This triggered many AM and non-AM actions, but for this research, the focus was directed on the actions taken in the steel melt shops. From this only three asset solutions were selected to conduct deep context analysis, modelling to optimize the replacement and repair of EAF lining and introducing a ladle furnace and replacing the external cooling rolls in continuous casting, with internal cooling rolls. These actions were a response to optimize performance by minimising production costs and/or losses and maximize the quantity produced or improve product quality. These three AM solutions are selected to make sub-case 3 because they aim at improving performance to enhance customer value.

Although these three embedded sub-cases dealt with different strategy events and contributed differently to the organisational strategy, they arguably required the utilisation of the same data analysis and interpretation approach. For each sub-case the particular strategy related event, termed ‘strategy event’, or change can be investigated to understand how certain triggers pertaining to the strategy are translated into asset solutions. The management behaviour related to particular asset-related activities and the resulting asset performance can be assessed.

These three embedded sub-cases were denoted as sub-case 1, sub-case 2 and sub-case 3. In the next section, each sub-case is analysed using the procedure in section 4.2, and then confirmed by asking relevant interviewees if they were direct responses to a strategic event.

The analysis is usefully divided into 2 stages. Stage 1 involves establishing the phenomenon represented by elements 1 to 4 presented in the hypothesized system functional model shown Figure 4.2. Stage 2 involves interpretation of the phenomenon and its relation to strategy. The AM system activities, relationships and mechanisms are represented by Element 5 in the hypothesized system functional model shown Figure 4.2. Implications for the AM system activities are drawn from the defined phenomenon in Stage 2.

In stage 1, the researcher identifies several sub-cases. Sub-cases are defined by identifying strategy events that were responded to by asset-related solutions. 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 in the hypothesized system functional model shown Figure 4.2. This involves identifying the strategy event, defining the asset solution, its provision and determining the asset performance and outcomes relative to the strategy. For each sub-case the particular strategy related event or change can be investigated to understand how certain triggers pertaining to the strategy were translated into asset solutions. The management behaviour related to particular asset-related activities and the resulting asset performance can be assessed. In stage 2, the search is for both negative and positive results while referencing the cause to the absence or existence of AM system activities, relationships and control and to the adequacy with which these are performed. Activities may not exist at all or may not exist to the extent that serves the strategic purpose and may exist with conflicting objectives or with negative impact on each other. The ultimate objective is to determine the extent to which the achievement of an organisation's strategy is dependent on having an adequate AM system in place.

5.5 Sub-Case-1 Analysis and Interpretation

5.5.1 Stage-1: Establishing the phenomenon

Establish Asset solution in Response to Strategy Event

Sub-case-1 as a strategy event was identified by an increased local demand for certain products which triggered the AM response(s). The responses in this event were identified by modifications to the slit rolling done in 1993 and development of the rod mill in 1997.

Evidence of this selected sub-case rose from company records and conformation of interview transcripts in Appendix-2. The ad hoc team members of the modification project who were managers in the Long Rolling Mills e.g. interviews (3, 4, 5, and 6) indicated that these development projects were a specific response to the increase in demand in the local market for certain bars and rods. Examples of their replies are:

"…There were several expansions projects in the long rolling mills; slit rolling modification in 1993, wire mill development in 1997 and … new production high speed slit-rolling mill ... These projects were introduced one after the other to fulfil the market increasing demand. .....Slit rolling modification in 1993, was one of the strategic decisions that we took here in this plant",(interview-5).

"…There was a demand increase of size 6, 12 and 14 of reinforced rods that required a fast response and the modification from single rolling to slit rolling was thought as the most viable alternative at that time"(interview-4).

"... The project was initiated in response to a sudden increase in demand for certain products in the domestic market"(interview-6).

With reference to interview-3 held with the production director, indicated that the objective in 1993 was to include this new segment of the local market without affecting export orders and therefore a dramatic increase in production was required in a very short time. But a review of the annual production planning reports issued by the production planning and control department showed that the bar and rod rolling mills were operating at full capacity and therefore there were limitations in its productive capacity. These mills have been operating three continuous eight hour shifts since their establishment in 1989. Production planning as presented in these reports was based on patch production campaign of the product mix to fulfil each customer's order of different products. According to interview-7 held with the marketing manager, the marketing status was and still is, 'whatever is produced can be sold'. Company strategy documented in the quality manual is to achieve quality leadership in the region by emphasizing customer satisfaction. According to an article on an online regional trade magazine (July, 2007), marketing records and interview-7 conducted with the marketing manager, the company had always produced quality products and maintained good relationships with customers.

As a common theme among participants, the company had increased its productive capacity to meet the increase in demand while maintaining the same level of quality and relationships with customers. As such, most interviewees e.g. production director and manager from Bar and Rod Mill interviews (3, 4, 5 and 6) indicated that under those certain circumstances in 1993, the company modified the single bar rolling mill into slit-rolling technology, so theoretically the productivity of this mill would double. However, those interviews held with operation and maintenance managers in the bar and rod rolling mills interviews (4, 5 and 6) who designed the modifications to the slit rolling mill stated that practical factors limited the productive capacity to a 50% increase. That is from 200,000 Tonnes of single rolling mill to 300, 000 Tonnes of the slit rolling.

The demand for certain bars and rods continued to increase beyond the capacity of the slit rolling development. Most mangers at high level and at operation or maintenance department level e.g. interviews (3, 4, 5 and 6) indicated that the introduction of the rod mill in 1997 was undertaken for covering the increase in demand; however, several years after commencing operations, the demand exceeded its capacity. As indicated by these interviews and shown in the industrial research centre development plan, a new high speed slit rolling mill is underway. The marketing department recorded that the shortage of production to fulfil demand almost reached the capacity of the rod mill during 2005. According to an online Regional trade magazine (July, 2007), the shortfall was imported. The strategy event and asset solutions for sub-case 1 can be summarized as shown in Table 5.3.

Establishing and interpretation of asset-solution provision and resulting indicators

The provision actions included in-house design, component acquisition, construction and 3 hours of operating trials prior to full production. In the process of investigating the asset solution provision, the transcripts of interviews in Appendix-1 reveals that most interviewed managers e.g. interviews (3, 4, 5 and 6) stated that the slit rolling project was an in-house modification that aimed at a low acquisition cost and fast implementation. For example, the general manager of long rolling mills clearly stated this as:

Table 5.3: Strategy Event and Asset Solutions for Sub-Case 1

(1) Strategy Event	(2) Asset solution
An asset solution was required to cope with the increase in the demand of the local market in 1993 The trigger of the strategy event is identified as the new developments in the country	In-house modification of the existing single rolling mill to slit-rolling for doubling throughput.
An asset solution was required to cope with the increase in the demand of the local market in 1997 The trigger of the strategy event is identified as the new developments in the country	Introducing a new production mill to double the Capacity

"…. it was a simple in-house modification internally done to convert the single line into slit rolling…. The project was based on low investment... only minimum requirement of equipment to be changed were acquired for obtaining slit rolling modifications… Also emphasis was on completing the transformation of the line in a very short time..",(interview-5)

According to the records of the slit rolling project, a report of the first three hours trial of operation was obtained from the records in the office of the general manager of long rolling mills. Also, the performance reports from the production planning and control department made accessible by this department manager, gave the performance data of single rolling over the years before and after slit rolling. The slit rolling trial is compared to the average performance of single rolling, as shown in Figures (5.2 and 5.3), and indicated that slit rolling performed poorly. As shown by Figure 5.2, while productivity increased by 100%, defects had reached over 50% of total production. Also, Figure 5.3 shows the low performance in yield caused by the high in process 'miss roll' losses associated with slit-rolling.

As a member in the slit-rolling design and implementation team, the general manager of maintenance in the long rolling mill indicated this low performance at the first trial and the measures that were taken to improve it:

"The productivity was doubled at first trial but the rate of defects was more than 50%. Efforts in terms of further modification and control were applied to gradually lower the defects percentage" (interview-6).

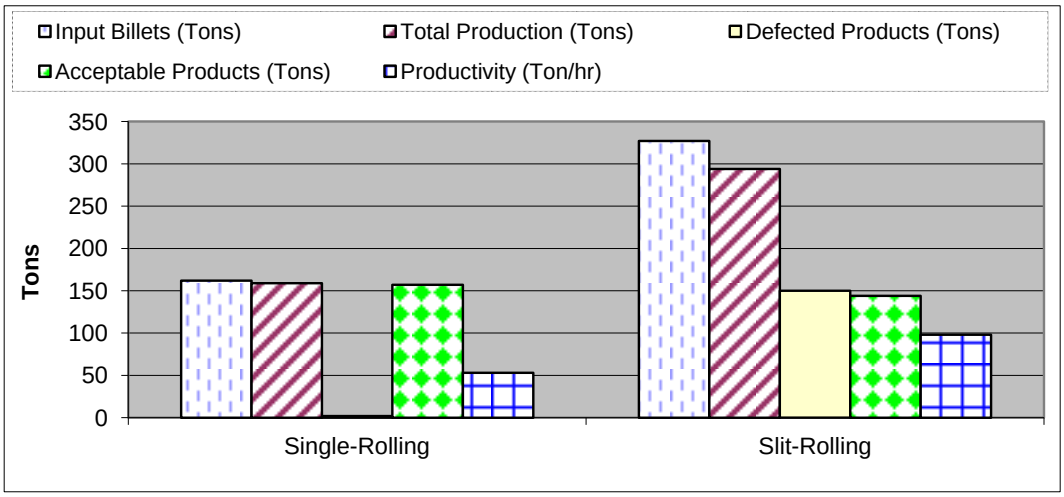

Figure 5.2: Single Rolling Average Production vs. Slit-Rolling Trial Operation

Development of the rod mill development was the second consequent solution where the provision process was outsourced. In the transcripts of interviews (4 and 5), the general manager of maintenance and spare part manufacturing and the general manager of the long rolling mills who were members of the project indicated that the company decided to use an expert supplier for the whole design and implementation of the project. They also indicated that the supplier complied with all the requirements and the project was completed on time and successfully commissioned. The design capacity was (200,000 Tonnes) as requested by the company. In brief, the resulting Indications relative to provision of asset solutions are summarized in Table 5.4.

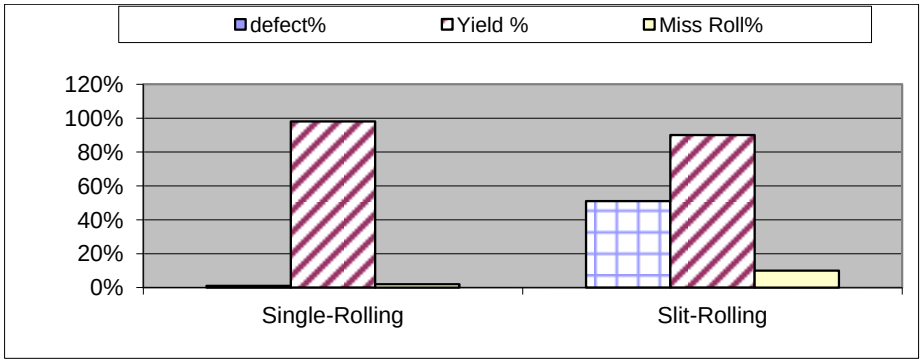

Figure 5.3: Comparing KPIs of Single Rolling Average and Slit-Rolling Operation Trial

Table 5.4: Resulting Asset Solution Provision Indications for sub-case 1

Asset solution	Provision of asset solution and its Indicators
▪ Modification of the Bar and Rod Mill from a Single to a Slit-Rolling Mill	▪ Selection and provision involved determining the required capacity increase; selection and design of modification; determining requirements for equipment acquisition; installation, operation and maintenance. ▪ Achieved through in-house modification & low capital investment. ▪ Expected doubling of capacity but also resulted in 10% process losses and more than 50% defect production
▪ Development of a new Rod Mill	▪ Selection and provision involved determining the required capacity increase; selection of supplier; establishing and managing a supply contract; commissioning, operation and maintenance. ▪ Achieved through outsourced supply; delivering on time; successful commissioning. ▪ Doubled capacity without significant process losses or defect production.

Establishing indications of resulting performance, outcome and contribution

The resulting indicators include asset performance, business performance, and the value contribution indicators. Indications of the resulting asset performance, the business outcome and value contribution are established and demonstrated by comparing the achievement and loss indicators after the adoption of the asset solution to those before it. Indications are summarized in tables for future referencing. Evidence for these indications was obtained from interview transcripts and company records.

In the process of providing evidence of the asset performance indicators and their impact on business outcomes and value contribution were investigated through interviews and review of company records. In this process, most interviewed managers from long rolling mills interviews (6, 5, 4 and 3), recounted that despite every effort to improve performance, the problems were not fully solved and the design targets were not fully achieved. For example, it was stated that:

"The main defect was irregularity but there were other minor surface defects. We were not able to really reduce irregularity defect to a very low level but the severity of the defect itself was controlled and minimized to a level that does not affect the functionality of the

products. Fortunately, we were able to sell products with minimum irregularity in the local market after downgrading their price. This played a role in contributing to cover the increase of demand…"(interview-6).

This was confirmed by a review of production and quality control records. From these records, a comparison between single rolling and slit rolling was established to show the trends in performance indicators. The indicators were plotted over a period that included 2 year of single rolling and 3 years of slit rolling as shown in Figures (5.4, 5.5, 5.6and 5.7). These represent the various indicators between slit rolling and single rolling over the specified period.

Although Figure 5.4 shows an increase in annual marketable production quantity, a large part of it was downgraded. It also shows an increase in acceptable production but it was associated with a high percentage of rejects. These losses are shown in Figure 5.5. The poor performance is shown in Figures (5.6 and 5.7) as low achievement and very low utilization. Variations in the values of these performance indicators compared to single rolling, reflects a lack of control over the slit rolling process.

Many participants' explanation of the slit rolling modifications indicated this lack of control. For example, the general maintenance manager of long rolling mill said:

"...with respect to slit-rolling modification, we had difficulty with controlling the operation resulting in quality problems and short repetitive breakdowns, delays, more handling and quality inspection, more over time and disturbance of the whole production process. Gradually the process was controlled to some extent and the project had achieved the objective of covering the short term increase in demand but could not continue to handle the increasing demand" (interview-6).

According to interviews (5 and 8), the managers of the operation and quality departments at the time of slit rolling indicated that the main defect was irregularity and after many design changes operations, the severity of this defect was minimized. But as a result, the utilization of the line became very low and the increase in production was not even close to what was expected. The process was controlled more stringently, but the percentage of defects and breakdown maintenance disturbed the operation and planning process. According to the production and quality data plotted in Figures (5.4, 5.5 and 5.6), only

about 18 % increase in annual production could be delivered, while no downgrading was achieved in production over the capacity for single rolling. These figures also imply that those production and quality losses contributed to increasing the unit costs. This is confirmed in interviews, for example:

"There were indications of losses in terms of reject, breakdown stoppages, non conformance products and more inspection efforts but the major problem was irregularity which we had to deal with it for three years and then reverted back to single rolling in 1995" (intervew 6).

In 1995, the company signed a contract with a well known supplier in the field to construct a rod mill. In 1997, the company started operation with this new single rod mill to double the capacity of the original modified mill. The performance achieved by this mill is shown in Figure 5.8, but as an expanded capacity it could not meet the continuing demand over the long term.

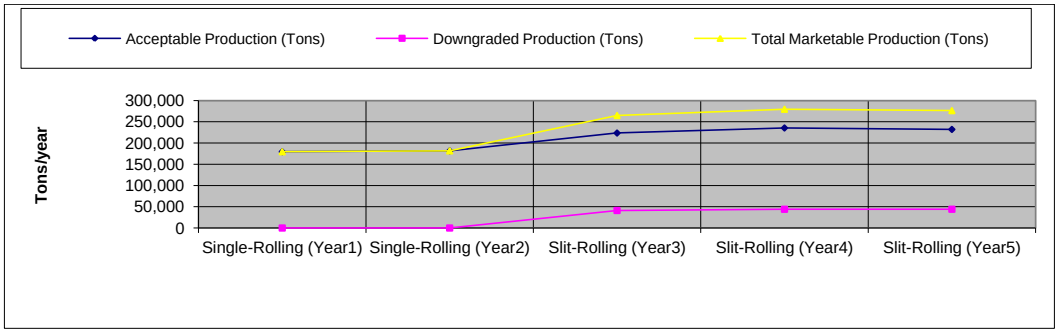

Figure 5.4: Comparing Saleable Production Quantities of Single Rolling and Slit-Rolling

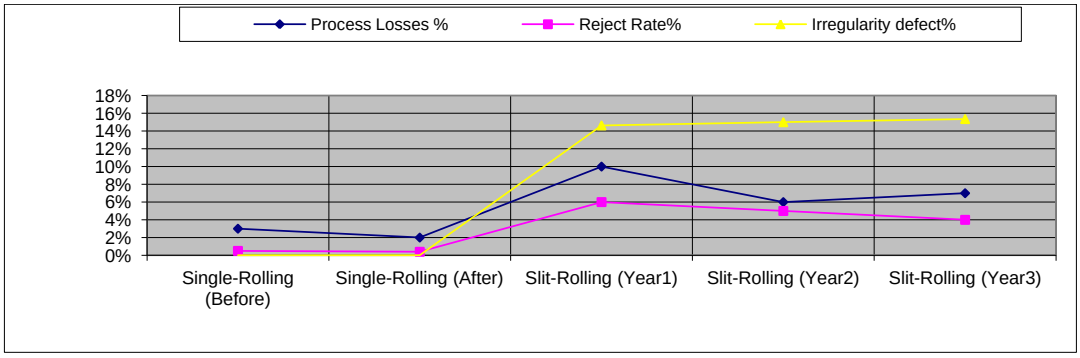

Figure 5.5: Comparing Rolling and Quality Losses of Single and Rolling Slit-Rolling

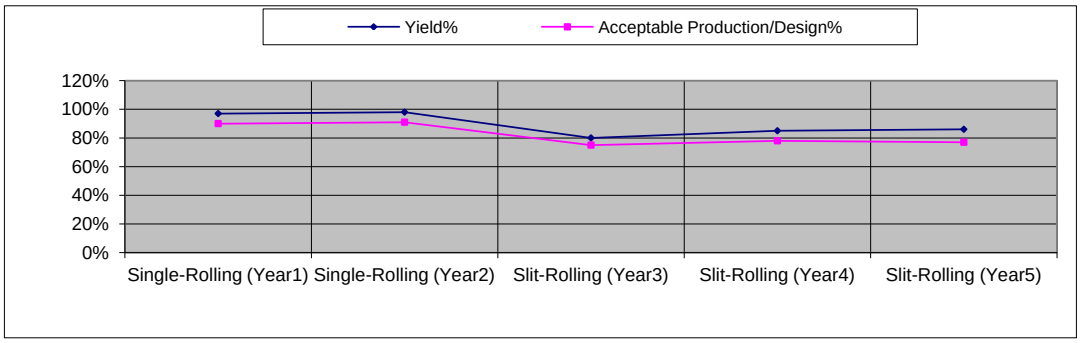

Figure 5.6: Comparing Process Achievement of Single Rolling and Slit-Rolling

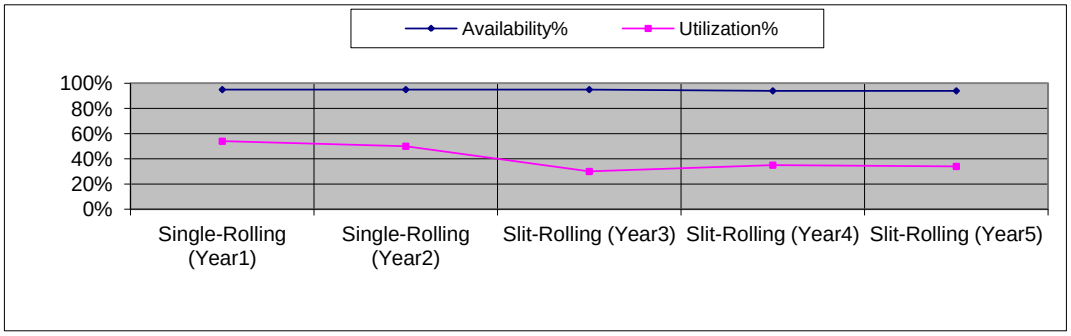

Figure 5.7: Comparing Availability and Utilization of Slit-Rolling and Single Rolling

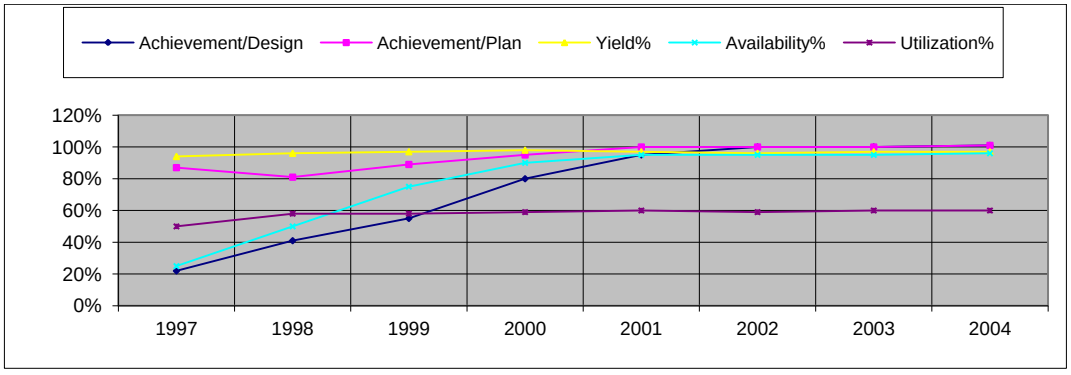

Figure 5.8: Rod Mill Performance Indicators

The resulting asset performance is summarized in terms of indicators relative to the asset solutions shown in Table 5.5.

In the slit-rolling modification, the first response to the strategy event resulted in poor provision and performance caused mostly by poor design. This led to inadequate operation or maintenance practices leading to negative impacts on business outcomes such as high cost, low product quality and delays to orders.

Table 5.5: Asset performance and its Resulting Indications for sub-case 1

Asset solution	Indications of resulting asset performance
Modification to Slit-Rolling	▪ The intended asset performance was to increase the annual production. ▪ Production targets were not achieved. ▪ The asset performance production indicators included high increase in production speed but a sharp decrease in utilization and reliability, high rate of defect products, new product quality defects, more quality inspection, high quality losses. ▪ The key asset performance quality indicator was the new defect (irregularity) which was the main cause of quality losses such as (rejected, scrapped, returned, downgraded and quality stoppages or delays) ▪ The asset performance financial indicators included: high quality cost, high production stoppages, more breakdown maintenance, high maintenance cost, production delays, and some minor injuries during operation and dispatching.
New production Rod Mill	▪ The intended asset performance was to increasing the annual production. ▪ The resulting asset performance included achieving high availability and utilization rate, low stoppages and delays, high productivity and reliability. ▪ The asset design capacity was less than required.

With respect to the rod mill, the results in these tables show high performance but an inadequate design capacity for a continuous increase in demand over the long term.

A summary of the resulting business outcomes and value contribution are presented in Table 5.6.

In this sub-case most participants indicated that the resulting asset performance led to poor business performance and therefore strategic objectives were not met. For example, the general maintenance manager of the bar and rod mill who was the leader of the ad hoc team indicated that the low asset performance did not meet the intended business objective:

"… the difficulty with eliminating irregularity problems and rejected batches, delayed orders and customers delay complaints forced us to revert to single rolling… After three years most of the causes of these problems were acknowledged and we could have

improved the results by further modification but the high increase in demand made us look for a more viable alternative" (interview-6).

As a common indication from participants, the reasons that led to such results were quality, maintenance or safety related factors. This can also be gleaned from the indicators plotted in Figures (5.2, 5.3, 5.4, 5.5, 5.6 5.7) based data obtained from company records. The quality factors indicated in these interviews transcripts showed that new defects in products (in particular irregularity) led to many losses, increased costs and impact on customer satisfaction.

For example, according to these participants and the performance and quality records, these included more appraisal costs (more inspectors, tied sampling, more inspection, and etc.) and disturbance in dispatching leading to mistakes and delays in delivery, and defective products that did not reach customers, but were either downgraded or scrapped. They also included re-inspection, down grading or replacement of sales orders. In particular, marketing manager, (interview-7) indicated that many complaints were registered from customers regarding delays and several penalties were encountered with delays to loading shipments. The maintenance factors in these interviews (e.g. Interview-6) are related to many repetitive short period stoppages. These were experienced in rolling operations that disturbed process stability and increased down time, despite an increase in the production rate. This resulted in operational disturbance and reactive maintenance action. This resulted in less utilization, more set up time and other stoppages, and higher losses and costs. Also, overtime for maintenance personnel had to be increased to handle the minor breakdowns, as indicated in (interview-6).He also indicated that this resulted in scheduling disturbance leading to shorter roll replacement times and rolls not fully utilized, which increased their replacement costs. In addition, safety and security department records showed that some safety events had occurred such as dispatching and handling accidents and miss roll which means hot rods diverted away from their bath, increasing the probability of human injury. Although no major accident occurred their indicators showed an increased risk of accidents.

Table 5.6: Resulting Business Outcome and Contribution to Strategy for Sub-case 1

Asset solution	Business Outcome Indicators	Value Contribution Indicators
Modification to Slit-Rolling	▪ Did not cover demand because the targeted increase in production was not achieved ▪ Quality and Financial losses ▪ Customer dissatisfaction ▪ Increased safety risks ▪ Delivery delays ▪ Transporting delay penalties ▪ Loss of some international customers ▪ loss of opportunity to gain more share in the market	▪ The intended contribution was to cover the increase in demand in time at competitive quality and unit cost. ▪ The resulting contribution included some short term benefit but overall negative contribution and the objective was not achieved. ▪ An increase in production was achieved but associated with high losses and cost. ▪ It resulted in undesirable business performance that led to negative contribution toward achieving the strategy.
New production Rod Mill	▪ For few years it covered the local demand and the rest is exported. ▪ High quality products ▪ Financial gains; all produced is sold ▪ Loss of share in the market due to the capacity shortfall	▪ The intended contribution was to cover the increase in demand in time at competitive quality and unit cost. ▪ The results included positive performance but contribution was short of covering long term demand. ▪ In few years after it started operation the company had to import to cover the local increase in demand up to almost equal to the production capacity

With reference to the interview transcripts, in particular interviews (3, 4, 5 and 6), there is indication of inadequate contribution to strategy achievement by modifying the slit-rolling or introducing the rod mill in response to an increase in demand. For example, the lack of contribution was stated by the ad hoc team leader for slit-rolling from the bar and rod mills as:

".. slit-rolling modification project was not a success,..... Before the end of 1995 a decision on a contract for a new rod mill to increase the production was finalized and started operation in 1997" (interview-6).

It is concluded that the outcome of this sub-case as business performance or value contribution resulted in conflict with or a negative impact on achieving the organisation's strategy or competitiveness.

5.5.2 Stage 2 - Analysis and Interpretation - Drawing Implications from the Phenomena

Mapping hypothesized framework relative to adopted AM control actions

The process of extracting information about the AM system evidenced by the phenomena set out in Section 5.3 allows its nature relative to strategy development and implementation to be analysed. The data for these tables was extracted from interviews with the relevant managers and investigation of company documents. Mapping the elements of the AM framework against the actions undertaken in actual practice for this sub-case are presented in Tables 5.7 to 5.10.

Table 5.7: Mapping the Asset-Related Activities Relative to Actions in Sub-Case 1

Element of Framework (Figure 3.7 or 3.5)	Status	Indication of Action and/or Resulting Outcome
Research, Engineering and Design	Absent	▪ Formal responsible departments were missing ▪ Ad hoc team work for the slit-rolling project but the new facility introduction project design was outsourced. ▪ Ten years later such departments were established
Acquisition, Deployment and Installation	Absent	▪ The slit-rolling modification managed by ad hoc team ▪ New facility contract supervised by ad hoc team. ▪ Ten years later such departments were established.
Operation (Utilization/Use)	Existed	▪ Operation management adequately existed in the company ▪ Operation managers were part of the ad hoc team to handle the modification of the old facility
Maintenance (Care/Service)	Existed	▪ Maintenance management adequately existed ▪ Maintenance managers were part of the ad hoc team to handle the modification of the old facility
Replacement and Disposal	Absent	▪ No formal responsibility of this activity found. ▪ It is found to be part of maintenance
Technical Support and Development	Absent	▪ No designated department to analyse development proposals. ▪ Technical support and development department established 6 years later.
Procurement	Existed	▪ Existed across several departments with lack of coordination between them with respect to AM.
Human Resources	Existed	▪ Existed as a central activity through several departments with indication of some good coordination between the life cycle activities e.g. training for the need.
Safety, Finance and Accounting control, IT/IS, Quality	Existed	▪ Existed through several departments ▪ Indication of good coordination between activities but mostly manually handled and lacked advanced IT. ▪ Lack of coordination between these activities and the cost accounting control department.

Table 5.8: Mapping the AM System Planning and Control Activities Relative to Sub-Case 1

Elements of Framework *(Figure 3.7)*	Status	Indication of Action and/or Resulting Outcome
Analysis and Evaluation	Absent/ Inadequate	▪ No real analysis or evaluation to define increase in demand. ▪ As a result, the slit-rolling modification resulted to losses. ▪ The capacity for both the slit-rolling and new facility could not satisfy the demand in the long run. ▪ Inadequate analysis and evaluation of life cycle requirement resulted in overlooking quality, operation and maintenance requirement for slit-rolling. ▪ Indications of possible negative impacts on quality by slit-rolling partly ignored. ▪ No action to mitigate risk to the customer satisfaction or product unit cost.
Decision Making	Inadequate	▪ Decisions not taken based on current and expected conditions. ▪ Decisions based on managers' opinions and debates. ▪ Lack of analysis, evaluation, feed-forward information and experience of ad hoc team members led to poor decisions.
Coordination and Planning	Existed	▪ Existed at the aggregate level between departments or teams. ▪ The slit-rolling modification implemented as planned. ▪ Records shows coordination and planning between departments were handled well. ▪ The production planning and control department and maintenance planning and control department handled coordination between activities for AM purposes through plans and performance reports. ▪ Planning activities adequate but manual or semi manual form.
Work Task Control	Existed/ Inadequate	▪ Operational work task control adequately existed, e.g. operation and maintenance departments were well managed for executing operational tasks. ▪ For slit-rolling modification, poor design resulted from lack of experience of team members and absence of a design activity. ▪ Work task control followed aggregate plans. ▪ Data recording was mostly manual or semi manual.
Measurement and Monitoring	Existed	▪ Data gathered in shift reports and then in weekly reports ▪ Many measured parameters but mostly lagging indicators. ▪ Condition monitoring limited to visual checks.
Control and Reporting	Existed	▪ Performance reports (monthly, quarterly and annual) produced indicating compliance to plans: i.e. lagging indicators. ▪ Used to prompt new strategy: new facility for example.

Table 5.9: Mapping AM System Strategic Relationships

Elements of Framework (Figure 3.7)	Status	Indication of Action and/or Resulting Outcome
Identification of Strategy Triggers and Definition of Strategy Event/Change	Inadequate	▪ Lack of interaction and inadequate relationship between AM and business management; No studies or research to define expected increase in demand ▪ Lack of market research/studies due to missing or inadequate strategic analysis and evaluation activities. ▪ Adequate internal identification of change triggers; internal indication of demand increase through production planning and control reports and increase shown in customer orders.
Definition of the Required Outcome and Asset Performance to Achieve Strategy	Inadequate	▪ Lack in definition of expected demand increase, required business outcome to cope with the demand increase. ▪ Inadequate definition of production capacity and requirements or asset performance to cope with the long run outcome. ▪ Lack of definition of required asset solution and its performance to cope with the required production output. ▪ Inadequate slit-rolling performance resulted in negative impacts on quality, operation and maintenance. ▪ The resulting performance was not as targeted or designed. ▪ Performance contributed to increasing production but did not cover increase in demand and failed to achieve strategy. ▪ Performance indicators: high quality defects and losses, high cost, delivery delays, low customer satisfaction, low competitiveness and risk to quality leadership achievement.
Definition and Provision of Assets Solution and Alignment with Required Performance and Resources	Inadequate	▪ Decision to select slit- technology not taken based on sound analysis and failed to achieve targets. ▪ Decision on design capacity of new facility was inadequate for the increase in demand. ▪ The decision to undertake in-house modification for slit-rolling was inappropriate and design overlooked the life cycle requirement: operation and maintenance.
Setting Strategies, Policies, Annual Business Targets and Aggregate Planning	Existed/ Inadequate	▪ Strategies and policies for asset-related activities set but no check of contribution to AM strategic objectives. ▪ Targets existed to provide direction to implement strategy. ▪ Approval maintained for sales, production and maintenance plans but there was indication of non compliance to plans.

Table 5.10: Mapping the Feed-Forward and Feedback Control Links

Elements of Framework (Figure 3.7)	Status	Indication of Action and/or Resulting Outcome
KPIs and Compliance Feedback	Existed	▪ Feedback on KPIs existed as manual performance reports ▪ KPIs information hardly used for analysis and evaluation
Results as direction for Strategic Decision	Absent/ Inadequate	▪ Feed-forward as direction or basis for strategic decision making absent or inadequate because of the absence of appropriate analysis and evaluation.
Control Direction for Planning	Existed	▪ This feed-forward link existed in terms of targets set by the business planning such as the sales plans or budgeting. ▪ These targets are translated into aggregate plans.
Direction for Task Control	Existed	▪ This feed-forward link existed in terms of these aggregate plans that are converted into schedules, work procedures, control measures for example
Data Accumulation	Existed	▪ This feedback link existed in terms of data collected in those shift reports
TPPs and CPs Feedback	Existed	▪ This feedback link existed as weekly reports presenting indicators of technical performance parameters measured based on data accumulated from shift reports.

5.5.3 Interpretation of Adopted Actions Relative to Hypothesized Framework

The interpretation involves defining how it was decided that a response to strategy event required an asset solution and how a particular solution was selected, established, adopted and implemented. It involves interpreting the adopted AM actions relative to the status of the asset-related activities, AM planning and control activities, feed-forward and feedback links and strategic relationship as proposed by the framework.

Status of Asset-Related Activities

Interpretation involves linking the evidence extracted from the analysed phenomenon to the status of the asset-related activities as proposed by the AM framework. It is evident from Table 5.7 that the fact that the organisation had to resort to forming an ad hoc team is an indication of the absence of some of the AM system activities implied by the framework. In particular, the responsibility of analysis and evaluation and decision making activities were not formally in existence. There were no departments charged with the responsibility to

undertake research analysis, engineering and design. Some of the AM supporting activities identified within the framework are absent. Perhaps this is because the company was new and still developing its management structure.

Due to the poor results in the case of the slit-rolling modification and other projects the company later introduced a technical support and development department and an industrial research centre. The role played by these in the recent development projects studied as part of the overall research was evident. For example, according to interview-10 held with manager of the technical support and development department and records from the industrial research centre, the analysis by these two entities has established that any further expansion in the production facilities requires development and expansion in the upstream facilities and supporting facilities. It is concluded that the introduction of these reflects the recognition of their need in order to achieve better results of asset development projects for the organisation. The industrial research centre prepared a master plan for development and expansion. Transcript of interview-10 and company records show that the introduction of a high speed slit-rolling was based on their recommendations analysis and initiative. The implementation of this high speed slit-rolling facility appears capable of satisfying the continued growth in demand. In contrast, when the decision was taken for the slit-rolling modification the company had no means but to allocate the responsibility to handle the analysis and evaluation for this strategic AM decision to an ad hoc team. The team had the advantage of having knowledge of various organisational activities but members lacked some of the specific knowledge and skill relative to this AM system activities strategic analysis. Due to a lack of resources and experience required to undertake an appropriate level of analysis, the resulting performance did not meet what was expected by the strategy. For example, the team overlooked the expected long run increase in market demand and did not request a study into it. This is clear from the ad hoc team leader response:

"We did not request a study of the market to base our decision for capacity and technical design. We were looking at indicators of current increase and we did not think of the possible huge and continuous increase in demand in long run. In fact, the continuous increase in demand has triggered another expansion project which is the high speed slit-rolling mill that is under implementation" (interview-6).

With reference to asset-related activities at the aggregate and operational levels, Table 5.6 shows adequacy of existence. In reviewing the operation and the maintenance practices in A-Steel, it was found that the company had these activities in place , e.g. central production and maintenance planning and control departments and quality control department to coordinate between asset-related activities. According to managers of these departments interviews (8, 9 and 19), coordination existed between departments to organize and prepare plans for executing all operational tasks relative to operation or maintenance. They also accumulate data and report periodically on the performance parameters. They prepared performance reports monthly, quarterly and yearly. Reports cover performance of all plants and submitted to all general departments in the company.

Status of AM System Planning and Control Activities

The AM framework represents the AM system planning and control activities as shown in Figure 3.7. A review of the status of these activities based on extracted data from interviews with the relevant managers and investigation of company documents is set out in Table 5.8. This table sets out the links between the existence and adequacy of AM system activities and the resulting performance, outcomes and contribution relative to the organisational strategy. The content of Table 5.8 implies that missing or inadequate analysis and evaluation led to improper decision making in this case. Consequently, this resulted in inadequate selection and provision and less than the required asset performance. According to members of the ad hoc decision-making team interviews (4, 5 and 6), that team lacked the expertise and experience to prepare the appropriate design. The lack of expertise and experience of the design team in doing the proper analysis and evaluation resulted in deficiencies in the definition and provision of this asset modification solution. As a consequence, no accommodation was made for the operation and maintenance requirements. The plant general and operation managers responsible for the modified plant interviews (4 and 5) indicated that the modification resulted in a ‘trial and error’ process that comprised of a continuous process of operation, failure, analysis and redesign. Records show that the final operation and maintenance requirements were far from what was set in the original modification design. The operational stoppages were very high as a result of quality problems and equipment failures. The plant general and operation manager

indicated that an unexpected number of additional and often successively modified spares had to be manufactured. This caused delays in spares provision. The overall result was a noticeable impact on business outcomes and on the achievement of the strategy.

According to most interviews e.g. interviews (2, 3, 4, 5 and 6), it is also evident that the team focused on minimizing the upfront capital cost and overlooked the effects on the remaining life cycle cost elements. This minimization included the use of internal resources. The team prepared the design based on redesign of some existing equipment and reprogramming the computer control system. In support of the new equipment, some minor mechanical spare parts were designed and planned to be manufactured in the company's mechanical workshop. The reprogramming of the control system was done by a team from the computer and telecommunication department of the company and therefore did not require any additional cost other than a single payment for team members as a reward and their overtime. According to these participants, only essential items for the modification were acquired in order to lower the initial capital cost.

In mapping the aggregate planning and control and operational task control level activities, the company records showed these activities were handled by several central departments such as planning and control, quality and industrial safety departments. Table 5.8 summarises evidence that the required activities were undertaken. However records showed lacked of integration between asset-related activities such as maintenance and supporting activities such as procurement due to inadequate information system. Table 5.7 also indicates that the aggregate planning level activities established annual planning, coordination between departments and performance reporting, while task control activities included scheduling and controlling tasks and feedback to the strategic planning and control activity. Plans and reports were coordinated but manually prepared and data was manually accumulated and periodically reported. Records indicate adequate monthly, quarterly and yearly plans and performance reporting systems were in place. Reports were submitted to all relevant departments in the company.

The framework proposes the AM system in terms of activities at operational, aggregate and strategic levels with feed-forward and feedback links between them implies the interdependence and integration of their responsibility to the asset-related activities. The

inadequacy of one AM planning or control activity may cause other AM activities to be inadequate. The poor slit-rolling design indicated in Table 5.7 reflects inadequate operational work task control activities. However, Table 5.8 indicates that the absence of responsibility for analysis and evaluation activities forced the company to form an ad hoc team to handle these activities.

Status of the AM System Strategic Relationships

In order to examine the nature of the link between asset management and the organisational strategy, it is possible to review the workings around the analysis and evaluation activity as evidenced by indications identified previously. Working through the framework and mapping its strategic planning and control activities, as set out in Table 5.9, it is evident that the link between organisational strategy and AM is important to an organisation's success.

With reference to marketing records and interviews held with the marketing and planning and control department managers, interviews (7 and 9), the first indication of the increasing demand was realised when the annual production forecast would not satisfy the sales forecast.

According to interviews held with managers interviews (3, 4, 5 and 6), as a result of realizing the need to increase production capacity and the formation of the ad hoc team, three alternatives were reported to have been considered:

1. Expansion by installing another production facility while importing the shortfall requiring a relatively large investment.
2. Increasing production of the high demand products by reducing production of other products.
3. Modification by installing the slit-rolling equipment requiring a relatively low investment.

From this proposition, it is evident that there was an effort by the ad hoc team to provide a suitable asset solution following the processes represented in the framework. However, the team lack the expertise to conduct the required evaluation and analysis for the proper selection. Team members e.g. participants (4, 5 and 6) stated that at that time the decision

to select the slit-rolling modification as a quick solution seemed logical. However, the expected long term increase in market demand, the impact on several performance aspects and life cycle requirement such as operation and maintenance were not so obvious and were not properly considered. Participant 6 indicated that there was a concern raised about the possibility of an increase in quality defects but not much attention was given to further investigate the concern because the impact was not expected to be a major one. From interviews' transcripts, team members stated that the low investment capital required was encouraging and the chief executive was prepared to take the decision. This indicates the inadequate evaluation and analysis that resulted in modification selection decision based on low acquisition cost and overlooked costs of later life cycle stages.

The low acquisition modification design did not account for the negative or positive impacts on or by operation, maintenance and the impact on product quality. This highlights that life cycle cost analysis is an essential consideration for AM to effectively manage interdependence between activities along the life cycle stages.

With reference to evidences extracted from interviews and company records in Table 5.9, the management actions indicate that there was a link and associated interaction between the asset managers and the strategic decision makers as proposed by the framework but it was inadequately managed. The AM actions studied in this sub-case indicate inadequacies in the definition and provision of the solution that resulted in less than the required performance, outcome and contribution to the strategy achievement. The actions were meant to cover the increase in demand by increasing the production rate; however they resulted in lowering the product quality, the asset's utilization and reliability, increasing the maintenance cost and damaging the organisation's reputation. The asset solution adopted did not meet the operational requirement. It is concluded that the strategic planning and control mechanism proposed by the hypothesized framework in relation to the relationship between AM and organisational strategy making was either not in place or was not interacting appropriately.

The specific outcomes of this sub-case are evidently related to this missing or inadequate activities, relationships and mechanisms proposed by the framework; in particular the analysis, evaluation and decision making activities as part of the AM strategic planning and

control activities. The role of these AM strategic planning and control activities is critical to achieve any production or quality strategy of the organisation and accomplish success.

Status of Feed-Forward and Feedback Control Links

The AM framework sets out feed-forward and feedback mechanisms connecting the various activities represented. A review of these aspects of the framework reflected by data from this sub-case are set out in Table 5.10. It is evident that the performance indicators employed by the company as part of their feedback mechanism were in the form of lagging indicators. Some of these indicators were extracted from records and represented in Figures (5.2 to 5.7) previously. The decision to increase the production capacity was based on lagging indicators highlighting the increasing backlog in customer orders for the specific product of interest. This reflects a reactive response mechanism and poor integration between strategic AM activities and business management activities, including analysis and evaluation activities that utilise feed-forward indicators. A better approach would have included early analysis of market demand as feed-forward information providing a leading indicator for decision making on production capacity changes.

This sub-case highlights the importance of feed-forward and feedback links to the integration of AM planning and control activities with asset-related activities. For example, the feedback indicators alerted the company to customer satisfaction and profitability shortfalls. According to some of the ad hoc team members interviews (5 and 6), realization of possible damage was clear. Combining the lagging performance indicator with the expected demand leading indicator provided a leading view on what the AM solution should be was established. For example, the operation manager indicated that it was not just the low performance of the slit-rolling modification that led to revert to original single facility and introducing a new single facility but also the realization that further performance improvement will not cover the expected increase in demand of the following year.

5.6 Sub-Case-2 Analysis and Interpretation

5.6.1 Stage-1: Establishing the phenomenon

Establish Asset solution in Response to Strategy Event

Sub-case 2 is a set of two of responses (*G&C Line* or HBI projects) to external triggers that led to a new mission of the company to compete in the international market. Transcripts of interviews with managers, interviews (1, 2, 3, 7, 8, 9, 10, 12, 13 and 14) indicated that 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. As will be shown by evidence from this sub-case, the decisions to adopt *G&C Line* and HBI projects were business driven and lacked technical consideration. Indication of these two asset solutions selected in response to this strategy event was evident from responses of many participants, for example:

"…The HBI module and the G&C Line in 1997 were triggered by the new mission of diversifying products for entering international markets. These projects were introduced to provide new commodities for export …" (interview-2).

"…The chief executive introduced the HBI module and the G&C Line in 1997 as a strategy to enter the international markets with new products that were expected to have high demand …". (interview-1)

Sub-case-2, summarised in Table 5.11, is a strategy event triggered by this new mission with the corresponding AM responses being the introduction of both the HBI module and G&C Line.

Table 5.11: Sub-Case 2 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 (Tonnes)
	Introducing HBI Module	Hot-briquetted Iron	650,000
	Introducing Galvanizing and Coating production line (G&C Line)	galvanized and coated coils and sheets	Galvanized (80,000 Tonnes) and Coating (40,000 Tonnes)

In section 5.3, Table 5.2 shows that the company had expanded its asset portfolio in 1997 by introducing new projects to diversify its products to the market. The HBI module and G&C Line were finalized and commissioned in 1997.

As indicated in the quality manual, the policy of the ministry of industry was to make the industrial sector a major contributor to the economy. This initiated a new mission for A-Steel. The new mission aimed at breaking up international monopolies by competing in international markets in addition to covering local demand. The new strategy adopted HBI module and G&C Line introduce new products and increase production of current products for export.

Establishing and Interpretation of Asset-Solution Provision and Resulting Indicators

There were troubles with the *G&C Line* in the provision process. With reference to (interviews (2, 3, 12, 13 and 14), held with company technical and production directors, general managers and managers from operation and maintenance departments in the flat mills, there were several problems encountered in the commissioning stage. They 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, which was an extra capital cost and caused major delays in starting the operation. The production director, general manager of flat mills, general manager of maintenance and electrical maintenance manager interviews (3, 12, 13 and 14) stated that the decision was taken individually by the chief executive. For example, general manager of flat mills explained the decision making:

"... the decision was taken by the chief executive as a business driven decision. It was based on analysis of the market but no analysis was done in terms of its design, acquisition, and integration with existing plants or the associated risks with it" (interview-12).

They indicated that the company had completely relied on the supplier for the design and implementation of this new project but integrating it 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 general manager of flat mills clearly described the provision problems as:

"There were problems with the design; specifically it was not possible to process our coils as an input in these lines. ..more investment was needed in rewinding our coils before using them as input to these lines. ...after starting using our coils, our production capacity of these coils was not enough for covering the increase in market demand and the input for these lines. Shortly after settling these problems, cracks were shown in the concrete structure of these lines. .. a complete disaster in my view that led to shutdown and reconstructing the whole concrete base. ..the supplier was responsible for the reconstruction, it took a long time before lines were back in operation" (interview-12).

The marketing manager indicated that the feasibility study done by the foreign consultant showed that this *G&C Line* were an opportunity to supply part of the demand in Europe. However, A-Steel failed to provide the proper asset solution as a response to this market trigger. He thought this began by choosing the wrong supplier. He stated that:

"... this supplier was unfamiliar with our plant's design. This resulted in unfit design with the rest of our plants. It also seemed that this supplier had construction problems that are not usual" (interview- 7).

Interviews (1, 2, 3, 7, 8, 9, 10, 12, 13 and 14), revealed that as well as this *G&C Line* project, the HBI project was also initiated by the company chief executive . However, the general manager of flat mills indicated that the HBI project started operation on time, had good results and did not have any trouble. In contrast the *G&C Line*, the marketing manager, production planning and control manager and general manager of flat mills interviews (7, 9 and 12) indicated that for the HBI module a contract was signed with the same supplier that previously implemented similar modules at the establishment of the company in 1989. The whole design and implementation process was outsourced to this supplier who knew exactly what was required for the integration. The maintenance manager of Direct Reduction Plant at that time explains the success of the HBI project as:

"I was one of the team members observing the implementation and commissioning of the project. It was submitted on time with successful commissioning. Its performance has been great since.." (interview-9).

In brief, the resulting indications relative to provision of asset solutions are shown in Table 5.12.

Table 5.12: Resulting Asset Solution Provision and its Indications for Sub-Case 2

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 and commissioning. ▪ The provision was done through outsourcing the design. ▪ Implementation was supervised by ad hoc team 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 new DR 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, commissioning. ▪ The provision was done through outsourcing design. ▪ Implementation was supervised by ad hoc team project team ▪ Supplier complied to requirement because of familiarity with existing company assets and plants. ▪ Project was delivered on time and successfully commissioned.

Establishing Indications of Resulting Performance, Outcome and Contribution

Evidence for the resulting asset performance, business outcome, and the value contribution indications were obtained from interview's transcripts and company records. Indications are established and demonstrated over the years for each asset solution and summarized in tables for later referencing.

In most of the transcripts of interviews (1, 2, 3, 7, 8, 9, 10, 12, 13 and 14), 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 reported by the production planning and control and quality control departments over the years.

For HBI module, relevant indicators have been extracted from records of these departments and plotted in Figures (5.9, 5.10, 5.11 and 5.12). These performance indicators confirm the

positive contribution to the business objectives. Figure 5.9 shows that the production rate was as planned over the years and Figure 5.12 shows uniformly high availability and utilization. The production rate shows a gradual increase from about 70% to around 95% as shown in Figure 5.11. Figures (5.10 and 5.10) show that most production quantities are exported, as aimed by introducing this module, and less than 20% is used in the steel melt shops. The trend in exports shown in Figure 5.10 is explained by the trends in the usage in steel melt shops and reflects a slight increase in usage of HBI and exporting some quantities of DRI in placement.

Unlike the HBI project, the *G&C Line* was unfit for the strategy and considered by many interviewees as a complete disaster. The low performance of this production line is reflected in terms of a low annual production rate, extremely low exports, and availability and utilization rates, as shown in Figures (5.13, 5.14 and 5.15). The low production performance indicators shown in Figures (5.13 and 5.14); e.g. less than 50% of design capacity and less than 20% of the achieved production exported reflect a negative impact on the business objectives.

Many Participants confirmed these resulting indicators, for example the production director, marketing manager, quality control manager and general manager of flat mills explain:

"The development of HBI module has been utilized with full capacity and contributed a great deal to profitability of our organisation. ...the G&C Line has not been fully utilized and its input coils from flat mills can be sold with more profit than processing them in this line (interview-3).

"[G&C Line] has resulted in high acquisition cost because of these mentioned problems and until now it is working with less than 50% of its capacity" (interview-7).

"...[G&C Line] has been operating with less than 50% of its capacity for two reasons: the first is that we could not maintain constant demand in the market for its products because of early operation problems and the second is that there is a need for expansion in the flat mills to supply the other 50% of their input coils"(interview-8).

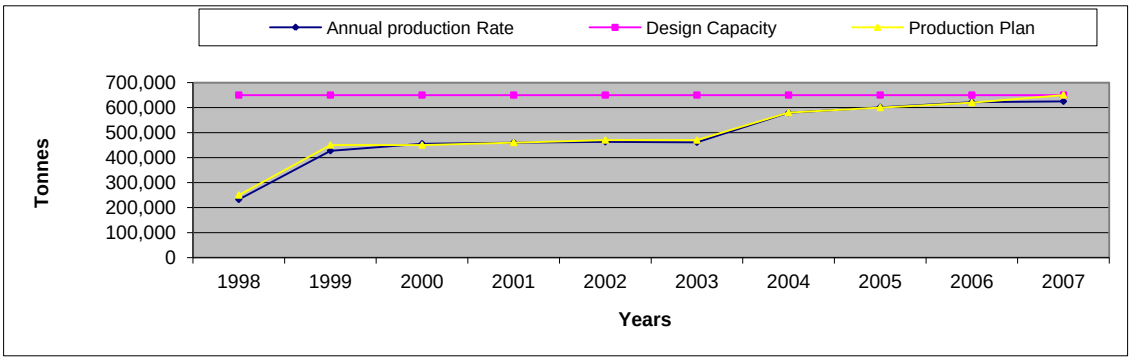

Figure 5.9: HBI Module Design Capacity, Production and Plan Indicators

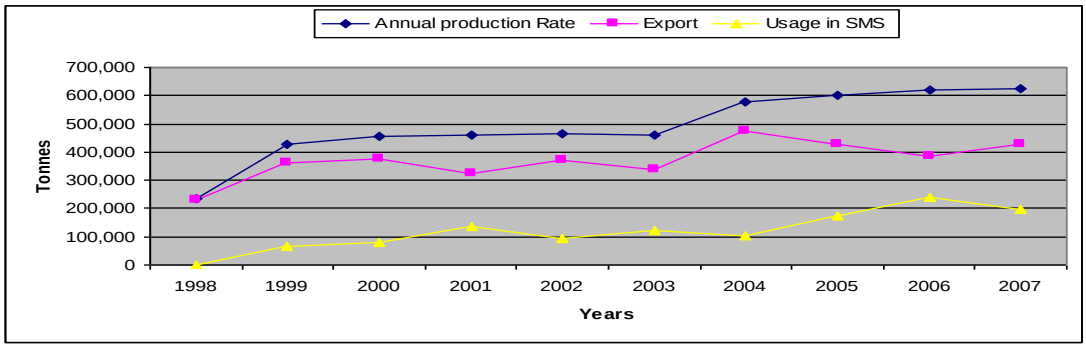

Figure 5.10: HBI Production, Export and Usage Indicators

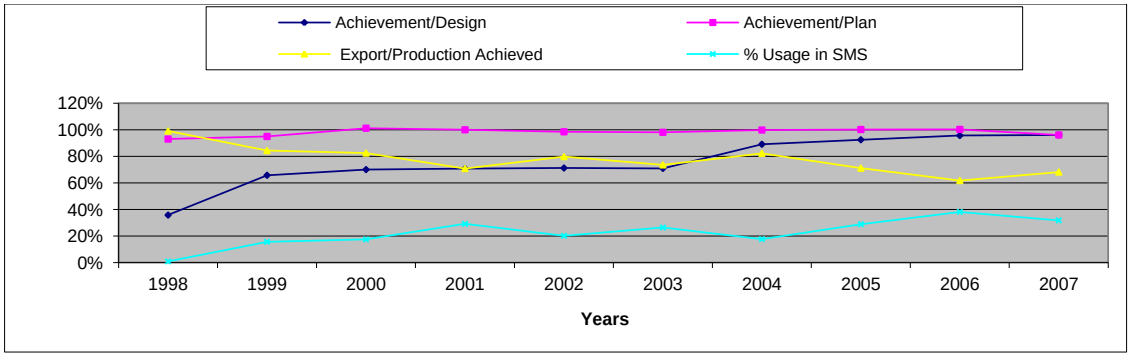

Figure 5.11: Percentage of HBI Module Performance Indicators over the years

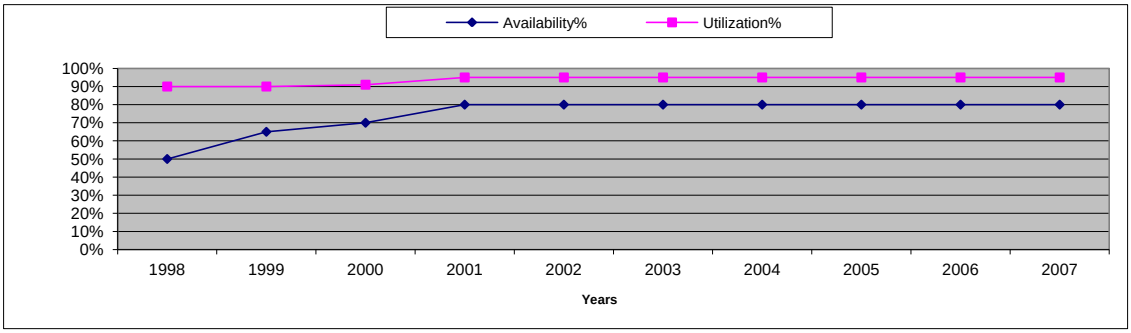

Figure 5.12: Availability and Utilization of HBI Module

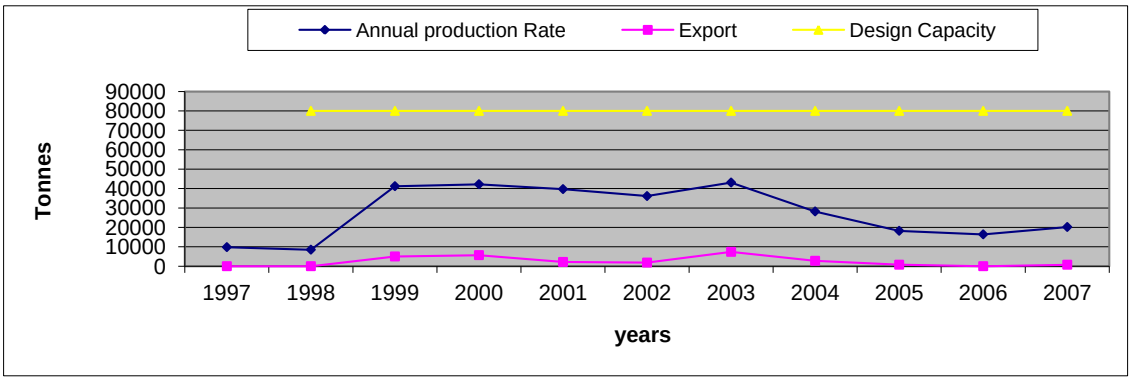

Figure 5.13: Design Capacity, Production and Export of G&C Line

Figure 5.14: Percentage of G&C Line Achievement Indicators

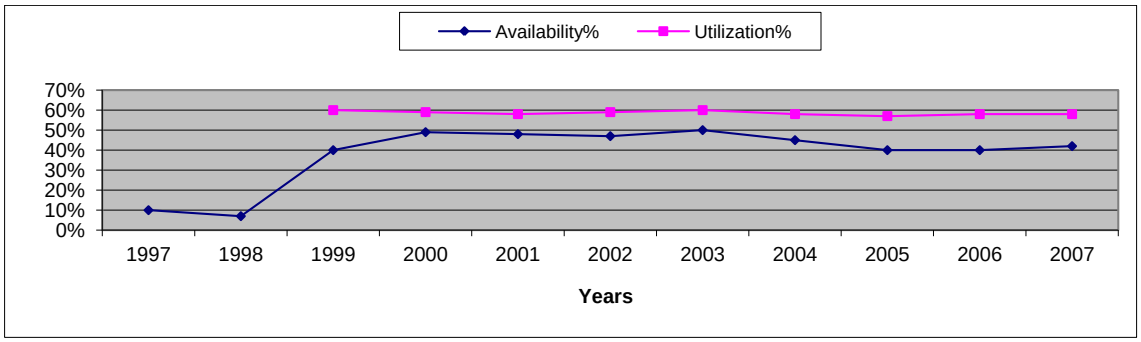

Figure 5.15: Availability and Utilization of G&C Line

"…Production rate of [G&C Line] has been low due to less ordering from customers in the international market and shortage of input coils. This has resulted in low utilization of this line. The production line achievement was less than 50% of its design capacity, a matter that most likely led to not cover even the fixed cost" (interview-12).

Based on the resulting performance indicators plotted in Figures (5.9, 5.10, 5.11, 5.12, 5.13, 5.14 and 5.15), a summary of the resulting asset performance indicators is presented in Table 5.13.

The two asset solutions in sub-case 2 were introduced to provide new products for export. The *G&C Line* experienced provision problems that resulted in low performance of this line and reflected on the business outcome as low quantities of exports. Figures (5.13 and 5.14) show indications of the low performance through the years that resulted in negative impact on the business objectives and therefore failed to achieve the strategy. Unlike the *G&C Line*, Hot-Briquetted Iron (HBI) as another concurrent solution it has performed well over the years as shown in Figures (5.9 to 5.11) and reflected a positive impact on the business objectives. The HBI project is considered to have been extremely successful in boosting exports and profitability, as indicated by most participants and shown by the export quantities indicators.

Table 5.13: Asset Performance and its Resulting Indicators for Sub-Case 2

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 of equipments. ▪ 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 new DR 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.

In addition to the performance indications, participants explained the positive resulting performance of HBI module solution and the negative resulting performance of *G&C Line*, which translated into business outcomes that consequently contributed differently to the strategy. For example:

"…[HBI module contributed a great deal to profitability ...., input coils from flat mills can be sold with more profit than processing them in [G&C Line]" (interview-3)

"…The company could gain more benefit now from sailing these flat mills coils than processing them in [G&C Line]" (interview-8).

"…The HBI is a success. It has increased our share in the market. ..its successful performance in terms of quality and production has shifted our export quantities dramatically as shown in the sale reports. … at some stage HBI products constituted more than 50% of the company export. .. … its products reach many markets in the world"(interview-7).

"… the G&C Line was unsuccessful. The sudden shutdown of the line due to some construction problems has caused loss of customers. It was hard to regain confidence of customers after all of the [provision] problems… there is high demand on flat mill coils in the market and it is more profitable to sale these than process them in the G&C Line . So, this line has resulted in a very high capital cost .. it is working with less than 50% of its capacity…it is a major loss for the company. Not only this line was a failure in terms of contributing to increasing the share in the international market but it caused major losses that affected the overall profitability of the company." *(interview-7).*

".. the HBI was a success but the G&C Line was a disaster. The HBI increased the export; on the other hand, the G&C Line was a major loss in terms of the high capital cost but caused other losses and was not good for the reputation of the company (interview-10).

"…[G&C Line] is a great loss. Its results were opposite to the intended strategy: instead of gaining share in the international market the project caused bad reputation and a great financial loss" (interview-12).

Overall, the business performance or value contribution in this sub-case is directly translated as an outcome from the asset performance. The business performance and value contribution relative to sub-case 2 are summarized in Table 5.14.

Table 5.14: Resulting Business Outcome and Value Contribution to Strategy for Sub-Case 2

Asset solution	Business Outcome Indicators	Value Contribution Indicators
Development Of a new DR Module	▪ High achievement rate ▪ Low product unit cost ▪ High export quantities ▪ High revenues ▪ High profitability ▪ High quality products ▪ More Customers Customer satisfaction.	▪ Intended contribution was to enter new markets with new products that have competitive quality and price. ▪ Positive resulting contribution: became a major export product of the company (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, lowered the company profitability and became a burden on the company. ▪ Caused loss of some international customers and the loss of opportunity to gain more share in this market

5.6.2 Stage 2 - Analysis and Interpretation - Drawing Implications from the Phenomena

Mapping hypothesized framework relative to adopted actions

As indicated for sub-case 1 in section 5.4, mapping the AM actions and interpretation relative to the proposed framework involves analysing actions taken to provide the solution, achieve the performance, and contribute to strategy. The data for mapping and interpretation of actions was extracted from interviews with the relevant managers and investigation of company documents. Mapping the elements of the AM framework against the actions undertaken in actual practice for this sub-case are presented in Tables 5.15 to 5.18.

Table 5.15: Mapping the Asset-Related Activities Relative to Actions in Sub-Case 2

Elements of Framework *(Figure 3.7or3.5)*	Status	Indication of Action and/or Resulting Outcome
Research, Engineering and Design	Absent	▪ Formal responsible departments were missing leading to outsource design and installation of the HBI and G&C Line projects. ▪ Their absence resulted in improper supplier selection ▪ Their absence led to failures in the G&C Line ▪ Familiarity of the supplier with context substituted for their absence relative to the HBI project. ▪ Seven years later an industrial research centre was established.
Acquisition, Deployment and Installation	Absent	▪ A responsible department for contracting, acquisition and implementation of projects was missing. ▪ Projects were outsourced and supervised by ad hoc teams. ▪ Improper contracting and poor supervision of installation.
Operation (Utilization/Use)	Exist	▪ Responsible department adequately existed and shared responsibility of other missing activities.
Maintenance (Care/Service)	Exist	▪ Responsible department adequately existed and shared responsibility of other missing activities.
Replacement and Disposal	Absent	▪ Not relevant for this sub-case but no formal department was found to claim the responsibility of this activity.
Technical Support and Development	Absent	▪ A responsible technical support and development department was missing. ▪ One year later a technical support and development department was established ▪ Its establishment 1 year later is an indication of its effect.
Procurement	Exist	▪ Existed across several departments with lack of coordination between them with respect to AM effectiveness.
Human Resources	Exist	▪ Existed as a central activity through several departments such as training but there was indication of lack of expertise.
Safety, Finance and Accounting control, IT/IS, Quality	Exist	▪ Existed through several departments ▪ Indication of good coordination with departments for AM effectiveness ▪ Mostly manually handled and lacked advanced IT.

Table 5.16: Mapping the AM System Planning and Control Activities Relative to Sub-Case 2

Elements of Framework *(Figure 3.7)*	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, technical 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 lacked technical consideration ▪ Decisions were based on COE 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 ▪ Data accumulation was mostly manual or semi manual leading 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 the 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 5.17: Mapping the AM System Strategic Relationships relative to Sub-Case 2

Elements of Framework (*Figure 3.7*)	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. ▪ There is evident 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 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 setting strategies and adopting plans for supervision of projects implementation. ▪ Adequate operation and maintenance strategies or plans existed.

Table 5.18: Mapping the Feedback Control Mechanism Relative to Actions in Sub-Case 2

Elements of Framework *(Figure 3.7)*	Status	Indication of Action and/or Resulting Outcome
KPIs and Compliance Feedback	Exist	▪ Feedback on compliance to projects implementation plans existed as manual reports. ▪ Feedback reports are used for follow up but hardly used for analysis and evaluation. ▪ Manual feedback reports on operation and maintenance performance indicators existed.
Results as direction for Strategic Decision	Absent/ Inadequate	▪ The feed-forward link as direction or basis for strategic decision making was missing because of the absence of the analysis and evaluation activities.
Control Direction for Planning	Exist	▪ This feed-forward link existed as aggregate plans derived from business driven plans set by the business planning, project planning or budgeting.
Direction for Task Control	Exist	▪ Projects implementation, production plans and maintenance plans existed and converted into schedules, work procedures, control measures and etc.
Data Accumulation	Exist	▪ This existed in terms of data collected from those shift and accumulated in data files.
TPPs and CPs Feedback	Exist	▪ This existed in terms of those weekly and monthly reports presenting indicators of technical parameters measured based on data accumulated from shift reports.

5.6.3 Interpretation of Adopted Actions Relative to Hypothesized Framework

As indicated in the previous sub-case, interpretation of the adopted AM actions can be made relative to the asset-related activities, AM planning and control activities, feed-forward and feedback links and strategic activities and relationship proposed by the hypothesised framework.

Status of Asset-Related Activities

From the evidence extracted from interviews and company records summarised in Table 5.15, it is evident that the activities responsible for analysis and evaluation in deciding the selection, design and implementation of G&C Line project were missing.

It is also evident from this sub-case that at the time of launching these projects the company had no department or means for analysing and evaluating, such as technical support and development, engineering, or design. This may be why the chief executive decided to outsource the whole process of market study, design and implementation for G&C Line and

HBI module. Handling the implementation of the HBI and G&C Line by ad hoc teams is also evident of the absence of such departments. This is reasonable because the company introduced some of these missing activities as 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. There is evidence from many managers' responses that the information was reported to other departments that were thought responsible for analysis and evaluation but they were not established to do such analysis. For example, one of the maintenance managers thought that the maintenance planning and control department was responsible for such analysis and evaluation:

"..these maintenance related activities are the responsibility of the maintenance planning and control department. We have been submitting all the information to them but unfortunately we are not getting any help from them to make decisions that allow us to achieve objectives."(interview-14)

Further, the manager of the maintenance planning and control stated that the control section in his department was not fulfilling the purpose at the aggregate level:

"..The control section of this department in my view is still not fulfilling the purpose of providing indicators on each asset that can be used to guide in managing the maintenance activities according to the most appropriate policy"(interview-19).

From these responses and others, it can be elicited that the absence of the technical support department has led to inadequate strategic planning and control activities. This is confirmed by the responses from the general manager of flat mill maintenance:

"..we did not have the experience and we were not aware enough to have the responsibility for development allocated to the experienced people. Therefore, a group of inexperienced people were selected somehow as an ad hoc team for the G&C Line project. The technical support and development department was established late but after its establishment, it helped us make decisions about several matters ... Perhaps if we had this department earlier we could have avoided some of the problem we had with G&C line"(interview-13).

According to an interview held with the manager of technical support and development department (interview-10), the introduction of his department and the industrial research centre reflects the recognition of their need in order to achieve better results of asset development projects for the organisation. Records showed that these introduced

departments played an important role in improving the process of making initiatives, contracting and implementation of many later asset-related projects.

With reference to aggregate and operational activities, departments with the responsibility of these activities existed as shown in Table 5.15. In reviewing the operation and the maintenance relative to the HBI and G&C Line, it is found that there was coordination with the central production and maintenance planning and control departments and quality control department. As shown in transcripts of interviews (11,12,13,14 and 19), managers of these departments referred to the responsibility of these departments relative to aggregate and operational activities proposed by the framework.

Status of AM System Planning and Control Activities

Evidence of the status of the AM system planning and control activities with respect to the hypothesised framework is set out in Table 5.16. These have been established by investigating records and data extracted from interviews with relevant managers. Actions were mapped relative to these activities at the three organisational levels. The mapped strategic activities in Table 5.16 imply that the inadequacy of the AM system strategic planning and control activities resulted in inadequate specification of requirement of new assets, and in lack of determination of priorities, technical capabilities, design and lack of integration of new assets with existing facilities. This is evident from the inadequate analysis and evaluation relative to requirement in the case of the *G&C Line* that resulted in poor performance.

As indicated earlier, the decisions to adopt *G&C Line* or HBI projects were business driven and lacked technical consideration. They were based on chief executive expertise and did not involve asset managers. According to a member of the chief executive committee (interview-1), the chief executive contracted a foreign consultant to do a market research study to decide on a possible expansion to produce new products and enter the international market. Two solutions were offered; the HBI and *G&C Line*. The chief executive decided to undertake these solutions and contracted with two different suppliers for the whole process from design to commissioning. He also appointed teams to supervise the implementation of each project, and coordinate with all parties for the necessary requirements.

According to many managers, the foreign consultant reported on the predicted demands for the new products introduced by the new assets based on market research but provided inadequate information on the integration of these assets with existing assets for technical capability. As mentioned by one of the now appointed technical support and development manager: "*The study was focused on what products should be introduced but overlooked the internal factors (interview-10)"*

It is not the objective here to investigate whether these predictions were right or wrong but to show how appropriate the outsourcing decision was. According to a member of the chief executive committee (interview-1), the chief executive outsourced these projects from design to installation. 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 sub-case confirms the inadequacy of a critical part of the strategic planning and control activities proposed in the hypothesised framework. That these activities were lacking was made evident by some of the participants. For example, the production director and marketing manager stated:

"I think we could have expanded in flat mills before the development of [G&C Line], or in the bar and rod mill or in the section mill that needed development to change its range of output to fit local and international demand. This is because there was no real study and analysis for priority relative to capability. I think the previous chief executive independently took this decision and accounted fully responsible." (interview-3).

"The investment could have been on other plants such as bar and rod mills that could have increased our sales and therefore revenue and profit. I think we lack the strategic planning activities.."(interview-7)

With reference to the operation and maintenance actions of the HBI and G&C Line, Table 5.16 also sets out evidence of adequacy of the aggregate planning and control and operational task control level activities. However, Table 5.16 indicates some inadequacy of these activities in relation to the implementation of the G&C Line project. Table 5.16 summarises evidence that the required activities were undertaken. However the records

showed a lack of coordination between supplier and implementation team due to inadequate contracting, incomplete information and lack of expertise of team members. This implies that this inadequacy has led to the problem in the implementation of the G&C Line.

Status of AM System Strategic Relationships

Investigating the strategic relationships of the AM system requires working through the framework and interpreting its strategic planning and control activities relative to the AM system actions taken through the process of sub-case 2. This is possible by reviewing the analysis and evaluation activity as evidenced by indications identified in Table 5.17.

With reference to the A-Steel quality manual and interview transcripts, sub-case 2 was triggered by the ministry of industry to make the industrial sector a major contributor to the economy. Most participants agreed that the decision to undertake the HBI module and *G&C Line* were taken by the chief executive in a top-down manner. For example, the production manager and general manger of flat mills interviews (3 and 12) said the decision was taken by the chief executive without consulting any of the technical departments.

"The decision was simply a business driven decision with no consideration to adoption, applicability or integration with the existing plants… we had nothing to do with their initiation. We were told that such projects were going to be implemented.". (interview-12).

This indicates an absence of interaction between the asset managers and strategic decision makers proposed by the framework. This interaction lacked the required analysis and evaluation to provide feedback to support the decision. This is also evident from the replies of marketing and quality control managers.

".. strategic decisions were usually taken by the chief executive based on his discussion with directors… but the company had no strategic system … or feedback from various departments to manage for better strategy making (interview-7).

" When I started here in this marketing department I wrote to the chief executive a proposal to introduce a strategic planning department to study these external changes in the market,… The chief executive settled for a strategic committee that meets periodically.. (interview-7).

"Some of [these projects] were required and added to the company sales but I think it is just luck and there was no good analysis or study of alternatives" (interview-8).

From these replies it can be seen that if these analysis and evaluation activities existed other alternatives could have been considered. Some of those alternatives are shown in Table 5.19.

Table 5.19: The Alternative Asset solutions for Sub-Case 2

Strategic Objective	Alternative Solutions	Contribution	
Diversifying Products for entering competition in international markets and covering local demand as well	Development Projects	New Products	Reasons
	Modifying or Developing the Light and Medium Section Rolling Mill	New variety of products (a variety of section-sizes)	▪ There is priority to overcome the original section mill output design problem. ▪ To avoid further financial losses ▪ To account for local market demand in design of new products
	Introducing a New Bar and Rod Mill	Increase quantity of current products (Bar and Rods)	▪ Evidence of demand in local and international markets. ▪ Evidence of high performance achievement

Despite the fact that the decision to implement these two solutions was taken under the same circumstances, in terms of results and contribution to organisational strategy, one turned out to be a disaster and the other a success. Although the evaluation and analysis activities were missing it is essential to determine what action led to the different results and contributions. The quality control manager (interview-8) indicated the lack of analysis and said it was just luck that some projects were successful, but success must come from the right decision and action. Therefore, comparing actions and determining their difference relative to the proposed model should help define these missing or existing activities, relationships, and control mechanisms.

For the HBI module the resulting indicators showed that it was a significant success for the organisation that contributed directly to the intended strategy. The reason given by managers (e.g. interview-9, 7, and 3) was probably luck to contract with the same supplier of existing DR modules 1and2. The quality control manager (interview-8) said that the investment process had not been established on appropriate and complete analysis; they

were usually based on capital or purchasing costs without realizing the consequences over the long term. Interviewed 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 so the management of the project was allocated to a team from operation and maintenance managers of the previous process Direct Reduction Modules (DR module) with previous experience. Furthermore, one of the project implementation supervisors (interview-19) stated that this HBI model was easy to integrate with existing facilities such as power or utilities. It was easy to increase the imported raw materials and facilitate the export of HBI as a new product because it did not depend on input from other plants or was a major supplier to other plants, therefore integrating and fitting it to the old modules and supporting facilities or services was easy because the suppliers of the previous process were the same. The marketing manager (interview-7) also said that the high demand and increase in prices of HBI at the start of operation enhanced the success in performance and contribution to the organisation.

From this explanation of the decision to purchase and install the HBI module, it is summarized that:

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. Selecting a project team familiar with the older modules helped to maintain successful implementation and utilization.

This leads to the conclusion that outsourcing the AM project to suppliers familiar with existing assets and facilities substituted for the missing evaluation and analysis, or strategic inter-relationship or control mechanism on the organisation side, as proposed by the hypothesised framework.

The indicators for *G&C Line* 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. Most managers interviewed e.g. interviews (12, 8, 7 and 3), indicated that decision, adoption and undertaking of the *G&C Line* project was business driven and done in isolation of the AM technical view. They explained that the engineering and technical people were only involved in coordinating and installing the equipment after the supplier was selected and the contract approved. According to them the decision was taken by the chief executive and his committee based on the expected need in international and domestic markets, they ignored the analysis for integrating with existing plants, as seen when the coils didn't fit the *G&C Line*, introduced as a downstream development. Many interviewees said that this project should not have commenced because expanding the bar rolling mill and flat mill were delayed. The general manger of the flat mill (interview-12) said that the flat mills should have been expanded before the G&C Line was installed. The manager of foreign marketing department (interview-7), stated that it was more profitable to sell these input coils than process them in this line because there was a demand for them on the market.

These managers were also opposed to the *G&C Line* as a solution and further indicated that the situation was worsened by the selected supplier. The general manager of flat mills, quality control and marketing mangers interviews (12, 8 and 7) stated that many problems would have been avoided if the project was given to one of the expert suppliers in the field (e.g. the same supplier of the existing flat mills). They said 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. Furthermore, the general manager of flat mills (interview-12) said the project was taken by the chief executive alone, without consulting the flat mills management. He explained that some problems could have been avoided if the chief executive had involved a team from the managers in the flat mills or took their views on the technical design, integration, or capability. He further stated that the project team appointed to supervise implementation lacked the expertise and experience and failed to coordinate the project.

From this interpretation of the decision, provision, and results of the *G&C Line* project, it is concluded that missing these asset-related activities led to absence of evaluation and

analysis activities, and interaction with strategic planning which resulted in an inadequate provision reflected in terms of:

1. Selecting a supplier based only on low capital cost.
2. Lack of proper contracting procedure.
3. Lack of expertise in supervising and coordinating the project.

Unlike the HBI solution in this same sub-case, the supplier of the *G&C Line* was not familiar with existing facilities and not the most expert, according to the marketing manager (interview-7). Therefore, in contrast to the HBI solution, the G&C Line implementation indicates that the absence of evaluation and analysis as part of the strategic planning and control activities proposed by the framework was not substituted by a supplier familiar with the existing assets.

An overall conclusion regarding the strategic role of AM can be made from the results of sub-case 2. The absence or inadequacy of proper AM system activities, control mechanisms and relationships, conflicts with strategy or results in an inadequate performance or outcome for achieving organisational strategy or competitiveness.

Status of Feed-Forward and Feedback Control Links

At the aggregate and operational level, Table 5.18 indicates that plans and reports were coordinated but manually prepared and data was manually accumulated and periodically reported. Records indicate adequate monthly, quarterly and yearly aggregate plans and performance reporting systems may be considered to be adequate. Reports were submitted as feedback to relevant departments and through the hierarchy of the company. From the production planning and control department records, the commissioning and performance feedback indicators were reported from the G&C Line and HBI model. However, according to many managers, initially the contractor has done market forecasts but inadequate analysis failed to provide information about the technical specification for integration of the new assets with existing ones and failed to predict any possible future technical problem. Such technical information and prediction constitute the feed-forward information for strategic decision making.

At the strategic level, Table 5.17 indicates inadequate feed-forward of such information for decision making as a result of inadequate analysis and evaluation.

5.7 Sub-Case-3 Analysis and Interpretation

5.7.1 Stage-1: Establishing the phenomenon

Establish Asset solution in Response to Strategy Event

Sub-case-3 as a set of responses for continuous improvement strategy has improved performance and helped achieve competitive quality, quantity, and unit cost of products. As identified in section 5.3, The AM responses in this sub-case were identified by several actions taken in the steel melt shops. Particularly, this is identified by modelling the optimization of replacement and repair of EAF lining, introducing a ladle furnace, and replacing the external cooling rolls by internal cooling rolls in continuous casting. These three AM solutions are selected to make sub-case 3 because they aim at improving performance to enhance customer value. That these actions optimised performance was indicated by interviewed managers' replies e.g. interviews (2, 15, 16, 17 and 18). The solutions included maintenance, replacement or development. These managers from the Steel Melt Shops stated that these solutions were taken to improve performance and remain competitive. For example, the technical director, general manger of steel melt shops 1and2 and operation manager of steel melt shop 2 have stated:

"…we have been trying in different ways to improve our maintenance practice and reduce cost and production losses. Those contribute to the profitability, products price and competitiveness…. those managers of the various plants or departments can give you better descriptions on these actions" (interview-2).

"…. The aim was to contribute toward cost minimization and achieving competitive products unit cost. It was necessary to do the required research and analysis to determine the optimum practice… The research study concentrated on EAF's lining replacement and repair optimization. .. ". (interview-15)

"Many actions were undertaken to enhance performance…. Example of these include the study to optimize EAF refractory lining replacement during 1998-99, the introduction of ladle furnace in year 2001 and the replacement of external cooling rollers by internal cooling rollers in continuous casting in year 2001 as well….other actions that contributed to cost reduction and better output quality such as improving purchasing policy to enhance

the quality of spare parts, the quality of raw material and additions to molten metal" (interview-16).

With reference to interview-2, the technical director said that benchmarking showed that the maintenance and production costs were higher than some competitors in the region, which had triggered efforts toward improving performance and obtaining more competitive unit costs.

"… by minimizing cost and maximizing performance of assets,… eliminating losses and reducing the high maintenance cost,…..the asset capital cost, operating cost and maintenance cost will have major impact on the products unit cost which will affect our prices of the products and consequently may reduce our profit margin. Benchmarking with other steel industries in the region tell us that our production cost and maintenance cost are high and our stock in general is high" (interview-2).

From interviews held with managers in various parts of the company, there were many actions taken toward this strategy. However, to better understand the relationships between actions and strategy, this sub-case was selected in terms of only three asset solutions in the Steel Melt Shops. The strategy event and asset solutions for sub-case 3 are summarized in Table 5.20.

Table 5.20: Strategy Event and Asset Solutions for Sub-Case 3

(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

Establishing and Interpretation of Asset Solution Provision and Resulting Indicators

Information regarding these solutions was collected from interviews with managers at different levels interviews (2, 3, 10, 15, 16, 17 and 18) and departmental records, including technical support and development, operations, maintenance, refractory, and others.

In brief, the resulting asset solutions provisions and its indications are summarized in Table 5.21.

Table 5.21: Resulting Asset Solution Provision Indicators for sub-case 3

Asset Solution	Asset Solution Provision Indicators
Replacement and repair optimization modelling of EAF refractory lining (El-Akruti 1999)	▪ The provision of this solution involved undertaking the research study 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.

For the refractory lining replacement and repair model, project documents from the technical support and development department records provided a detailed account of the development of the model, although the refractory department manager and operation manager interviews (15 and 16) explained what led to this provision and how they arrived at this model.

The refractory department manger explained that pressures toward lowering cost led to a tendency to reduce budgets for operation and maintenance in the steel melt shops. Such situation created conflicts between operation or maintenance in the steel melt shops and those finance, accounting and purchasing departments.

".. We had realized that the best practice relative to our replacement and repair of lining need to be defined to support our argument. ... suppliers indicated that such criteria depend on the conditions, operating parameters and other context factors. ..We had to develop decision support models for refractory lining practice on our own. The aim was to contribute toward cost minimization and achieving competitive products unit cost. ... Our department did not have the expertise to do such analysis but made available all the required data... The matter was reported to the technical support and development department which allocated the work to one of our engineers who worked in conjunction with [IND-university]to develop a model for EAF's lining replacement and repair optimization" (interview-15).

One of the steel melt shops operation managers explained that this solution established decision criteria regarding several operational and strategic management actions. He also explained how its application contributed toward customer value.

"...proved with no doubt that the most expensive lining material in terms of purchasing is actually the cheapest in use or its use results in less lining life cycle cost. The (solution) provided dollar value comparison between suppliers and showed the optimum replacement and repair cycle based on life cost analysis. ...its application served in determining decision criteria relative to the optimum replacement cycle and hot repair sequence and cold repair limit based on life cycle cost analysis. It also gave us basis to estimate the lost value do to stoppage time..... its application served in lowering liquid steel unit cost that consequently resulted in lowering all final products unit cost that contributed to customer value" (interview-16).

In reply to the question of why the project was done in conjunction with the [IND-university] and not by the technical support and development department: the technical support and development manager (interview-10) explained that, his department had only been established in the early 1998 and could not do the analysis, but it followed up the

project results. He said that a lack of expertise in this field forced them to contract with universities to analyse problems and to allow employees to gain knowledge and experience in the technical support and development related fields. He indicated that a set of models were developed in association with [IND-university] and a copy of the document is kept in the department records.

The project document showed how this set of models was developed based on previous data of operation, replacement, and repair of the lining. It also showed how these models should be used to support decision making regarding which suppliers to use to supply the linings, how long it would take to replace them, when to undertake cold repair and how to plan a hot repair sequence. Examples of such criteria were obtained from this document. Figures (5.16 and 5.17) show the data that determined the criteria for optimising replacement and frequency of hot repair for one of the suppliers of lining material. These show how the models were used by feeding in the input data, starting with replacement costs and accumulating the repair costs, through to using the lining to optimise the amount of time for repair and point of replacement, and ensure these points are not passed over. According to this document, these models did not replace the usual inspection procedure for safety; they gave a view of the economics of repair and replacement for decision making.

The provision of the ladle furnace and replacement of the external cooling rolls by internal cooling rolls in the continuous casting were handled by the technical support and development department in collaboration with the related departments in the steel melt shops. From interviews held with the technical support and development manager, general manager and operation managers of steel melt shops interviews (10, 15, 16 and 17),

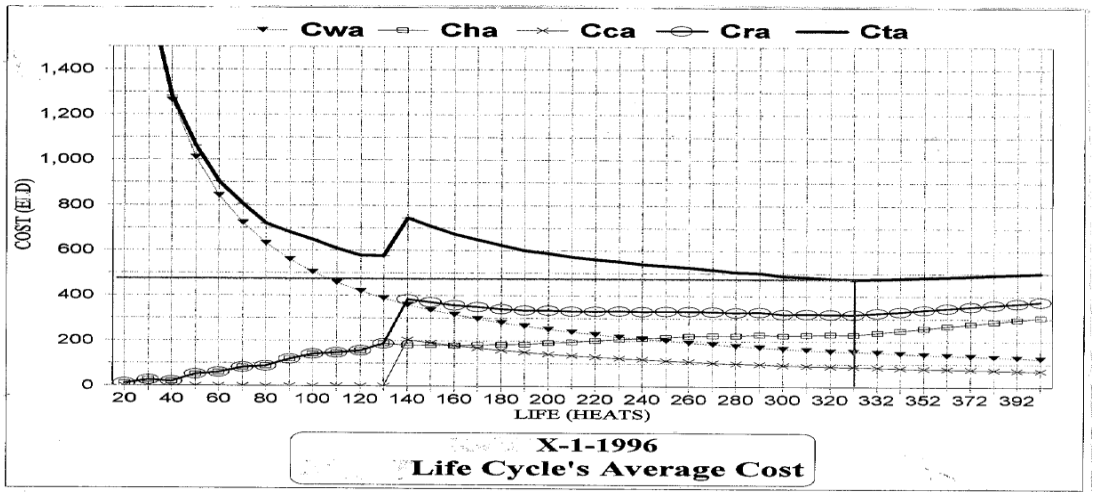

Figure 5.16: Determining the Optimum replacement (A-Steel Technical Support and Development Department Records)

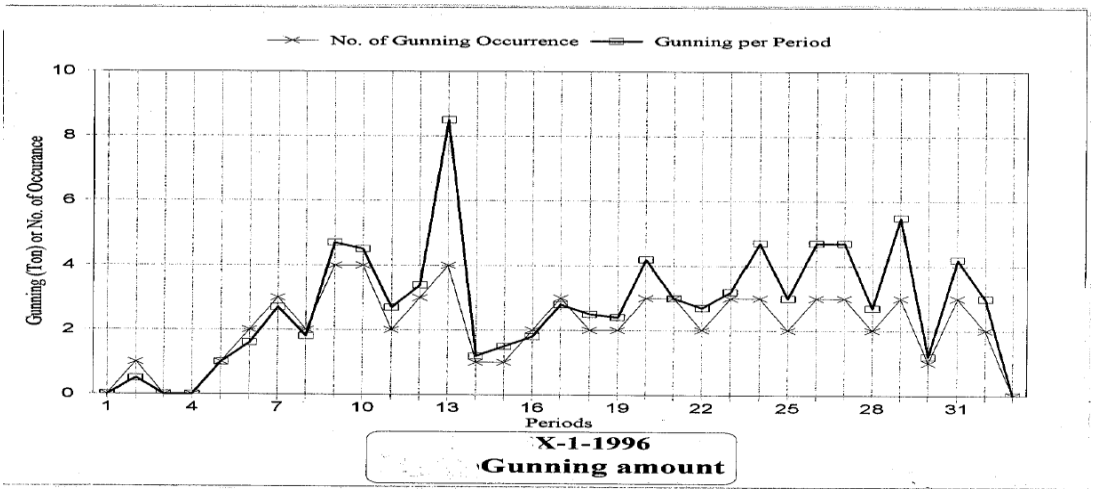

Figure 5.17: The Hot Repair Sequence (A-Steel Technical Support and Development Department Records)

it is revealed that the technical support and development department played an important role in initiating these two projects and providing a basis for top management to make the decisions. They stated that they reported these problems to the technical support and development department and that these two solutions resolved the problem. The technical support and development manager (interview-10) explained that in 2001 the technical support and development department was able to analyse problems and performance data from operations and plant maintenance, including a cost and benefits analysis, and then proposed replacing the external cooling rolls by internal cooling rolls in the continuous

casting cooling bed. Managers explained the role the technical support and development department played. For example:

"....At first we were thinking of putting more control on operation process procedure but reviewing the latest technology in the field highlighted the opportunity for improvement by the ladle furnace solution. So, there was the analysis to define the problem and the different ways of approaching its solution and defining the ladle furnace as one of the alternatives or opportunities for improvement relative to the problem defined. Therefore, before even thinking of the saving made by the ladle furnace, there was the work to determine that the ladle furnace was an alternative solution. When it was realized as an alternative, we focused on gathering all information about its acquisition, installation and the viability and flexibility of its integration within the steel melt shops. This led us to the cost and benefit analysis for adopting the ladle furnace for improvement of the steel melting and casting processes (Participant 10).

Such explanation was confirmed by one of the steel melt shops operation managers:

"Coordination between technical support and development and steel melt shops resulted in studying the possible alternatives and adopting the ladle furnace solution. The solution was established in terms of acquisition and installation of a ($..) million ladle furnaces project" (interview-16).

The technical support and development manager (interview-10) indicated that the improvement in performance relative to the unit cost of products while maintaining quality highlighted the advantages of these two solutions. The technical support and development manager (interview-10) and managers of refractory and operation in the steel melt shops interviews (15, 16 and 17) said that the ladle furnace eliminated 'pour-back' and associated losses such as energy and utilities, and provided better control to produce more precise ranges of steel grades or alloys. According to the technical support and development department records, the analysis had shown that the advantages directly serve the organisational strategy and outweigh the investment costs over the long term. These managers' interviews (10, 15, 16 and 17) also indicated that the analysis showed that using the internal cooling rolls eliminated 'scale' and reduced stoppages for repair or replacement, which compensated for the cost of purchasing the internal cooling rolls.

Establishing Indications of Resulting Performance, Outcome and Contribution

The resulting indications include those related to the resulting asset performance, business performance and the value contributed to the organisational strategy. Evidence for these indications was obtained from interview's transcripts and company records.

From the records and transcripts of interviews held with the technical support and development manager (interview-10) and managers of operation, maintenance and refractory departments interviews (15, 16, 17 and 18) in the steel melt shops, the three asset solutions presented in this sub-case that respond to the improvement strategy improved asset performance.

For the EAF refractory lining solution the main result was developing these models that were used to improve performance. According to the project document in the technical support and development department records these models were developed as a program to establish the analysis and optimise the policy in terms of decisions based on monitoring the replacement lining, operation, and repair data. This is evident from applying these models on the EAFs in the steel melt shops at A-Steel, as shown in Figures (5.16 and 5.17), and from the models application in the refractory department's records. From the project document in the technical support and development department records, it is stated that:

"The decision criteria ... for decision making regarding the action of replacement, repair and the material type to be used ... are related and dependent on many other criteria in the process of steel making.....The model was developed ... with respect to the different situations or conditions that may exist in EAF steel making process. Therefore the model analysis defines the relative situation by assessing and finalizing input variables from statistical data as the first stage of analysis, and in the second stage, the analysis provides different optimum policies or solutions in terms of the values for decision criteria depending on the relative EAF's situation and statistical data" (Project document in the technical support and development department records).

As presented in this document and revealed by these participants, the model was used to improve asset performance and determine the criteria optimising performance. For

example, the refractory department manager (interview-18) from the refractory department explained optimization as:

"The study was based on the total life cycle cost which included replacement verses repair and stoppage cost taking in consideration the worst and best operation conditions. The results were:

1. *Defining the optimum replacement of the lining to be within a specific range (e.g. 300 to 350 heats for one lining supplier material). This showed that it was more costly to operate with lining over this life range with the amount of repair done.*
2. *Defining the limit for using cold repair based on remaining life estimation; that is at what age of life is cold repair economical to use.*
3. *Defining the optimum range of using hot repair as a function of the lining life; that is when to start hot repair, periods of doing it and what amount of repair should be used at each period.*
4. *Defining the best supplier of refractory based on the life cycle cost per unit produced e.g. per heat or per ton of liquid steel." (interview-18)*

The asset performance parameters used to formulate the decision optimising the repair and replacement of the EAF refractory lining and their quantitative values for the suppliers' material are presented in Table 5.22 extracted from the technical support and development department records. Managers operation and refractory in the steel melt shops stated that having these models and enhanced the performance of the EAF in particular and steel melt shops in general. They commented that the introduction and application of these models enhanced performance and increased the availability, reliability, and productivity of the EAF, including a reduction in stoppages for replacement and repair. This is for example seen in the statement made earlier by the operation manager in steel melt shop 2 (interview-16).

The technical support and development manager (interview-10) and operation and refractory maintenance managers interviews (15, 16 and 18) in the steel melt shops explained that the ladle furnace had 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.

Table 5.22: Optimum Performance Indications (Technical support and development department records and (El-Akruti 1999))

Parameter	Unit	Material Suppliers		
		Supplier-D	Supplier-X	Supplier-V
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
Maximum Hot Repair Cost per Period	$	13,682	14,007	15,907
Optimum 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, and mostly 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-D	Supplier-X	Supplier-V
Supplier-D	--------	-$451,703	-$862,653
Supplier-X	$862,653	--------	-$410,950
Supplier-V	$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

It provided better control and helped produce more precise steel grades/alloys leading to better final products quality. For example the operation manager of steel melt shop 2 (interview-16)explained this as:

"… This increased process yield, utilization and helped reduce production cost by eliminating such losses……. was a push toward performance improvement. For example, looking at eliminated losses from pour back losses in SMS1 alone is a great achievement. It is usually 50% less in SMS1 due to the less complexity of steel grades/alloys produced but still a great loss" (interview-16).

The technical support and development manager (interview-10) stated that introducing a ladle furnace was proved by their analysis to improve performance and contribute value to the company that can be quantified in dollar value, i.e. the savings in these losses can pay for the cost of the ladle furnace in less than two years, and its use contributes value relative to the quality of the final products.

A review of performance records from 1998 to 2005 confirms the statements made in interview transcripts interviews (10 and 16). For example, the average pour back was 38,000 tonnes in SMS2 and 16,000 tonnes in SMS1 before 2001, and dropped to zero after 2001 as shown in Figure 5.18. This is also reflected on the process yield as it improved from an average of 85% in SMS2 and 86% in SMS1 before 2001 to 92% in SMS2 and 95% in SMS1 after 2001 as shown in Figure 5.19.

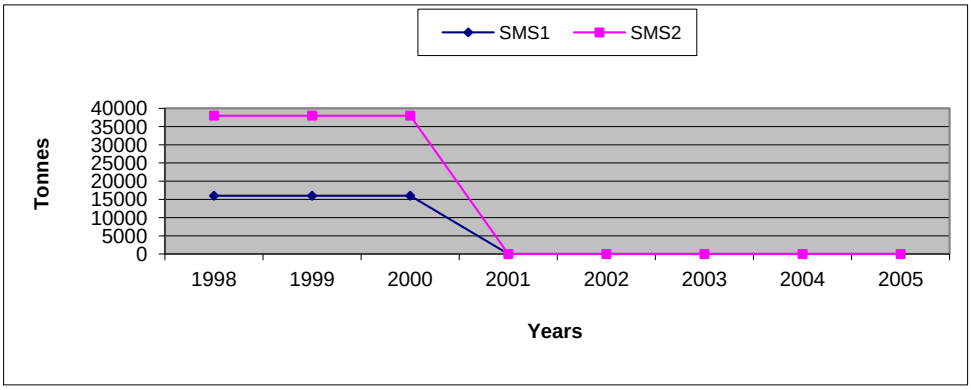

Figure 5.18: Eliminating Pour Backs by the Introduction of a Ladle Furnace

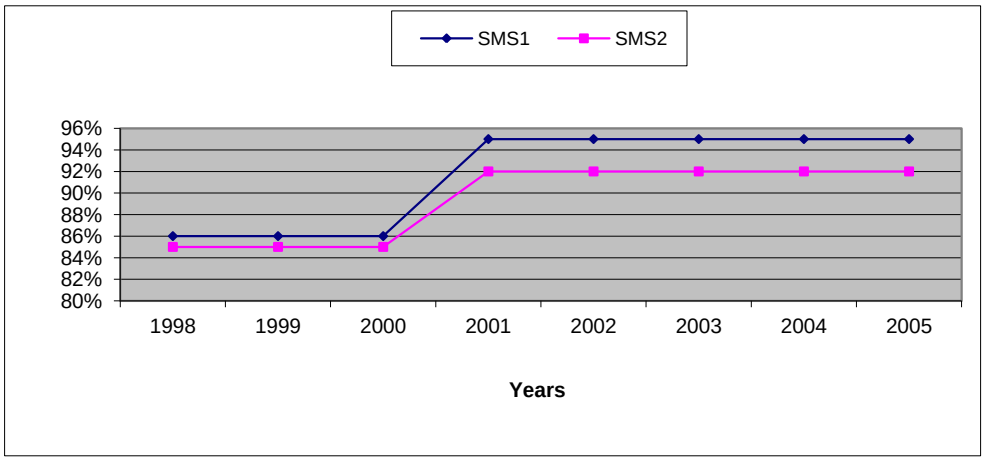

Figure 5.19: Yield Improvement by the Introduction of a Ladle Furnace

As a rough evaluation, the savings made by eliminating these losses, was over $21 million per year (Omar, El-Akruti et al. 1996). From this the result is more than the price of the ladle furnace ($17 million) in just one year. In this respect the manager of technical support and development, (interview-10) indicated that evaluation might be simple but defining the opportunity for improvement and the appropriate solution needs more effort and analysis before deciding which evaluation can be done.

With respect to replacing the external cooling rolls with internal cooling rolls in continuous casting, managers from the steel melt shops and technical support and development department explained that it eliminated scales and reduced the replacement and repair time. Operation managers interviews (15 and16) explained that the purchasing cost of the internal cooling rolls was very high compared to the external ones but according to manufacturers' recommendations, and as proven in practice, in one period of replacing the internal cooling rolls, it is necessary to replace 5 to 6 external rolls. These participants indicated that internal cooling rolls increases availability by reducing unscheduled replacement and repairs from cooling problems that cause scales to form. Participant 10 stated that scales on billets, blooms, or slabs cause breakdown or stoppages in rolling process and affect final quality. He explained that the problems caused by scales cannot be tolerated in the rolling process and scales must be eliminated. According to these managers from steel melt shops, adjustment of the cooling rate and repairs to maintain uniform cooling causes a lot of stoppages that reduce the availability and utilization of the process.

In brief, the asset performance and its resulting indicators are summarized in Table 5.23.

Table 5.23: Asset Performance and its Resulting Indicators for sub-case 3

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 stoppage 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% as shown in Table 5.21.
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 overcoming the formation of scales on slaps in SMS2 and on billets or blooms in SMS1. ▪ 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. ▪ Resulted in enhancing the utilization in the rolling processes leading to higher productivity, better final products quality and less processes stoppage or breakdown.

The business outcome and customer value contribution in this sub-case as summarized in Table 5.24 is an outcome from asset performance.

Interview transcripts and the performance records from the production planning and control department show an overall improvement in the performance of the steel melt shops from 1998 to 2004. Although there may be other factors that contributed to this improvement, the impact of these asset solutions is evident from the specific assets performance indicators such as EAFs availability or utilization.

Table 5.24: Resulting Business Outcome and Value Contribution to Strategy for Sub-case3

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 as shown in Table 5.21. ▪ 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 grades/alloys. ▪ Contributed to lowering unit cost of all products and enhancing products quality. ▪ Contributed to better products quality and gaining more competitive prices of products or higher profit margin and maintaining a competitive position in the market.
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 the steel melt shops. ▪ Enhanced utilization in the rolling processes leading to better products quality. ▪ Resulted in a better quality slabs or billets produced. ▪ Contributed to increasing final products' quality, quantity and lowering unit cost. ▪ Contributed to better products quality and gaining more competitive prices of products or higher profit margin and maintaining a competitive position in the market.

Some of the performance indicators highlight that these solutions were the direct cause of improvement, as confirmed by some participants. For example, early quotes from operation managers' interviews (15 and 16) indicated that the process yield improved when the ladle furnace was installed. As stated earlier by several participants, the asset solutions in sub-case 3 were introduced to improve performance and achieve competitive quality, quantity,

and unit cost. The three solutions of this sub-case improved asset performance and values, as summarized in Table 5.23 and the business outcome and customer value contribution in this sub-case is summarized in Table 5.24.

From these solutions the strategy was improved. This is related to increasing production, enhancing the quality of final products and achieving competitive product unit cost. Tables 5.23 and 5.24 imply that these solutions improved asset performance, gained more competitive prices or higher profits.

5.7.2 Stage 2 - Analysis and Interpretation - Drawing Implications from the Phenomena

Mapping hypothesized framework relative to adopted actions

As with previous sub-cases, this section maps the elements of the AM control system relative to the status of AM actions and provides a structured summary of the results shown in Tables 5.25 - to - 5.28. The data for these tables was extracted from interviews with the relevant managers and investigation of company documents.

Table 5.25: Mapping Asset Related-Activities Relative to Actions for Sub-Case 3

Elements of Framework *(Figure 3.5& 3.7)*	Status	Indication of Action and/or Resulting Outcome
Research, Engineering and Design	Exist	▪ There was no engineering and design department but a technical support and development department was introduced and took the responsibility for the research, analysis and evaluation to identify asset development needs.
Acquisition, Deployment and Installation	Adequate	▪ This is existed in coordination between departments: purchasing and maintenance or purchasing and operation or purchasing and technical support and development or involving all of them.
Operation (Utilization/Use)	Exist	▪ Operation management adequately existed and shared actions to do or coordinate the responsibility of AM activities (inspection and repair: gunning & fettling).
Maintenance (Care/Service)	Exist	▪ Maintenance management adequately existed and shared responsibility with other departments. For example, replacement of rolls is handled by the maintenance and operation.
Replacement, Retirement and Disposal	Exist	▪ A refractory department existed since the establishment of the company and have handled the refractory lining replacement, repair and reuse.
Technical support and development	Exist	▪ This existed in terms of the introduced technical support and development department which played a role in deciding on these asset solutions presented in this sub-case.
Procurement	Exist	▪ Existed across several departments with lack of coordination between purchasing and refractory department with respect to AM effectiveness.
Human Resources	Exist/ Inadequate	▪ This existed as a central activity through several departments but there was indication of lack of expertise.
Finance and Accounting control, IT/IS, Quality	Exist	▪ Existed through several departments ▪ There was indication of good coordination with departments for AM effectiveness. ▪ There was also indication of lack of coordination between several departments and the cost accounting.

Table 5.26: Mapping AM System Planning and Control Activities Relative to Sub-Case 3

Elements of Framework *(Figure 3.7)*	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 the strategy.
Decision Making	Adequate	▪ Due to the existence of appropriate analysis and evaluation by the technical support and development department, decisions in this sub-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 reported to the technical support and development department by relevant departments. ▪ 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 shift reports presented indicators for weekly reports. ▪ Technical performance measurement indicators established. ▪ Many measured Indicators but mostly lagging Indicators. ▪ Condition monitoring was limited to inspection techniques such as visual and preventive measures that are mostly time based.
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.

Table 5.27: Mapping the AM System Strategic Relationship relative to Sub-Case 3

Elements of Framework *(Figure 3.7)*	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 costs that were higher than competitors. ▪ Reviewing Available technology served in identifying 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 in terms of minimizing the products unit cost, maximizing production and sustaining the required 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 and was shared by operation, maintenance and technical support and development departments and in coordination with the supporting departments.
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 business targets.

Table 5.28: Mapping the Feedback Control Mechanism Relative to Actions in Sub-Case 3

Elements of Framework *(Figure 3.7)*	Status	Indication of Action and/or Resulting Outcome
KPIs and Compliance Feedback	Exist	▪ Feedback on KPIs existed as manual performance reports and used for analysis and evaluation by the technical support and development department.
Results as direction for Strategic Decision	Exist	▪ Direction or basis for strategic decision making existed as a feedback from the analysis and evaluation activities done by the technical support and development department. ▪ Results fro analysis in technical support and development department severed in proving that the solutions were the most appropriate and obtaining approval to adopt these solutions.
Control Direction for Planning	Exist	▪ This existed in terms of these business driven decisions and targets set by the business planning for project plans or budgeting.
Direction for Work Task Control	Exist	This existed in terms of these aggregate plans that were converted by each department into schedules, work procedures, control measures and etc.
Data Accumulation	Exist	▪ This existed in terms of data collected in those shift reports.
TPPs and CPs Feedback	Exist	▪ This existed in terms of those weekly reports presenting technical data accumulated from these shit reports

5.7.3 Interpretation of adopted actions relative to the hypothesized framework

As stated in the previous sub-cases, establishing the AM actions and interpretation relative to the proposed framework involves interpreting them in relation to how it was decided that the strategy event required an asset solution and how a particular solution was selected, established, adopted and implemented. This involves interpreting the adopted AM actions relative to the existence or adequacy, and/or absence or inadequacy of asset-related activities, activities, mechanism, and strategic relationship, as proposed by the framework.

Status of Asset-Related Activities

With reference to the evidence extracted from interviews and company records and summarised in Table 5.25, it is evident from this sub-case that the introduced technical support and development department took the responsibility for analysis and evaluation in deciding the selection, design and implementation the three solutions. Allocating these analysis and decision basis to the technical support and development department shows that some of the AM system formal structure (life cycle and supporting activities) existed, as detailed representation in Figure 3.5 and proposed by the framework in Figure 3.7 and the. Specifically, the company had a technical support and development department to undertake analysis relative to research, engineering design, and modelling, as part of the life cycle activities or a technical support and development as part of the supporting activities. With reference to previous sub-cases (1 and 2), the organisational structure of the company did not include this activity at that period of time. The technical support and development manager (interview-10) indicated that the company established a technical support and development department later, and it is considered as one of asset-related activities proposed by the framework in Figure 3.5.

Introducing a technical support and development department formed the analysis and decision making to adopt the three solutions. This is evident from interview transcripts, for example, according to (interview-10) held with the technical support and development manager, it was stated that the analysis and basis for the decision were established by this department.

"This department [technical support and development] studied the process in terms of all performance parameters and obtained all required data for the analysis. At first we were thinking of putting more control on operation process procedure but reviewing the latest technology in the field highlighted the opportunity for improvement by the ladle furnace solution. .. Therefore, before even thinking of the saving made by the ladle furnace, there was the work to determine that the ladle furnace was an alternative solution. … we focused on gathering all information about its acquisition, installation and the viability and flexibility of its integration within the steel melt shops. This led us to the cost and benefit analysis of adopting the ladle furnace for improvement of the steel melting and casting processes. .". (interview-10).

For this solution, the technical support and development department proved and quantified the cost savings that may be achieved by having a ladle furnace. This case gives direct evidence of improving performance by developing the asset, (introducing the ladle furnace) to reduce the cost of products and maintain competitiveness. Furthermore, it proves that this was made possible by an analytical evaluation done by the technical support and development department.

As evident from Table 5.25 and from interview transcripts, there is evidence that departments existed as proposed by the framework. These departments interacted for the responsibilities of aggregate and operational actions. Maintenance and operation managers in the melt shops e.g. interviews (18, 15 and 16) explained that their coordination with the technical support and development department was essential for the success.

Status of AM System Planning and Control Activities

From Table 5.26, it is evident that the adequacy of the AM system strategic planning and control activities resulted in a definition for the asset development that was suitable for the need, and in an asset solutions and requirement that was fit for integration with existing facilities. Evidence of the status of the AM system activities at the strategic, aggregate and operational levels set out in Table 5.26 from investigating records and data extracted from interviews with relevant managers implies that these AM system activities existed adequately by the coordination between several departments. For all three solutions of this sub-case, the participants indicated that the analysis was coordinated between the technical support and development department and the operation and maintenance departments of the steel melt shops (SMS1 andSMS2). Operation managers' interviews (16 and 15) in the steel melt shops indicated that they had coordinated and reported on the performance and any requested data to the technical support and development department. For all three solutions, the technical support and development department assisted in the analysis and decision regarding the selection and adoption of these solutions.

It is evident from the above that the strategic planning and control activities existed as a result of coordination between these mentioned departments and provided a means for conducting many analysis and evaluation activities that helped make AM decisions relative

to development, maintenance, and operation practice. It is also evident that analysis and evaluation as part of the strategic planning and control activities proposed by the framework in Figure 3.7 served the organisation strategy. The coordination between the technical support and development department and maintenance and operations served the selection and adoption of asset solutions to support many initiatives and resolve operation and maintenance problems. For example the general manger of steel melt shop 1 (interview-15) explained that the coordination with the technical support and development provided basis for better relation with purchasing and helped set a purchasing strategy that serve in minimizing the refractory lining life cycle cost.

The coordination between these mentioned departments and with other supporting departments such as quality control department served in providing operational task control and aggregate planning and control activities that are well-suited with the strategic planning and control activities. As set out in Table 5.26, the existence of these AM system activities served in maintaining better suited maintenance and operation strategies, confidence in production and maintenance planning and reporting on those key performance or compliance indicators.

Status of AM System Strategic Relationships

The strategic relationships of the AM system are maintained by the strategic planning and control activities and their interpretation in sub-case requires investigating the AM system actions taken as evidenced by indications identified in Table 5.27. From this table, it is evident that the relationships of the AM system with the strategic management are enhanced by the analysis and evaluation activity provided by the coordination between the technical support and development and other departments and that this enhancement contributed to the organisation's success.

In order to understand the strategic relationships, interpretation requires investigating the process from the strategy triggering event to the final contribution to the strategy. With respect to this sub-case, the technical and production directors interviews (-2 and 3) explained that benchmarking showed that the company had higher production costs than its competitors. This realisation led the company to improve its performance. He indicated that 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 company directors' interviews (2 and 3) revealed that benchmarking triggered this improvement and adopted the three solutions of this sub-case. The production director indicated that one of the first steps taken to minimise production costs focused on the melting process in SMS 1and2 because it was thought to be a major cost contributors for all the products.

The production director indicated that the decision to benchmark and define which costs were higher than competitors resulted from a discussion between the production director and departments' mangers. According to him the matter was allocated to the new established technical support and development department. According to the technical and production directors' interviews (2 and 3), benchmarking showed that maintenance and production costs were higher than competitors, so the company was forced to improve their performance.

From this management procedure there was interaction between the asset managers and strategic decision makers, as proposed by the framework in Figure 3.7 and its integration in Figure 3.8.

According to interviews held in the steel melt shops and the technical support and development department with managers' interviews (18, 17, 16, 15 and 10), the decision to adopt the three solutions of this sub-case were based on analysis done by the technical support and development department in coordination with the related departments in the steel melt shops. They indicated that using the EAF refractory replacement optimization modelling was allocated to the technical support and development department which coordinated the project in conjunction with [IND-university]. This was because the department was just established one year before initiating this project and could not do the analysis.

With respect to the adoption of replacing the ladle furnace and rolls in 2001, these participants explained that the technical support and development department did the cost/benefit analysis to justify the decision and approval of these two solutions.

The performance Indicators showed that these three solutions helped to achieve competitive prices and maintain product quality. This indicates the right selection, provision and application of solutions and the existence of proper activities for analysis and decision making, as proposed by the framework in Figure 3.7.

As indicated when defining this sub-case, these three AM solutions were selected because each one of them aims at improving performance to enhance customer value. It is also concluded that all three solutions improved performance and contributed positively to the organisation strategy achievement. This confirms that the AM control of interdependence between decision making, solution provision and the resulting performance of asset-related activities has an effect on strategy achievement. For example, the coordination between the purchasing, operations, and maintenance departments was essential for EAF refractory lining replacement and repair optimization. In other words, the cost of the lining life cycle was high due to purchasing the cheapest material, and then repairing or replacing it before the economical replacement point.

This also implies that the life cycle cost is essential for AM control in considering the inter-dependence of asset-related activities along the life cycle stages. Therefore, having the AM activities in place as proposed by the framework and managing the inter-relationships between asset-related activities for decisions relative to development, performance, strategic planning are 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.

The overall conclusion is that the existence of proper AM system activities, control, and relationships resulted in an adequate asset performance and business outcomes to achieve the organisation's strategy.

Status of Feed-Forward and Feedback Control Links

Table 5.28 indicates the existence of a reporting and feedback mechanism, as proposed by the framework shown in Figure 3.7. However, they are mostly lagging indicators. These performance indicators reflected the resulting improvement in performance where it was needed, which indicates the existence of a feedback mechanism in terms of indicators, and the reporting of these, as proposed by the framework in Figure 3.7.

5.8 Overall Findings of the Sub-Cases

The research findings may be expressed in two ways:

1. The existence or adequacy of the elements of the proposed framework explains the asset performance which is proved necessary to achieve A-Steel's organisational strategy.
2. The absence or inadequacy of these elements explains the low asset performance and the resulting outcomes that does not allow A-Steel to achieve its strategies.

The existence or adequacy of the framework proposed by this research, and its contribution to organisational strategy are reflected by the findings of the sub-cases.

Sub-case 3, present findings related to introducing a technical support and development department that helped to establish those elements presented in the proposed framework. These elements include the strategic planning and control activities, links to business activities, and feedback mechanisms. Sub-case 3 observations tend to indicate that these activities, relationships, and mechanisms helped to provide the solutions that improved asset performance to achieve organisational strategy.

The findings of sub-cases 1 and 2 are related to the absence or inadequacy of the elements of the proposed framework. Sub-cases 1 and 2 took place during the period from the commencement of A-Steel and until one year before the occurrence of sub-case 3. The initial structure of A-Steel did not have or was missing some of the structure required by the proposed framework to facilitate those three levels of AM system activities. The findings of sub-cases (1 and 2) imply that A-Steel was unable to define the needs of future stakeholders' and determine the necessary asset performance, and that A-Steel was also unable to analyse and evaluate the type of assets required for future needs. These two sub-cases show that most if not all planning and control activities proposed by the framework were absent. That the company resorted to team work reflects that some of these organisational asset-related activities as proposed by the framework did not formally exist. Moreover, missing such activities is related to the deficiency in the initial structure of A-Steel.

The missed market opportunities or customer dissatisfaction in sub-case 1, losses experienced in sub-case 2 as a result of G&C Line problems and the value derived from performance improvement in sub-case 3 tend to suggest that the long term benefit of having the AM system activities is much greater than the initial cost of establishing the structure required for them. Such long term benefits are realized through being better able to achieve the organisational strategy and enhance the capability for growth, as well as the life cycle cost savings. These benefits are difficult to quantify compared to the initial cost of establishing an asset management system. The existence of the structure in terms of asset-related activities in Figure 3.5 is required to conduct the AM activities proposed by the framework in Figure 3.7.

The findings from these sub-cases imply that the advantage of having the activities, relationships and mechanisms proposed by the framework provide the ability to eliminate any deficiencies that may be encountered. From the sub-cases these deficiencies are related to:

1. Making the wrong strategic decision such as inadequate design to undertake development or expansion projects. Deficiencies that may be caused by the absence of AM system activities are:
    a. Not properly defining the strategic or stakeholders' need and the compatible AM management action or requirement.
    b. Not defining the priority/criticality for initiatives to undertake action such as the development or expansion of projects.
    c. Not defining up-stream requirements for down-stream actions such as development or expansion.
    d. Not defining the design required to meet the asset performance desired such as modification or development projects.
    e. Not considering all the factors in contracts made for the acquisition, installation and commissioning of assets.
    f. Not undertaking the required testing, validation, and verification of design in the implementation of projects.

2. Adopting inadequate strategy or practice of asset-related activities at the utilization stage. For example, maintenance and/or replacement, or practice that does not assure the required availability and reliability of assets for production or operation. Such deficiencies may be caused by the absence of AM system activities and result in:
    a. Reactive maintenance that raises the risk of major breakdowns and accidents as well as disturbing production and imposing high inventory costs.
    b. Operational disturbance by minor breakdowns that delay orders' delivery to customers.
    c. Quality losses due to lack of maintenance or disturbance of operation that contribute to customers' dissatisfaction and higher production costs, and therefore lower profitability and affect the company's reputation.
    d. High maintenance costs that raise unit costs and reduce profitability.
3. Adopting inadequate procurement policies, strategies, and practice that does not consider the cost of the life cycle and only rely on the cost of procurement to make procurement decisions. This usually results in high costs, operational disturbance, quality losses, and other deficiencies.
4. Adopting an inadequate budget allocation policy, strategy, and practice that reduce the budget on an unclear or wrong basis and for short term gains. This usually means over looking long term gains and failing to achieve the strategy.
5. Lack of performance assessment and feedback to assist in making decisions. This result in an unclear view for decision makers and a tendency to make the wrong decisions.

6 Conclusion

6.1 Introduction

The appropriate design of the AM system and its role in organisational strategy making has been investigated. The objective was to advance understanding of its strategic role by defining the activities, relationships, and mechanisms that influence an organisational system and strategy making process in particular.

6.2 Findings Relative to the Conception of Asset Management

It was concluded from a review of literature that the links between competitive strategy and AM strategies is part of the organisational systems. By definition, AM is a socio-technical system that incorporates overlapping inter-disciplinary activities within an organisation. It is hard to isolate the AM system activities from the other organisational management system activities in addition to any overlapping with organisational strategy making. The relationships between strategies of the various asset-related activities of the organisation and its business strategy were discovered to be complex relationships. These relationships required integration across asset-related activities and an alignment of the strategy of each activity with competitive and corporate strategies of the organisation. Alternatively they were involved with AM activities that extend across asset-related activities. From reviewing many strategy related models it was concluded that conformance to the enterprise competitive strategy can be achieved by an integrated decision making process that includes AM activities. Such integration involves an alignment of decisions within an organisation and a consideration of the entire life of assets. The link between an organisation's competitive strategy and the strategies of its asset-related activities is more complex than can be represented by a simple top down hierarchical approach. Due to the inter-disciplinary nature of AM and its interfaces with many organisational asset-related activities it was concluded that this complexity of relationships with competitive strategy is part of an AM system and requires formalised activities and mechanisms to integrate it with the competitive strategy development activity.

The focus in literature has been on specific issues such as reliability or maintenance, while the concept of an enterprise AM as a holistic approach is not yet fully developed or understood. As such, the research proposition addresses the problem that organisations are not sufficiently in control of the required AM system activities, and relationships between activities, to properly prioritize and align them to assist with competitive strategy development and implementation.

The research methodology applicable to AM research in particular must be suitable for exploring a subject area that is not well understood. It was concluded that the combination of a retroductive research strategy and case study method is appropriate for this research problem and AM research in general. The use of this methodology resulted in the development of significant insights and was demonstrated to have suited its exploratory nature. The retroductive model as a logic of inquiry was based on developing a hypothesized model. To fit this logic, it was concluded that a hypothesised model had to be constructed representing an organisation's system.

6.3 Case Study Findings

Utilising case studies, this research aimed at gaining understanding of the AM system within the organisational strategy making process. The overall findings have depicted the identified AM activities, relationships, and mechanisms as playing an essential role in organisational strategy making and competitive strategy. These were represented in a framework allowing the examination of their existence or adequacy. The retroductive logic used allowed a view of the AM system and a reference for examination of actions by organisations aimed at improving their systems.

With reference to the framework developed, Chapter 3, the absence or inadequacy of the elements proposed by the framework resulted in:

1. Making the wrong strategic decision such as inadequate design to undertake development or expansion projects.
2. Inadequate definition of the strategic or stakeholders' need and the compatible AM management action or requirement.
3. Inadequate definition of the priority/criticality for initiatives to undertake actions.

4. Inadequate definition of up-stream requirements for down-stream actions.
5. Inadequate definition of the design required to meet the asset performance desired for modification or development projects.
6. Inadequate contracting for acquisition, installation and commissioning of assets.
7. Inadequate testing, validation, and verification of design in the implementation of projects.
8. Adopting inadequate strategies for asset-related activities such as maintenance or replacement that does not assure the required availability and reliability of assets for production or operation.
9. Reactive maintenance that raises the risk of major breakdowns and accidents as well as disturbing production and imposing high inventory costs.
10. Operational disturbance by minor breakdowns that delay orders' delivery to customers.
11. Quality losses associated with lack of maintenance or disturbance of operation that contribute to customer's dissatisfaction and higher production costs, and therefore lower profitability and affect the company's reputation.
12. High maintenance costs that raise unit costs and reduce profitability.
13. Adopting inadequate procurement policies, strategies, and practice that does not consider the cost of the life cycle and only rely on the cost of procurement to make procurement decisions. This usually results in high costs, operational disturbance, quality losses, and other deficiencies.
14. Adopting inadequate budget allocation policy, strategy, or practice that reduces the budget on an unclear or wrong basis and for short term gains. This usually means over looking long term gains and failing to achieve the strategy.
15. Lack of performance assessment and feedback to assist in making decisions. This results in an unclear view for decision makers and a tendency to make wrong decisions.

However, the findings of sub-case 3 demonstrate that providing these elements of the framework through departments that take the responsibility of these elements and perform them adequately resulted in making the right initiatives, design and performance of assets.

Based on these substantive findings it can be concluded that:

1. The absence or inadequacy of the AM system activities, relationships and mechanisms did not allow the proper management of asset's life to result in an asset performance that enables the organisation to achieve its strategy.
2. The existence or adequacy of AM system activities, relationships, and mechanisms allowed proper management of asset's life and resulted in an asset performance that enabled the organisation to achieve its strategy.

This is considered to constitute progress in understanding the role of an AM system in organisational strategy.

6.4 Implication of Research Findings in Theory and Practice

AM research has only recently acknowledged the strategic role of AM. Compared to the current state of knowledge in strategy process research, this understanding of the strategic role of AM is limited. This study made a concentrated effort to explore the underlying activities, relationships, and mechanisms of the AM system to advance this limited understanding. Its contribution is to building theory.

The retroductive research strategy and case study method for engineering AM research resulted in these key findings for the case investigated as stated in the previous section. This in turn demonstrates that the proposed AM system framework and research methodology enhances understanding of the strategic role of AM and demonstrates the potential for developing it into a plausible building block of theory with strong explanatory power.

The knowledge and understanding of these activities, relationships, and mechanisms of the AM system proposed by the developed framework may be utilised by organisations to better manage their assets through their life cycles. .

By using the framework as a guide, an organisation may identify missing or poorly implemented asset-related activities. In the case of the organisation studied, it was identified that the organisation recognized the need for establishing a technical support and development department and a research centre after experiencing many failures with projects examined in sub-cases (1 and 2). If the organisation had such a framework and used it as guide to establish its structure for AM or provide the expert teams for such

projects, it could have avoided many losses and strategic failures. This led to a demonstration of the customer value creation in managing the asset-related activities by applying the AM system activities, relationships and mechanisms as proposed by the hypothesised framework and integrated by the system functional model.

The analysis of the sub-cases in this study, and the framework developed by this research can also assist future AM research. Specific activities, relationships or mechanisms may be analysed within the overall context of the framework. Furthermore, they can be used as a basis for validation studies on causal links to strategy making and/or contextual factors, or operating variables. This can be extended to investigate the links between the AM system and stakeholder perspective.

It is suggested that the proposed framework can be used to control practice across industry. Despite the focus of this research on selection of case studies from capital intensive industries, the development of the framework and its integration model with the organization were based on the management control and the system theory that can apply to any organization. Further research possibly could be undertaken utilizing the same framework and research methodology for non-capital intensive organizations or non-profit organizations that depend on assets for their functions. The key issue is to define the asset performance and its relation or impact on the overall performance of the organization and identify the triggers that may indicate the need for an asset solution. For example, in a hospital the health of patients requires uniformly distributed constant temperature that may be provided by a reliable in floor water heating system. The point to highlight here is that the performance of the heating system has to comply with the regulations to have positive impact on the health of the patients and consequently reflects on the reputation of the hospital. The status of the asset management system in the hospital can be verified based on the performance or outcomes that reflect the existence or absence of the framework based on useful insights provided by the case study.

6.5 Limitation of Research Findings

The nature of the research problem and constraints imposed by the circumstances under which this particular study was conducted tended to enforce limitations on the methodology. This research was exploratory, and aimed to build theory. The approach

focused on maintaining a qualitative methodological rigour and required depth of analysis from a case study organisation over a relatively long period of time. Exploratory studies and theory building research imposes specific challenges on the researcher. Positivists may associate its findings with limitations if compared to theory validation or a quantitative approach. The socio-technical nature of the problem and exploratory objective led to using qualitative techniques to develop insights into the phenomena.

Care must be taken to identify the contribution and limitations of the findings. When using a qualitative approach there is a possibility of errors arising from the imprecise nature of the data, its method of collection, and the difficulty associated with its analysis, interpretation, and presentation. Errors may result from inaccurate interviews or methods due to deliberate distortion or genuine loss of memory. Although multiple sources of data and various collection methods and analysis are used in this study, errors can never be totally eliminated. There is also the possibility of misinterpretation or multiple interpretations of the qualitative data as well as analytical errors in display or presentation. Despite trying to provide as much detail on the research procedures as possible, alternative or misleading interpretations remains a possibility. To avoid errors, confirmation of evidence from multiple sources was ensured. This included using company records to confirm interview data or confirming the data from two interviews or more. To make this possible all interviews were recorded and copies of records were obtained whenever is possible. These measures to avoid such errors were applied in this case but errors cannot be completely eliminated.

This research study acknowledges that any generalization of the findings was not based on statistical generalization that is to be generalized to populations. The study used sub-cases from one case study to provide replication logic. In this study, only one case study organisation was used in a particular industry but replication in terms of other organisation could strengthen the study. However, that does not necessarily mean that the findings were only applicable to the organisation in the particular industry division studied. The aim was to generalize to ‘what could be’ in order to account for how organisations succeed or fail to achieve their goals or strategies, with the idea that the framework can be used to control practice. This can be verified based on the performance or outcomes that reflect the

existence or absence of the framework based on useful insights provided by the case study methods. This allows for further studies for validation of various industrial organisations.

The impact of the social phenomena associated with the existed asset management system activities, links and mechanisms has not been pursued in this research. The assumption used is that the socio-technical interrelationship is not relevant. This of course is a tenuous assumption. This assumption will need to be relaxed in further research. The research focused primarily on relating the strategic success or failure to the existence or adequacy or inadequacy or absence of the asset management system. However, social aspects such as desire, behaviour, individual objectives, feeling, traditions and others may have impact on the strategic success even when the asset management system adequately exist. Conversely the absence of elements of the proposed framework may be compensated by the people involved with the system. Although, it was stated in the methodology that such factors should be indicated if it is observed that they have effects on the strategic results related to the case study, none of the sub-cases had clearly shown the effect of these social factors. In addition, the longitudinal nature of the sub-cases has limited the effect of social factors on the research results. Nevertheless, further research that would investigate the effects of social factors on cases proven to have adequate asset management system in place.

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8 Appendix 1: Case study protocol

Background

The investigation of the project focuses on situations that represent a change of strategy, change in practice or influence of AM system or the impact of AM practice on organisational strategies. The results of such situation may affect the organisation in achieving its strategic targets, or may enhance the organisation to achieve its strategic targets. Example of such situations may be:

a. Investigating projects that have been undertaken (e.g. asset development, modification, replacement and the like).
b. Investigating AM practice or its change within asset-related activities (departments) within the organisation.
c. Investigating relationships between different AM-related departments such as production or operation, planning, technical support and development, maintenance and so on.

The detailed data contained within files and data banks or conveyed during meetings or the normal course of each day's events is not of interest for the research but rather the interest lies with identification of procedures within the management functional entities (departments, sections or divisions) in relation to managing assets or systems and procedures pertaining to processing the inputs to outputs and outcomes to serve the objective, as well as the relationships between these systems management entities.

The aim is for identifying the AM system structure and mechanism that possess the potential for:

a. Translating the organisational strategy into the appropriate AM solution(s) that assures the asset life cycle performance for the strategy achievement.
b. The integration and coordination of efforts to align the objectives and strategies of asset-related activities and provide the performance to serve the organisation targets and mission achievement.
c. The control of asset-related activities to serve the organisational strategy.

Research Objective

The research aims to build a theory on the form of AM system and its customer value creation mechanism by developing a framework for the strategic role of AM in capital intensive organisation involving a holistic view of the AM system for the enterprise. The strategic role of AM is to be based on this customer value creation mechanism of the AM system for delivering customer value to attain the organisational competitive strategy.

Research Questions

It is suspected that the AM system plays a supervisory or control role in the organisational strategy and its activities are inseparable of the various asset-related activities within an organisation's system and therefore there exist a large number of interrelationships that have effects on the organisation's system as a whole.
The point here is that these general concepts raise the questions as to:

5- What are the value-added activities, relationships and mechanisms of the AM system?
6- How do these create customer value for competitive strategy?
7- How do these need to be configured and aligned to achieve the strategy and sustain the competitive advantage for the organisation?
8- To what extent is this recognized by organisations and if not, then why not and what are the costs and benefits of instituting the missing concept?

It is proposed that these are questions yet to be resolved.

Research Hypothesis

AM practice beneficially plays a key role in the organisational strategy development and implementation. Certain AM activities, links/relationships and control mechanisms need to exist within an organisation for this to occur effectively.

Research Instruments

Hypothesized Frameworks:
The developed framework as proposed in Figures (3.4 and 3.5) will be used as template for the case study analysis. The search is for the existence of the activities, relationships and mechanism of the AM system as proposed by the framework.

Case Study Type and Unit of Analysis:
In the context of this study, the research will incorporate longitudinal case study to establish the causal relationships. It follows the analytical logic to an experiment. The unit of analysis will be identified as strategy events that required an asset life cycle solution resulting in (good or bad) achievement of the organisational strategy. Therefore, there will be more than one unit of analysis and the method will follow the embedded case study analysis where each unit can be analysed in perspective of the impact or effects on the organisation. This allows for having sub-cases while still treating the organisation as a single case-study. From the analytical inference, the findings of each sub-case are analogical to the experimental results and can be determined from the performance outcomes. And these outcomes or results reflect the contribution (positive or negative) compared to the intended objectives of the organisational strategy event. From the logical inference, these outcomes are interpreted relative to the extent of existence or absence of the developed framework as proposed Figure 3.7. This interpretation is guided by the construct of the framework.

Case Study Organisation:
A capital intensive organisation is to be selected for the for the case study analysis

Sub-Cases:

Several sub-cases are to be selected for detailed analysis to determine the existence of the AM system structure and mechanism as proposed by the framework. A sub-case is the unit of analysis which will be identified as strategy events that required an asset life cycle solution resulting in (good or bad) achievement of the organisational strategy.

Archive Analysis:
The data collection should start with archive record. This may guide the interviewing process and enable it identify strategies, their triggers and define changes in strategy, missions and objectives of the organisation. Archive record may include publication, documentation, archival records, physical artefacts, organisational charts, company website, company's newsletter clippings, asset life histories, reports, manuals, service, personnel or financial records, performance record and consumption data record, user manuals, contracts, letters, meeting minutes, proposals, progress reports, formal studies and observation.

Direct Observation and Analysis:
Observation of physical artefacts such as layout of assets and processes help build a view of the actual technical system and define asset-related activities to be targeted for the study. This leads to a better view on the selection of departments and individuals that should be targeted for interviews.

Interviews:

Interviews will be used in this case as the main source of data. Questions are designed to be open-ended so that the respondent can add any information he/she consider pertinent. This approach to interviews is considered of particular importance for the exploratory nature of the research and can help in identifying areas that may have been overlooked. Information extracted from Interviews is to be validated by comparing to other sources of data and among different interviewees to maintain a good chain of evidence.
When conducting interviews, certain measures are essential to considers:

6) Interviewees from all asset-related activities.
7) Relevance and application of the framework to the asset-related activity under investigation.
8) Allowing interviewees to widely express their view and opinion widely about certain events and relate to dates of events and make recommendations for other relevant source of evidence.
9) Ensuring interviewees' perceptions are captured.
10) Ensuring alternative sources are available for confirmation of evidence.

There will be two meetings with interviewees. The first is for introduction and answering questions related to identifying sub-cases; that is the AM-related solutions, actions or decisions in response to strategy events. The second meeting can be then set for the detailed investigation with interviewees that have information or were involved with the sub-case or sub-cases identified.

Ethics Requirements
Information sheets, consent form, letter of invitation were all prepared in accordance with ethics requirement and ethics committee approval was obtained.

Participant sheets provided information for participants to be fully aware of the involvement in conducting the project titled above. So they are informed of what is expected from their participation and can freely decide based on the information if they consent to participate. The participants are encouraged to ask about any technical terms or any ambiguous aspect of the research aim or approach.

Participants will be interviewed (mainly open ended interviews) about system procedures, processes, situations or projects that they have been involved in or events that were observed by them in the past, currently occurring events and the expected consequences or pattern of results or outcomes of such situations in the future. Or researcher may participate with them in observation: attending, observing and asking questions.

Participation in this research is voluntary, any participant is free to refuse to participate and free to withdraw from the research at any time. His refusal to participate or withdrawal of consent will not affect either his treatment or his relationship with the organisation at which this project is conducted and with which he is employed.

Information provided to the project will be retained in confidence between the researchers and each participant. Participation by the employees will be entirely voluntary at all times. Employees will not be identified in any report and their organisational position and unit will be disguised. A coding system will be used to identify all departments, section, units and personnel within these units.
Throughout the research as much feedback as possible will be given to every participant because their cooperation and understanding is central to the success of the project.

If participants have enquiries about the research, they can contact Khaled El-Akruti (Phone No +61 403717686) or Associate Professor Richard Dwight (+61 242 213183)) or if they have any further concerns or complaints regarding the way that the research is or has been conducted, they can contact the Complaints Officer, Human Research Ethics Committee, University of Wollongong phone (+61 02 42 2214457).

Only if a participant is willing and feels that he can contribute to the project and have the time that he can spare for interview, then he/she will be provided with a consent form to sign indicating his consent to participate in the research project.

Participation is voluntary and Participants are free to refuse to participate and will be able to withdraw without the matter being notified to anybody in the organisation.

Every participant should be aware that his consent is required for data collected from participation to be used in a thesis, journal publication, conference presentation and notes.

Records of interview and observations containing names or identifications will be kept strictly confidential to the researcher and his supervisor. Participants will be given a number, and only this number will be used in association with the actual data collection activities. The relationship between the code and the identity of the person will be maintained in a separate book, to be destroyed at the completion of the research.

Participants and their specific position will not be identified in any report either provided to the company or produced as part of the research report, or in any other publication, except with the written permission of the person concerned.

Interviews Guide

The investigation process of interviews is expected to analyse the existence of the AM system as proposed by the framework. The focus is toward investigating the structure and mechanism of the AM system; that is the existence of its activities, relationships and control as a systematic management process across the asset-related activities and at the various levels of the organisation system. Participants are expected to reveal information/data on the existence of the AM system activities, relationships and control mechanisms that link AM to the strategy making of the whole organisation as proposed in the framework. In doing so, participants are expected to provide data/information to:

a. Identify and define AM solutions, actions or involvement in decision as responses to strategy events that may be triggered by corporate missions, external or internal factors.
b. Define the achievement of the strategy as a result of applying such AM solutions.
c. Define the resulting asset life cycle performance associated with the particular AM solutions and its link to the organisational business performance for the strategy.
d. Define the extent of existence or absence of AM system activities, relationships and control relative to the resulting asset life cycle performance.

This is expected to be best captured through explanation of the action of asset-related activities (through departments) in response to a strategy event. Such narrative explanation is expected to reflect the existence of AM structure and mechanism as activities, relationships and control process. The inquiry is set to follow the proposed frameworks as a template.

Given below is a sample of questions that would be used during the interviews for the three investigation parts identified by the procedure in section 5.3. During interviews, the following question should be asked in order to stimulate the discussion in each part of the investigation.

- **Identification of Sub-Cases**
  1. Can you narrate/describe events that represent a change of organisational strategy and required AM solution or action? (*These events may be triggered by external factors such as market or internal factors such as cost or achievement.)*
  2. Can you narrate/describe any change in AM practice or action that impacted on the achievement of the organisational strategy positively or negatively? (*These may be any project related to asset development, expansion, insertion, modification, replacement, maintenance or disposal.)*
  3. Do you consider any of this (project(s) or 'AM action(s) or solution(s)') direct response(s) to strategic events or changes? And can you identify the triggers of these strategy events and describe how the AM solution or project may contribute to the organisational strategy?

The above three questions (1, 2 and 3) are expected to provide enough data from the various participants to decide on selecting several sub-cases for the detailed analysis. When sub-cases are selected, the second meetings should be conducted with interviewees to gain in-depth investigation of each case. From such in-depth investigation, narrative explanation by participants is expected to reveal the outcomes relative to the organisational strategy and the AM system contribution to achievement of these outcomes. These outcomes can be specifically defined by investigating the achievement of the strategy as a result of applying such AM solution and the resulting asset life cycle performance associated with each particular AM solution. The following four questions (4, 5, 6, and 7) are expected to investigate these outcomes relative each sub-case.

- **Establishing the Outcomes Relative to the Strategy Achievement**

4. What was/is the positive or negative contribution of this AM action or solution to the strategy achievement? And how the customer value contribution or destruction was realized by the organisation?
5. What was/is the business performance parameter/indicator for success or failure of achieving the strategy? Or to what extent was or is the organisation successful in achieving its intended business performance?
6. What was/is the asset performance parameter/indicator associated with such success or failure? Or to what extent was/is the organisation/your department successful in defining and achieving its technical performance targets relative to this AM-solution in response to the mentioned strategy event.
7. What was/is the impact of this particular AM solution(s) on the production targets, quality targets, safety targets and maintenance targets, acquisition or design targets?

When outcomes from each sub-case are defined, narrative explanation by participants is expected to reveal the management action that reflect the existence of AM system structure and mechanism as activities, relationships and control process of the asset-related activities (departments). The action of these AM-related departments relative to dealing with the particular sub-case (strategy event and the responding asset life cycle solution). The action may be reflected as activities or control in different department, interrelationship between AM-related departments. Or as relationships (involvement) in strategy making process with strategic management decision makers or external parties (e.g. asset or technology suppliers, outsourcers, contractors, government or environmental bodies). The existence of such activities, relationships and control can be revealed by detailed analysis of how the AM-related departments dealt with each sub-case. To uncover existence of such activities, relationships and control relative to those proposed by the framework in Figures (3.1, 3.2, 3.3a&b, and 3.5), the investigation of each sub-case may involve part or all of the following questions (8, 9, 10, 11, 12, 13, 14, 15, 16, 17 and 18).

- **Establishing Existence or Absence of Proposed Framework**

1. How did your organisation/department identify the strategy trigger of this particular strategy event and how the gap in the business performance was defined?
2. How did your organisation/department decide that this particular strategy event required an AM solution or action?

3. How did your organisation/department deal with determining the required asset life cycle performance to bridge the gap introduced by the new business performance for this particular strategy event?
4. How did your organisation/department deal with formulating the suitable asset life cycle solution(s) (e.g. selecting, designing, acquiring, installing, operation, maintenance or replacement) to achieve, ensure or maintain the required asset life cycle performance?
5. How did your organisation/department selecta particular solution or a set of solutions if there were alternative solutions developed?
6. How did your organisation/department define and pursue the asset life cycle requirement to establish and implement such action(s) or solution(s)?
7. How did your organisation/department maintain decision for adopting and implementing a particular solution(s)?
8. How did your organisation/department deal with translating such action(s) or solution(s) into strategies, policies, plans and control action to perform the asset-related activities, so as to achieve the determined asset life cycle performance?
9. How did your organisation/department implement such solution(s)?
10. How did your organisation/department maintain feedback from implementation and how such feedback was used or supported the strategy decision process?
11. How was your department and other departments involved in the strategy review process if there was a strategy review process in place

9 Appendix 2: Case study Interviews Transcripts

Interview -1
10:30 am, 4th January, 2009

Participant-1 has been in many high positions in the various divisions of the company.

1. Can you narrate events that represent a change of organisational strategy and required AM solution or action?

First of all, I think the concept of asset management is new to us and definitely it does not exist in our company. A-Steel has a quality policy manual that you should review for identifying A-Steel's strategies. If asset management is about strategic investment in assets then, it is perhaps this is why A-Steel lacked a formal procedure relative to asset related development projects.

2. Can you narrate these development projects? Do you consider any of these project(s) 'AM solutions' you have mentioned as direct responses to strategic events or changes? And can you identify the triggers of these strategy events?

We had a lot of developments projects in the various plants that were undertaken as responses to changes in the strategy or mission. In response to the mission imposed by the ministry of industry the chief executive initiated the feasibility studies of some expansion projects to introduce some new products. For example, the chief executive introduced The HBI Module and the *G&C Line* in 1997 as a strategy to enter the international markets with new products that were expected to have high demand in the international market. I think a quick way to identify most of these is to review the company's news letter. All issues will be available in the central library within the training centre or get the editor (Participant-26) to help you with this matter. You can then get information about any of them from records in the technical support and development department or the industrial research centre or general departments of the plant in which these projects took place. But the managers of the departments in the plants are in better position to give you information on their outcomes relative to these projects.

3. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes in your company?

Many of these activities or interrelationships that constitute asset management are not properly in place in our company. Our company lately has realized that we are experiencing difficulties in coping with our increasing targets in production, quality and cost reduction because we have been concentrating more on operations and less on how to achieve strategies. In response to defining the problem, we hired a consultant "Price Water House" to study our practice and define the problems and what to be done to overcome such situation. The consultant has pointed out the most critical gap as not having a strategic planning system with other gaps in our practice presented in a list of missing things and incomplete procedures. As a proposed solution to all these gaps the consultant advice was the adoption of an IT system "Enterprise Resource Planning" (ERP) The implementation of TPM and Six Sigma as well as upgrading our CMMS. This should integrate all the

organisation's systems because most of our systems are working manually or semi-manually. The company has started implementation of these but we still in the construction stage where these are still projects and we really have no clear vision of how these can be set in place in the organisational structure for the right transformation of our practice. It is clear that your model main purpose is in agreement with our situation; to assist in strategy making by exploring the key activities or links between systems and has most activities relative to gaps identified by consultant list. But the model presentation of activities and relationships between systems provide the basis for us to think about how to go about instituting these activities or changes. The model highlights many critical points to think of what to be introduced and where in the organisational structure.

4. From the model can you indicate those activities that you have in place and those that you do not, or to what extent do they exist?

It is clear to me that what we are missing are some of these activities that are related to analysis and strategic decisions. We have no systems in place to predict performance of assets based on condition monitoring, nor do we have analysis of assets' life or capability. On the business level we lack on the stakeholders analysis, market research and how to link them to operational activities. On the other hand, we have the PP&C, performance measurement and QC activities in place. Overall, most of the aggregate and operational activities in your model may exist but do not exist to the extent indicated or interlinked in your model. There are activities scattered with no integration to form the control mechanism of asset management for strategic purpose. For example, we have a department under the finance division called asset accounting; it is an assets register and deals with depreciation of current assets but it has no link to maintenance nor does it do any cost analysis. Furthermore the IT system to facilitate the interlinking of all of these and maintain the right control is not in place. As such the implementation of ERP is starting with financial division to maintain the financial control which may lead to overlook the importance of operational performance for improvement. I do not agree with this top down implementation but it is the priority of our chief executive to start with financial division because he is too alert to the cost control sort of thing.

5. Any thing to add or comment?

Your model definitely, provide basis to think about the change. For example, maintenance is becoming a limiting factor for target achievement or availability of lines for production. There are complaints about this. Our company introduced a central MP&C department to resolve this maintenance problem but things are going worst in some cases. I do not know if this situation is going to be resolved by time or not as some think so. I guess experience is needed for making maintenance programs not just the right planning activities. This introduced department may reflect some of the aggregate planning activities in your model.

Interview -2
11:30 , 5th January, 2009

Participant-2 has been in many high positions for many years as well as a manager of several departments through his long experience with the company.

I have provided a copy of the organisation chart for you to see the layout of our division within the whole organisation and it clearly identifies the departments of this division with their sections and how they are connected to the top management and other departments.

1. Can you narrate events that represent a change of organisational strategy and required AM solution or action?

To answer your question, I think I should give you a view on the factors affecting our strategy making process. We follow the mission set in the quality manual but our company as one of the steel industry producers its strategy depends on three major factors:

a. Product quality; how to maintain a competitive quality level of our products? Quality is very important for us and we cannot compete without having high quality standard. So it has a very direct impact on our strategy.
b. Product price and cost; how to maintain a competitive price for our products? Cost reduction is very important for us and we cannot be competitive or get a reasonable profit without keeping our cost as low as or lower than competitors. So cost is a determining factor for our strategy.
c. Customers and demand in the market; how to satisfy our customers and win new customers? This affects our profitability and annual return and will be reflected on development and growth.

So most changes in the organisational strategy are related to these factors, or it can be put in another way; our company has always aimed at continuous improvement strategy to cope with changes related to these factors. You have to realize that our company is operating in a developing country but we are competing in the international market, so a huge effort is required to survive.

2. Can you narrate/describe any change in AM practice or action that impacted on the achievement of the organisational strategy positively or negatively?

There are many actions and it will not be possible to talk about every thing here but you can identify any relevant action or project from records and then we can discuss it. However, as an important issue, we have been trying in different ways to improve our maintenance practice and reduce cost and production losses. Those contribute to the profitability and products price competitiveness. I think archives records in the technical support and development and those managers of the various plants or departments can give you better descriptions on these actions. These are also currently many projects under implementation for the enhancement of our practice such as TPM, ERP and Six Sigma. We also have undertaken many expansions and development projects for coping with market demand. For these you better review the records in the IRC.

3. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes? And to what extent do these activities in the model exist in your company?

I think asset management will be very important for us in the steel industry or maybe in all manufacturing industry. I have noticed that you used the term asset management director instead of the technical director. The reality is that the concept of asset management is new to us and if we are in this division do some of the asset management responsibilities, but we

still do not realize the full concept of asset management as you have described it in your introduction and presentation of your model. It seems to me that asset management is very important for production industry and it might just be what we are missing for direction toward best practice.
Probably the only part that we do in the same way as you present it, is project management but we lack in the other activity that should be with it such as condition monitoring, research and analysis as shown in your model. I have realized from your illustration that system engineering and project management are essential parts of asset management but in our case we do a lot of projects, however; my experience tells me that their initiations were some how not well connected to our company objectives and the rest of the systems in the company and some of them turned out not fully satisfying our need.

Regarding relevant activities, I think in our (technical) division the most important activities to control well are the maintenance and the spare parts and maintenance materials inventory system. They are important because they have a lot of connections with other activities/systems in the organisation and have major impact on the production activity in many ways like production rate, utilization rate, cost and plans or delivery.

4. Do you consider 'AM solutions' or actions to have direct responses to strategic events or changes? And can you identify the triggers of these strategy events?

I think AM actions have an impact on the strategy making success. To help our company in strategy making or implementation, there are many important things to consider such as:

a) To take decision about what asset should be selected as a start in terms of project initiation or development.
b) The decision should be well made to serve the objective.
c) The asset should be well operated and fully utilized.
d) The other concern is how to fully use these assets that we have invested capital in.
e) The assets capital cost, operating cost and maintenance cost will have major impact on the products unit cost which will affect our prices of the products and consequently reduce our profit margin. Benchmarking with other steel industries in the region tell us that our production cost and maintenance cost are high and our stock in general is high.

The real question is how to keep our assets well maintained and well utilized to give the best results or the required results that can make us competitive in the market; as we operate in the international market we face a very high competition. Keeping our assets in good condition while maintaining the best performance depends on many factors:

f) Manpower skill and experience
g) Systems integration, as systems are interconnected and interdependent. They have impact on each other in many ways and any undesired output of one system will work through to affect the output of the overall system and therefore the objectives.
h) Integrity of the systems; if 99% of the elements perform well but 1% has bottlenecks then these will affect the overall performance in a negative way.
i) One important thing is to make sure that there are no bottlenecks
j) Another thing is to make sure that you do not end up with excess capacities of some assets in the utilization stage which is a problem that may occur if care was not taken at the design stage.
k) Also observing criticality and interdependency of the assets in the process

l) Another thing is selecting the proper maintenance strategy or actually the right combination of strategies with effective maintenance practice. (e.g. preventive, breakdown and time based maintenance).

5. How do you think AM can enhance the competitiveness of your company?

By minimizing cost and maximizing performance of assets. Some of our assets are not fully optimized; I mean not getting the best level of performance. Our company is facing the challenge of eliminating losses and reducing the high maintenance cost and I think we should use condition based maintenance. When compared to other steel industry, our maintenance cost and production cost are high and need to be reduced. I am suggesting this type of maintenance to chief executive's committee because it depends on monitoring assets conditions and a lot of additional maintenance (preventive) will be removed and cost will be reduced.

6. Don't you think that condition based maintenance may require high investment that might not be justified for adopting it as a strategy?

No, I do not agree with you on this because the only investment will be in monitoring instruments and at the end I think it will reduce the cost.

7. You said that you have suggested the adoption of condition based maintenance, but don't you think it is better to make some analysis regarding the adoption of condition based maintenance as a strategy? And define what other alternatives can be compared to it in terms of cost and benefit?

Yes, there is a need for real analysis; I mean analysis of the situation to provide alternatives and to what assets or critical equipments will this strategy be justified. We need some good analysts not just data collectors and reporters, because we have faced many problems as a result of not having done the right analysis of the situation and decision was not well carried out because it was based on information not result from analysis.

8. Have you thought of outsourcing as an alternative strategy for maintenance?

Outsourcing was not possible for the last 30 years because the country did not have local contractors for such task, but we have started outsourcing some facilities now days. However there are different opinions on outsourcing among managers and there are debates on adopting it.

9. But, don't you think it won't be an issue of opinion or debate if the organisation has some sort of mechanism to make the analysis and provide the basis for the adoption decision?

Yes, but we have not appointed the responsibility to do such task to any department or even appointed our experts or recruited the expertise for handling such task.

10. What do you think of ISO9000 as a strategy? From experiencing its implementation in your company, did it assist improvement in fields other than the product quality? Or did it have an overall positive impact on performance?

I think the system approach or specifically the system auditing is fully understood or in some cases it is well used and fully developed. For example, our company has been implementing ISO 9000 for about 15 years. However, I think ISO 9000 is not the answer. Even that other people 'ISO-supporters' in the organisation may not agree with me, but it became a paper work focused activities without real effect on the actual practice. It is clear now to me from the application in our company for over 15 years that we are in the stage of realizing that the only benefit that we got out of ISO 9000 is the certificate and a form document organisation. Even the product quality was hardly improved as a result of ISO 9000 application but because of the tied quality control system and inspection. No real positive results out of ISO 9000 but a lot of paper work, reports and documentation for which time and resources were lost.

11. How initiatives are made in your company? In particular, those associated with strategic decision?

Do you mean how a new project is initiated? Yes, for example.
Such initiatives can come through different way:

a. Some times R and D brings up some initiatives concerning problems raised by some departments in the plants.
b. Some times it may be raised by individual engineers working and reporting on how a problem can be solved.
c. We also have arranged for meeting of different managers for brain storming ideas that if selected will be sent to R and D for feasibility study.

12. Do you have any strategy revision process in your company? And is it continuous?

We do not have a set process for such revision but the financial crises for example have caused us to meet and revise our mission in which case 2 expansion projects were canceled and our production plan is reduced by more than 50%. This indicates that strategy should be revised periodically to adjust for external changes.

If we continue talking about maintenance problems and management problems in steel industry, we will never end, but I think that is all I wanted to say about the project investigation. If you have any more questions make it as brief as you can because I have only another few minutes to give you.
Researcher: thank you very much for the full coverage and I have noticed your well prepared replies to the interview investigation. However, I have one more questions in brief.

13. From the model can you indicate those activities that you have in place and those that you do not, or to what extent do they exist?

Most important thing to realize that we do not have the strategic planning and control activities in place, nor do we have the control loop mechanism working in place as represented in the model and therefore not able to make decision on the right basis. We in the first stage of implementing 2 new programs; the enterprise resource planning (ERP) and the (TPM) which will hopefully serve in accommodating some database for the purpose of analysis for decision making.

The operational and middle management planning and control activities do exist but lack some information management tools, like IT technologies.

Interview -3
13:30, 6th January, 2009

Participant-3) has a high position in production division and a very long experience with the company.

1. Do you think that the slit-rolling modification and rod mill introduction represented a response to a change of organisational strategy?

Expansions in long rolling production mills were needed for the increased demand in the local market. In addition to these two there are projects under way; most of them are for the purpose of coping with markets demand locally or internationally. So, the major introduced projects were based on growth strategies or to cope with the increase in the market demand.

2. Can you describe how these impacted on the achievement of the organisational strategy? Or did they have a positive or negative contribution relative to the strategy.

It is hard to describe their contribution either as positive or negative but the contribution could have been much better if the decisions were made differently at the initiation of these projects. They have contributed toward covering the increase in demand, however; we have been importing the shortage in production for the increasing demand despite undertaken these projects. Each project at its starting point, its production capacity covers the demand for couple of years or less then we end up importing the shortage and plan for another expansion. I mean we lacked in making the decision about the design capacity that should cope with the expected long term increase in demand. We could have introduced a new mill in 1993 instead of the slit-rolling modification and we could have designed the capacity to be doubled. If we had done that we could have avoided the shortage in production and saved in capital cost, production cost and quality losses due to slit-rolling. We could have exported any surpluses. I mean we were exporting some quantities of bars and rod due to some contracts obligation until 2004 while we were importing the shortage for local demand. All of these were good signs for the opportunity and adequate reasons for expanding the capacities three or four times the expansion capacity of rod mill in 1997 for example.

3. Do you consider the slit-rolling modification or the rod mill development projects a successful achievement toward their strategic objective?

No, I do not consider slit-rolling a success. Although, in actual production the productivity was increased but not as designed and there was many quality and operation problems with it. In less than three years the people at the plant decided to go back to single rolling. The people at the plant can give details of these problems. On the other hand the rod mill performance has been very good, but the initial design capacity should have been double or triple as I mentioned before. So, even that the rod mill was as designed the design capacity was not good enough to cope with demand in the long run.

4. What about the HBI and the G&C Line, do you think that they represented a response to a change of organisational strategy? And can you describe how these impacted on the achievement of the organisational strategy (positively or negatively)?

Those introduced projects were based on growth strategies. The development of HBI plant was introduced for exporting and has been utilized with full capacity and contributed a great deal to profitability of our organisation. The high demand on this product coincided with a good and on time establishment of the module. I think the selection of the supplier had a lot to due with the success of this project. The project that I think was not based on good investment decision is the G&C Line. These lines are not fully utilized and their input coils from flat mills can be sold with more profit than processing them in any of these lines. I think we could have expanded in flat mills before the developments of these lines, or in the bar and rod mill or in the section mill that needed development to change its range of output to fit local and international demand. This is because there was no real study and analysis for priority relative to capability. I think the previous chief executive independently took this decision and accounted fully responsible.

5. In reviewing this research model presented in the sheets and illustration with it, give your view of the existence and role of these activities in strategic changes in your company? Or how is your company handling its practice relative to these activities?

If this concept of asset management was presented to me let say 15 years ago I would probably pay no attention to it. But as I was looking at your model and thinking through my experience in terms of events and actions that took place since starting operation 25 years ago, I realized that it is a concept that should have been introduced in our company many years ago because things like developments and expansion of production equipments, their availability, reliability, condition monitoring, maintenance effectiveness, performance measurement and integrated information system are the limiting factors for us today to achieve targets or make improvement toward best practice. As I mentioned earlier that we lacked the appropriate decision making processes for making those decision on development and expansion projects in 1997 and the slit-rolling in 1993. At these years we had no formal departments with the responsibility of activities such as evaluation, analysis and strategic decision making. They were all handled by forming teams that had no expertise or experience. After experiencing some setbacks with these projects the company realized the lack of some important activities such as decision analysis, research and design. I think the experience with these projects highlighted the need for the technical support and development department which was introduced in 1999. This department was established with limited resources and therefore its role remained limited as well. It was only in 2004 when the Industrial Research Centre (IRC) was established to handle the analysis for need, design, acquisition and implementation of the development and expansion projects.

6. How about the existence or adequacy of these activities relative to operation and maintenance? Or how is your company handling its maintenance and operation practice relative to these activities?

I think our company has realized the need for such activities but it struggled and still struggling with establishing the right structure and system that can be implemented in place to transform the practice for achieving such objective. In 1999, the company has also

introduced MPandC department to handle planning maintenance programs and activities but I do not think it is serving the purpose. These activities associated with the right maintenance of the various equipments should be in place on a functional basis and can not be handled by a central department. Equipments are numerous and are different in terms of operation or maintenance requirements, e.g. what is required for a furnace in the steel melt shop is different from requirements in flat mills, long mills, power station or distillation plant. We have always concentrated on production process and emphasized quality improvement as a strategy to compete in the market and we have succeeded to a certain level which can be seen from the growth of our company in sales, production and products or projects development through the years. However, it is wise to admit that the situation today reveals that it is impossible to make any further improvement or perhaps our competitive position is threaten, if we do not invest heavily on these mentioned limiting factors of asset management. This is because of the following:

a. For the last 10 years or so we have been operating with full capacity on most of our production mills and more important we have overloaded our steel melt shops capabilities. The need to keep up with the required availability and reliability is becoming challenging due to the increased operation load and age of equipments.
b. It is hard to track interdependencies of performance along processes and among equipments of the same process because we have not developed the required data systems and IT systems to manage information for the right indicators.
c. It is becoming very costly to do time based maintenance and preventive maintenance to avoid breakdown and in many cases breakdown is evident despite the massive time based and preventive maintenance.
d. Our production or maintenance cost is shown by benchmarking to be high and focus on reducing cost at the steel melt shops has already started to reduce the input cost for rolling products.
e. But what is required is to monitor conditions of equipments and have the condition based maintenance that assures the reliability and availability for the performance to achieve the set targets. This may require capital investment now but will definitely pay back in terms of eliminating the excessive preventive maintenance and assurance of equipment availability for operation.

7. You have only commented on these technical activities, what about the business activities and relationships for the strategy making?

I have commented on what is not in place in our company or need to be in introduced in the company in relation to your model. I think we are handling the production planning very well in coordination with the business division and its activities such as marketing or purchasing, budgeting and so on. The PP&C department is playing a good role in making all these links between operational and business objectives. The production plans prepared by PP&C are complete and detailed in terms of production, resources and time pattern. They are used as basis by most departments to plan their activities such as procurement of raw material, utilities consumption, inventory and budgeting. And with the performance indicators report, they constitute the only reference for managers at all levels to relate to when making decisions. However, these plans and indicators do not tell us much about requirements of maintenance or replacements of components in the production lines. Nor

do we have a reliable planning system for such activities in the long run. One thing we know for sure is that operation stoppages are increasing and maintenance cost is high and still going higher.

8. How does the decision process take place in your company? For example, where initiatives are made for strategic decision?

We maintain a good arrangement of meetings at all levels that allows problems to be discussed or initiatives to be proposed at any level and transmitted for discussion to higher or lower levels. Every department manager, meets periodically with his sections members, and attends periodic meetings with his general manager. All general managers meet with plant manager who has to attend the division director meetings with other plants' manager of the same division and so on. Usually, committees and teams are formed to handle specific problems and report on it. The whole mechanism depends on face to face discussion of managers and the effectiveness of decisions is driven by the knowledge and awareness of managers of the situation. We lack the data base system and information analysis techniques therefore we depend totally on the managers' view and experience for deciding matters.

Interview-4
15:00, 7th January, 2009

Participant-4 has a long experience with the rolling production lines in the company and has been in many manager positions.

1. As one of the team members of the slit-rolling project back in the early 1993, Can you tell me about its initiation decision and performance? Do you consider it a direct response(s) to strategic events or changes? And can you identify the triggers of these strategy events and describe how slit-rolling project may have contributed to the organisational strategy?

Slit-rolling was a strategic decision taken regarding increasing the production capacity of the rolling mills. The project was for increasing production by a modification from a single rolling to slit rolling of one of production mill-1 which started production of reinforced bars and rods in 1989 with annual capacity of 200,000 ton. Now we are operating four production lines of long rolling mills and there is another project for slit rolling that will start operation by next year.

The project was really an in-house development which was proposed by operation and approved because of its low capital investment. The whole project development was carried by a team from operation, maintenance, and system and computer department. It lasted only for three years but we have learned a lot from it. It enlightened us about how to deal with changes in the production strategy and the possible impacts of such change. There was a demand increase of size 12 and 14 of reinforced bars and rods that required a fast response and the modification from single rolling to slit rolling was thought as the most viable alternative at that time. Even though returning to single rolling of the production line was done when the new production line started operation, we have to admit that during these three years we experienced many problems in quality, maintenance and operation

stoppages. These problems have resulted in increasing the production cost in terms of delays, reject products and repair cost. However, we have maintained our customers' satisfaction by increasing and tightening process and products inspection. The reality is that there was relatively higher percentage of defects or non conformance to specifications than targeted in the final products which imposed large efforts on the inspection work and d caused some delays in deliveries. Consequently, all of these add to the production cost. So, the operation practice of slit-rolling increased production but had negative impact on the strategy in terms of quality losses, low utilization, more breakdown, higher maintenance and production cost.

2. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? Or to what extent do these activities exist in your company?

I think my contribution would be more related to my experience in the rolling mills production lines because I am new in the current position of this division. I will comment on your model and the points that you have raised in your questions from an operation manager viewpoint.

Regarding our competitive strategy, I think the change in strategy has always been based on improvement in products' quality. Incrementally, every year we set a new target for quality. The ultimate goal is zero defect products. This is also related to the adoption of ISO 9000 in our company and quality improvement program. However, our set goals has always been achieved in terms of delivered products to the customers but not in terms of those produced.

The other thing relating to strategy change that I think is very important and our company has not been doing very well and I am not sure if your model covers it, is the change of strategy in the way of improving the contribution of people. There is a need for good motivation and reward systems to get people involvement in improvement programs. We have tried team work and quality circles but we were not successful because in my opinion people took it as another burden or extra work with no clear benefit to them. It is only lately were our company has started a bounce reward based on achieving a specific production target. The good thing about this system is that all employees of the line get the reward. This has helped in integrating the effort from operation, maintenance and quality control people to achieve the target.

In relation to operation, your model indicates the important links to performance measurement, maintenance and quality control for achieving targets. These relations are indeed very important from my experience and the important element is planning which is carried out by central departments in our company; production planning and control and maintenance planning and control department.

My view of managing these assets is that maintenance is production. The integration of these under one authority is very important for success. In fact, defects in quality can be cased by inadequate conditions of any component of the mills or can be caused by defects in input billets. On the other hand, any fault may be done by operators can cause damage to mills that certainly cause delays and require maintenance. In fact, when reporting stoppage times of operation to planning and control department we have a difficulty in identifying the real causes of these stoppages.

3. Can you elaborate on this difficulty?

For example, if we have a mechanical problem some where in the production line that caused a stoppage of operation, this may be a result of a fault in operation, calibration of the specific equipment, electrical control signal, defects in input billets, improper maintenance or deteriorating parts such as bearing. In addition, the stoppage time may be increased by inefficient repair or unavailable spares and so on.

4. Do you do any type of analysis to overcome this difficulty?

When I was general operation manager, I enforced a team work forming for carrying two types of analysis for improving utilization:

a. Using Pareto diagram method for finding the few major problems and the many but mini-problem that causes stoppages or delays of the production lines.
b. Using the fish-diagram method for finding the real causes of stoppages or delays.

The team works have analyzed several cases but did not continue because of several reasons:

a. The members were too busy to spare time for the team work for analysis.
b. The large amount of data to be reviewed on PC and organized for the analysis as well as the doubt to its accuracy, quality and completeness.
c. The lack of a good computerized information system and organized database for the purpose.

For good practice, I think there should be some specialized people allocated to this type of analysis as their job and provided with the resource, skill and information technology to handle the analysis and connect information from all sections of the mills and other departments in the company. It is only lately, our company started to put some thoughts toward fully integrated information and one step has been taken by adopting ERP.

5. What about performance measurement? Do you have the practice that provide good base for strategic decision making?

We have our operation performance measurement and periodic reporting system which is partly manual and fed to PCs for filing and reporting. But this process is done jointly with the planning and control department by its office at the plant where data is gathered shift by shift and the P&C department produce parameters and indicators that are used for setting the production plans and targets or defining the possibility of achieving new targets for a strategy.

6. How is your maintenance practice?

We do planned maintenance and preventive maintenance for the purpose of minimizing operation stoppage. However, I think our preventive maintenance is not effective enough for the purpose and many think it is the cause of the high maintenance cost. We need some system for analysis to define conditions and criteria for the types of maintenance, repair or replacements and take action accordingly. We are thinking of condition monitoring for better utilization and we have to provide the technology for such method.

7. As an operation manager did you have any role in initiating strategy?

Not directly but through PP&C department and quality control department. Most discussion with them usually relates to the performance indicators generated by these departments in

relation to our operation and the possibility of setting new targets and the requirement in terms of operation and maintenance to make such targets possible to achieve.

8. Finally, do you any comment to add?

Relative to these activities in your model and their relation to strategy, I think every strategic decision regarding the capacity increase or quality improvement in our case had required asset development, and efforts from operation, maintenance and quality to maintain the required utilization rate. Other activities that I think our company has not been doing well are the analysis, evaluation and measurement of the asset conditions or reliability. I do not know if these activities are practiced in the maintenance department or any other department.

Interview -5
10:00, 8th January, 2009

Participant-5 has been in many manager positions and very long experience with Long Rolling Mills (bar, section rolling mills).

1. In relation to your plant what changes took place that you would consider strategic or responding to the organisational strategy and how the decision was taken to deal with such changes?

There were several expansions projects; actually the current capacity is almost tripled compared to initial capacity and we are going ahead with further expansion. These projects were introduced to fulfil the market increasing demand. But this also I think a result of the quality achievement on our products in the market. Improvement in quality was and still our main strategy, so there is always changes to further improve products quality. However, the challenge is now to improve our process quality, which relate to some of the problem that we have. Perhaps, in quality terms we think more of the role of people for improvement but the management aspects that you have raised in this discussion as asset management are important because they are related to organizing how people should carry activities and handle relationships in dealing with investment, maintenance and perhaps operation of physical assets as well for achieving business goals.

2. Since you were one of the team members of the slit-rolling project, can you elaborate on your experience with this project or the modification? To what extent was it successful? And if not what difficulties did you have with it?

We had the slit-rolling modification in 1993, introducing a new rod mill in 1997 and the current development of high speed slit-rolling mill. Slit-rolling modification project was one of the strategic decisions that we took here in this plant. It was also the first action we took in respond to increase in demand but it was in-house modification of the single line into slit rolling. The idea was initiated by the people in this plant and established by a team from our company. The project served its purpose, however; we experienced some difficulties with quality due to the change of process. The project was based on low investment. Only minimum requirement of equipments to be changed were acquired for obtaining slit rolling modifications. Also emphasis was on completing the transformation of the line in a very short time. As a result the calibration and control required more efforts

and experience than what we had. But eventually the process was controlled and the out of specification problems were reduced to an acceptable level for the purpose of increasing the productivity. The final products had a high percentage of irregularity comparing to operating the single rolling but that only affected the production cost and final inspection took care of making sure that no irregularity was passed to customers. The main reason for introducing slit rolling in that manner was to win the new customers in our domestic market and not let other competitor get into our market. I think for a short period the goal tactically was achieved but with less profit or losses and some risk taking by the management of this plant. But it was not the right decision in terms of providing an alternative to cover the increase in demand for the long run.

3. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? Or to what extent do these activities in the model exist in your company?

Your topic seems to cover a wide range of activities and relationships among many departments. If I understood it, it concentrates on the connection between the business objectives and the operational practice to achieve these objectives. You seem to concentrate on the equipments but I think the role of people is very important and I do not know how asset management deals with that.

Some of these important activities are carried out by existing department like PP&C, MP&C, QC, and Technical support and development but I can comment on the situation or the relation of these departments and the operation and maintenance of this plant. In this plant we maintain good coordination with the PP&C and QC and I think the planning and control activities are handled very well with operation and the customers demand and satisfaction. But I think the MP&C and Technical support and development departments are not well developed to handle what is to be done to the assets by knowing the conditions, or indicators to use for making maintenance programs. These departments are central and the task requires people who are really professional or very close to the assets and familiar with conditions and capabilities. Maybe it could be done if there is a fully automated information system but still the job is better handled by people close to the assets because matters can be rationalized by experience and observation of the situation. This problem is common among plants in general and this cause a gap in coping with the production plans or set targets for quality based on the long objectives. These situations act as barriers to continuous improvement toward achieving best practice. The situation results in unexpected stoppages that disturbs work procedures and put pressure on people ending up with wrong decision that make things worst.

4. Why the CMMS is not enough for facilitating knowledge for such task?

It is a tool which is useful in many situations but it is not comprehensive enough. We need to sense equipments conditions. So far, our practice is mostly designed on time based maintenance and can not handle trade off decisions. Actual practice forces us to do things earlier or delay things depending on the time available. For example, what requires stopping for repair or what can withstand until the next stopping for maintenance. If we are going to follow the recommendation on the CMMS for each component of equipments then we will be lowering the availability of lines for operation. In addition, there are the issues of in accurate input data or not enough information on the CMMS as well. So, I think we

can not totally replace the role of human knowledge and experience with technology in actual practice but those experienced people should use technology as a tool and rationalize with their experience and conditions or situation at hand. The company is taken one step for resolving some of these by implementing TPM and I hope it will help us in this direction.

5. How about the performance measurement? How is it handled?

Again, the PP&C has handled this matter all along and with very good system that in my view serve the production planning purpose but it does include indicators that are very important for other purposes such as stoppages, Utilization rate, availability and productivity. But these are process indicators or for the whole line and are not representative of each equipment. Therefore, asset wise performance measurement is not generated in terms of indicators. There is raw data which is available from operation or on maintenance work orders but it is not organized to develop indicators that would help in making analysis for decisions.

6. What about getting your message to top management or in specific how the link between operational and strategic decision makers work for better decisions? Or how effective is the coordination between technical people in your plant and the business and administrative level?

I think the traditional way through managers meeting is working well in getting the message through hierarchical levels. Coordination with departments such as marketing is done through PP&C purchasing through MP&C and the QC maintains relation with customers and coordinates with us on what should be done. But I think the lack is in the understanding of links with the accounting and finance. For example, we discuss stoppages in meeting and consider them as real cost factors but we do not know how does accounting deals with their effect on products unit cost neither do they define bases for us to make trade off decisions or how pricing of our products should be done based on these stoppages for example. In meetings, we discuss such matters and it has been realized by our company that integration through information system is essential for getting best output. Now the company is in the way of implementing ERP which should serve in making the relation between the technical operation and financial parameters more clear.

Interview -6
12:00, 9th January, 2009

Participant-6 has been in many general manager and manager positions and has a very long experience in maintenance.

1. As one of the masters of the slit rolling development or modification in 1993, give me your view on the initiation, success or failure of slit rolling in relation to this concept of asset management.

The project was initiated in response to a sudden increase in demand for certain products in the domestic market. At that time the innovation and development department and the MP&C did not exist. The general manager of our plant was asked about the possibility of covering this increase in demand, other wise the shortage will be imported from foreign competitors. It was realized that the required time to establish another production line is not less than two years. So we contacted CobeSteel being the manufacturer of the rolling

production mill for developing it into slit rolling. Their offer was very high and required more time than we asked for. In addition, they advised us to establish another mill instead. After discussing the matter with managers in our plant and consulting with the system and computer departments for the adjustment of the electrical and computer control equipments, we came up with a team that was ready to take the challenge and do the modification in a very short time and with only the cost of the new equipments. I think there was a lot of ambition to prove our selves as being able to handle the design challenge that made us overlook the lack of expertise and experience for such modification project. The project was approved and the development was established on time.

The productivity was doubled at first trial but the rate of defects was more than 50%. Efforts in terms of further modification and control were applied to gradually lower the defects percentage. The main defect was irregularity but there were other minor surface defects. We were not able to really reduce irregularity defect to a very low level but the severity of the defect itself was controlled and minimized to a level that does not affect the functionality of the products. Fortunately, we were able to sale products with minimum irregularity in the local market after downgrading their price. This played a role in contributing to cover the increase of demand.

So with respect to slit-rolling modification, we had difficulty with controlling the operation resulting in quality problems and short repetitive breakdowns, delays, more handling and quality inspection, more over time and disturbance of the whole production process. Gradually the process was controlled to some extent and the project had achieved the objective of covering the short term increase in demand but could not continue to handle the increasing demand. There were indications of losses in terms of reject, stoppages, non conformance products and more inspection efforts but overall it served the purpose and we operated it for three years. However, the difficulty with eliminating irregularity problems and rejected patches, delayed orders, customers delay complaints forced us to revert to single rolling. After three years most of the causes of these problems were acknowledged and we could have improved the results by further modification but the high increase in demand made other alternative more viable. I think this resulting low performance is a result of the poor modification design that required ongoing adjustment and further modification. However, the operation and maintenance processes requirement were overlooked as well at the design stage and we had to learn and no choice but to train people as we proceeded with operation (Participant-6).

After all, the slit-rolling modification project was not a success, however; it was not a complete failure because it handled the increase in demand for about two years. We have also learned a lot from the experience and realized many important things. One of the things that were triggered by the experience with this project was the importance of incentives and rewards for motivation. This was realized and the company adopted the production target achievement reward system which worked very well in improving plant availability and productivity when given to all people in the plant when achieving target.

2. It seems that you consider the project as a success, but what do you think the reasons behinds these problems?

The main reason was the emphasis on minimizing the capital cost, so there were modifications made instead of changing the whole system; total set of equipments. This required certain expertise that we did not have at the start. There were also spares made on

site in the central machining shop which were not as perfect as we wanted, however; they served quit good after several trials.

3. How the introduction of the rod mill in 1997 was related to the organisational strategy? And was it a replacement of slit-rolling?

The ever increasing demand in the market led to realize that improving slit-rolling performance can not cover the increase. In a meeting in the late 1995, that included the slit-rolling project team, general managers from the plant and directors from production and technical divisions, a report was prepared for the chief executive committee explaining the problem and proposing the introduction of another single rolling mill. A decision to reverting back to single rolling and import the shortage of production for the demand was made. Before the end of 1995 a decision on a contract for a new rod mill to increase the production on size 6 and 10 was finalized and started operation in 1997. Perhaps this is what should have been done in 1993, but we did not request a study of the market to base our decision for capacity and technical design. We were looking at indicators of increase and we did not think of the possible huge and continuous increase in demand in long run. In fact, the continuous increase in demand has triggered another expansion project which is the high speed slit-rolling mill that is under implementation now.

4. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? Or to what extent do these activities exist in your company?

I found the topic very interesting because it touches on some of the problems that I am experiencing in terms of the confusions among some of the departments on the responsibilities and accountabilities regarding important decisions specifically those maintenance related decisions. Your model explores the various activities required toward managing the various aspects of owning and utilizing assets. I do not think the term asset management will be well understood in our company but from my long experience in maintenance, this concept as you illustrated it in subheading (maintenance, life cycle management, asset conditions, performance and analysis) sheds lights on some of the shadow areas we are experiencing specifically about “who takes the decisions regarding many tasks such as replacement or repair, what maintenance should be done and what should be delayed to the next shutdown, to what extent should inspection be done and so on. These decisions may not look strategic but they all affect the achievement of production targets. I will touch on this later, but I would like to illustrate my understanding of your model by first explaining what we have in actual practice for the purpose, what is wrong with current practice and how your model can assist if tailored to this type and size of organisation.

When this company first started maintenance was totally decentralized; that is every plant has its maintenance department. At the first few years, these departments carried out the maintenance activities according to the manufacturer recommendation and had really no problem because the assets were new and the increase in demand for products was gradual. As the pressure increased on higher production rate and assets got older things got out of hand and maintenance required more thoughts into designing maintenance programs to handle the situation. These maintenance departments gained a lot of experience and were

able to handle things but the driving factor was the experience of these maintenance and operation people who became very familiar with the assets requirement. At this point of time the company had realized the need for better maintenance practice and upgraded the CMMS and introduced a new central department called the maintenance planning & control (MP&C) department.

Feeding of data to the CMMS took very long time and its use has only started lately. The MP&C was introduced based on the need for coordination for shutdown maintenance. Since plants dependency in operation is high, the central planning of such activities is essential and such plan is better done in a central office by integrating plans from all plants to minimize time for maintenance. But this department took over all planning of maintenance of all plants and started to collect information and data to control and report on the performance of these production lines. The problem I have been dealing with as a general manager of these maintenance departments is that the people of MP&C could not make the right and complete programs and plans for maintenance because they are not expert on the assets and their manager can not comprehend the uniqueness of all assets in the different plants. We ended up making the programs and decisions on their behave which I do not like. According to the organisation chart the responsibility of my departments is the execution of maintenance programs or plans and any breakdown maintenance. The people in my departments and maintenance departments in other plants are disturbed and stressed by doing the job for these people in the MP&C department. We can provide information but can not teach some people the experience.

They should be analyzing the data and information, defining the right maintenance programs (what to be done) and the plans and schedules as well as following up on manufacturer recommendation and the assets' conditions and the need to alter these recommendations.
To your knowledge, we have been exceeding the design production capacity by quite a margin year after year and not adjusting the maintenance programs to the requirement is critical. Other wise, breakdown maintenance can dominate the practice, which to some extent we starting to experience if things are not changed.

The points I want to indicate here for changing the current practice and relative to these activities in your model are:

a. There should be an asset management department in each plant and the maintenance is part of it. Meaning that this asset management department should handle the requirements programs and planning, performance and conditions of assets, data analysis and asset life data in separate sections and the maintenance section would be executing the maintenance programs as they are design by the other sections and feed back information only. This department should utilize the CMMS system by all sections for better practice. There should be an asset management department in each plant because the assets in each plant are unique and require to be managed accordingly. In this manner, each section knows what information is needed for the decisions to be taken and the tasks to be handled. Also this will facilitate the ease of initiating proposals for assets developments which can be discussed with innovation and development department for further analysis or submitted to for further study.

b. The people working in each asset management department specifically those dealing with analysis and assets life should be experts on the maintenance and operation of the assets and should get training on various techniques for analysis. The manager of the asset management department should be the one to appoint these people according to their expertise and the section they will be working on.
c. The Central MP&C should be reduced to an office to handle the integration of plans from all plants. The required programs for shutdown maintenance should be produced by each plant and handed to this central office for alignment and scheduling of activities. It also should handle the procurement of spare parts in coordination with inventory and purchasing. This is to handle common spares for all plants, minimize inventory and centralize authority for procurement. This also assists in keeping asset management people concentrating on their assets' management activities and plans while the MP&C manage the interrelationships with other departments.

5. Do you think the way you set this mechanism is worthy of sustaining the capability for strategic change? And is it linked to the strategy making?

I am not going to say, yes or no, because the way I think of it is that any thing done on the assets will have some effects on the output of these assets and therefore at the end it will affect the strategic objective in a positive or negative manner. To every action or decision a consequence and the accumulation of operational decision can lead to success or failure. And every strategic decision has to be broken down to operational decisions. Therefore, I think defining the requirement to keep assets available for operation and reliable to operate is the key to achieving targets and therefore the strategy.
In terms of coordination with others, I thik the traditional way is working fine in our company. We maintain periodic meeting in all levels that can convey any message from lower level to higher levels and visa versa.

Interview -7
14:30, 11th January, 2009

Participant-7 has been in many manager positions and very long experience with the company.

1. Do you consider slit-rolling project and the introduction of the rod mill project direct response(s) to strategic events or changes?

The slit-rolling project and the introduction of rod mill were two consequent actions to cope with the increasing demand on a range of products; size 6, 8, 10, 12 and 14. The marketing reports from 1990 to 2008 show a continuous increase in demand on these products over these years. In each report the sales plan for the next year exceeds the past year by quite a margin. These plans are based on annual surveys on next year orders from current customers. For example, after introducing the rod mill in 1997 to cover the increase in demand, it took only three years before we had to import the shortage in 2000. In fact, the shortage has reached 168,000 Tons in 2005. This matter has cause the contracting for the high speed slit-rolling mill which is under implementation.

2. Can you describe how these impacted the business performance and contributed to the organisational strategy?

With respect to slit-rolling there were many quality and operation problems that resulted in downgrading prices, delays of customers' orders, customers' complaints, shipment delays and penalties. Although, no defected products reached customers but many orders had to be reinserted others replaced. Overall there were many losses. Above all that it did not cover the increase in demand. The downgraded production was sold in the local market to cover this gap but shortly it was not enough. I think the decisions for slit-rolling was not based on studying the local market to determine the expected increase in demand. Although, the marketing reports showed repetitive increase through the years and a sign of the size or percentage of increase every year, the decision in 1993 for slit-rolling or in 1997 for rod mill expansion did not reflect the understanding of the expected demand increase. The slit-rolling should have not been taken and the rod mill should have been introduced in 1993 instead. Even in 1997, the capacity expansion in terms of the wire rod should have been doubled.

3. Can you describe how the introduction of HBI and G&C Line were initiated in 1997? And how did they impact the business performance and contributed to the organisational strategy?

The decision was undertaken by the chief executive at that time for the purpose of introducing new products that can increase our company share in the international market. The HBI is a success in the direction of increasing our share in the market. The acceptance of its products in the international markets and its performance success in terms of quality and production has shifted our export quantities dramatically as shown in the sale reports since its start of operation. I will give you access to view these reports but there is also a summary of these annual reports for the last 10 years available on the company website. You will see that at some stage HBI products constituted more than 50% of the company export. With the increase in market prices after its establishment, HBI export has contributed extensively to the profitability of our company and has served its goal by making its products reach many markets in the world.
On the other hand, the G&C Line project was unsuccessful. Its problems that resulted shortly after its start of operation has caused a lot of damage that resulted in many setbacks afterwards. At first, we were not able to utilize our coils in these lines because of some design problems. When this was solved by investment in further development other problems aroused and the lines were shutdown. This sudden shutdown of the lines due to some construction problems has caused loss of customers. It was hard to regain confidence of customers after all of these problems. Furthermore, after solving all those problems, we experienced shortage of input coils and it was realized that expansion in cold mills is required. In fact, I have stated in one of my reports to the chief executive committee that there is high demand on cold mill coils in the market and it is more profitable to sale these than process them in the G&C Line. So, these lines have resulted in a very high capital cost because of these mentioned problems and until now they are working with less than 50% of their capacity. This is a major loss for the company. Not only this project was a failure in terms of contributing to increasing the share in the international market but it caused major losses that affected the overall profitability of the company. The investment could have been on other plants such as bar and rod mills that could have increased our sales and therefore revenue and profit. I think we lack the strategic analysis and planning activities.

4. What do you think was the cause of all of these problems with G&C Line project?

I do not want to go in the details of this but it originated at the selection of the wrong supplier. The feasibility study was done by Dastur Engineering and according to this study there was opportunity for our company to supply part of the market demand in Europe. Unlike the case of HBI this supplier was unfamiliar with our plants design. This resulted in unfit design with the rest of our plants. It also seems that this supplier was new in this field because these construction problems are not things that usually occur. On our side the project engineer should have observed and reported the improper action that led to these but the project team lacked expertise and experience.

5. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? And to what extent do these activities in the model exist in your company?

It is very important for any company to have some strategy setting process. Our company has already realized the importance of strategic planning in taking in consideration the external factors and internal factors. In our company in the past, strategic decisions were usually taken by the chief executive based on his discussion with directors in the different divisions but the company had no strategic system or formal mechanism for feedback from various departments to manage for better strategy making. When I started here in this marketing department, I wrote to the chief executive a proposal to introduce a strategic planning department to study these external changes in the market, government regulations, and competitors and provide view for us of how things may be in the future so we can make our strategy accordingly. The chief executive settled for a strategic committee that meets periodically to set the order of the main strategies and policies instead of introducing a department to do forecasting and analysis of both internal and external factors. In meetings we have been discussing strategic matters and issues where usually raised that reflect some of the activities you have in your model. I do not know much about asset management but our company has always emphasized quality management and concentrates on production process. But these activities in your model such as analysis and prediction and developments reflect the link to strategic success. The most important thing is the analysis which we are missing really in our company. The performance measurement is there on functional basis but not integrated and may not be complete and it is usually manual.

What is very important for our company to consider is the analysis of the external factors such as markets, competitors, government roles or regulations, technology and so on. Any change in these would require from us to review our strategy to cope with the change or expectations of changes. In my view, this way the strategy is initiated by any external change and the strategy development inside the company follow the requirement to act in response to this external change. So there is a need for analysis to define expected change in what you call stakeholders and analysis at the business level to define what should be our new direction or targets in terms of production, quality and product mix, then the technical analysis is needed to define our capability to cope with these new targets. For example, do we need to develop or expand for expected demand? Or do we need to improve our quality? Or do we need to shutdown some plants? Once, the strategy is set, requirement assessment for implementing it should be done. And feedback on its implementation should be sent for follow up and analysis. In reviewing your model and this system flow diagram it is clear

that the model emphasize this view in terms of a cycle that include the top down and bottom up approach to the strategy development.

But we are missing the formal structure for the responsibility of the analysis on both levels: the business and operational level. What we depend on is really opinions of managers who may have experience but can only do some debating to set a decision with no appropriate analysis. And when the general strategy of the company is made on this basis, there will always be lack in translating it into individual departments' strategy. This is because so many requirements of these departmental activities were not taken in consideration.

6. If this model to be implemented in this company, in your view, how could that be done?

The important thing is that these activities will be in place and have the means to link them properly. I am sure we have to introduce a system for strategic analysis at the business level but these activities at the operational level could be inserted in some of the existing departments. For example, we have a section in the innovation and development department called industrial section which can be updated to do some of the activities. Also the MP&C department may take care of other activities. Or maybe combine these activities in a department to gather information for performance indicators generation, reliability analysis and development analysis. There is a need to think of restructuring the organisation to facilitate the integration of departmental systems for the purpose of serving the strategic mission.

7. Can it be done through forming functional teams?

From my experience I learned one thing clearly; when you form a team to do a continuous process it will not work. It is effective for specific task such as analysing a specific problem and presenting a solution for it but not for following continually reoccurring things. Specially the analysis activities in your model requires specialized people and involves as the model illustrates investigating system, procedures, life cycles, prediction, constrain and so on. These require established work system with appropriate tools to handle the tasks and can not be done by team work. Of course there is a need to coordinate with many other departments or systems but the work requires experts on the analysis.

8. Any comments?

From a long experience in this company, I totally agree that what your model is presenting coincide with what our company require at this stage for better management toward strategic success.

Interview -8
14:00, 13th January, 2009

Participant-8 has very long experience with the company as a manager.

1. Can you narrate/describe events that represent a change of organisational strategy and required AM solution or action? (These events may be triggered by external factors such as market or internal factors such as cost or achievement.)

The company has always focused on quality improvement strategy, however; lately there is a tendency toward competitive price strategy. The quality manual is the document that you should see regarding this point.

2. Can you narrate/describe any change in AM practice or action that impacted on the achievement of the organisational strategy positively or negatively? (These may be any project related to asset development, expansion, insertion, modification, replacement, maintenance or disposal.)

I am not familiar with the concept of asset management but if you are talking about investment in new assets then development projects have been undertaken consequently to cope with domestic and international markets. Currently the company is implementing a huge expansion plan and its projects are managed by the IRC. Perhaps they are in better position to talk about these projects.

3. What about those projects or changes that took place along ago and you can comment on their impact on the achievement of the strategy?

I think the major change projects were the HBI and G&C Line in 1997. Also the adoption of ISO 9000 in 1999, if it can be considered related to AM. Perhaps other changes might have taken place in areas such as maintenance but I am not the person to comment on this.

4. What is your view of these expansion or development projects that took place in the company? I mean, were they the right decision at the time and how did they contribute to the strategic objectives?

Some of them were required and added to the company sales but I think it is just luck and there was no good analysis or study of alternatives. For example, the HBI was a success but I think it was just by luck that the same supplier of the similar existing was selected. Our company does not have good basis for making the investment decisions. It is basically who ever makes the lowest pet wins the project. However, some of the expansion projects have imposed high demand on the up-stream plants in the process. This indicates that these up-stream requirements should have been expanded first. But there are those two development projects G&C Line that were a disaster in my view. I do not know on what bases were these investment decision taken. There have been operating with less than 50% of their capacity for two reasons: the first is that the demand in the market is low for their products and the second is that there is a need for expansion in the flat mills to supply the other 50% of their input coils. The company could gain more benefit now from sailing these flat mills coils than processing them in these two lines.

5. What is your view of the slit-rolling modification and rod mill expansion projects that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

The slit-rolling modification was an act of inexperience people at that time. It did not serve the purpose of its establishment. Actually, it caused us a lot of headache with quality inspection. The rates of reject and defect were very high. I mean the defected products were over 50% at the start. Then it was lowered to about 20% defected but most of it was downgraded and sold because it was cased by minor irregularity defect. However, they were not able to eliminate or further lower the defect rate. It was not able to cover the

increase in demand for long and cased increase in losses that contributed to increase the overall cost of production. It caused many delays in delivery to customers and many shipments delays that resulted in penalties. It also increased the risk of having defected products to reach customers.

6. What do you think of the competitive product unit cost strategy of the company?

The way they are going about it in many departments, is conflicting with the quality improvement strategy. They do not see that directly because here in quality control we cover up with inspection to protect the customer. However, if they continue with it this way, they will suffer in orders delivery delays and loss of customers and maybe in higher cost than they ever thought of.

7. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and the model fitness and need in your company?

I am not familiar with the concept of asset management and not sure how it extends beyond the maintenance management to include the infrastructure management. But the idea of having a system, call it a department in a company like our company to link the operational activities with the business activities for strategy formulation is very practical and essential in my view. In fact, such system existed in other steel industry with similar structure to your model. In my visit to a steel plant in Ostrava in the Republic of Checkoslovakia in 1999, I found that they had a department called 'investment and strategic planning' and its work or structure reflects to large extent the activities you are proposing in your model. I did like the idea then very much and discussed the idea of introducing such department in a meeting with the directors and general managers of the company but I think the idea was not comprehended and that was it. So, from my view I would think that the link between the operational perspective and business perspective for strategic purpose should be managed by introducing a department probably called strategic planning.

8. And to what extent do these activities in the model exist in your company?

In regard to what we have in place in this company, I can not speak of what is there in terms of maintenance or even of what should be there but I hear a lot of complains in meetings regarding maintenance. However, the strategic activities indicated in your model are not in place in our actual practice. But I think most of the departments reflecting the other activities of your model are there in place but, are they carrying the right activities to interact with each other, is something that need to be activated. The coordination is there but through manual reporting and managers meetings; this way does not serve the strategy making because concentration is always on current operation, short term planning and even when strategic issues are discussed are usually handled by debating rather than real analysis and study of the issues. One thing can be stated that is our company is in need of a good IT system to serve integration of performance monitoring for this purpose of strategy making. They are implementing ERP but I am not sure if it is the answer. All the current performance measurements exist as functional entities; that is every department produces indicators serve the purpose of that department.

Interview -9

12:00, 15th January, 2009

Participant-9 has been in more than one manager position in the company.

1. What is your view of the slit-rolling modification and rod mill expansion projects that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

I am not the right person to ask about these because I was in the direct reduction plant and do not know much of the details about them. However, I have already arranged to give you access to the annual reports of this departments that contains the performance indicators of the entire bar and rod mills for that period. I think you have got the key to the archive room and I think you have already been there. You can find out how their performance was and you can observe any information you want from these reports. All annual reports since 1989 to 2007 are there and the 2008 report is still unfinished but you can ask me about any information for the 2008. These reports contain the annual plans as well.

2. Since you were in the direct reduction plant, can you describe how the initiation of the HBI project took place? And how did it contribute to the business and strategy of the organisation?

The HBI project was really initiated by the chief executive of the company and I do not know how did arrive at such decision. However, the HBI was a real boost in terms of increasing export of our company and it is considered as the best decision taken for the company by many colleague managers.

3. How did the design and implementation of this project take place?

The company made a contract with Dastur Engineering for the feasibility study and a contract with the same supplier of the module-1 and 2 to do the complete design and implementation of the HBI module. I was one of the team members observing the implementation and commissioning of the project. It was submitted on time with successful commissioning. We did have much problem with integrating the new project with power or utilities or the other modules mainly because the supplier was aware of all the requirements. Also the module was mainly for export and we only had to be concerned with imported materials and how to handle exporting of HBI. Its performance has been great since it has started operation. You can get the performance data for the annual reports.

4. In reviewing the model presented in the sheets and illustration with it, give your view of the role of its activities in strategic changes and their fitness and need in your company? Or to what extent do these activities in the model exist in your company?

I have reviewed the sheet you gave me and I agree with the activities of your model. I can only talk about the role of this department. First, the PP&C must be defined in the context of this company. It is a central department in the production division that consists of planning and control sections. It has its supervisors (4-to 10) present in an office at each plant to supervise the production processes and be close to events. I think that PP&C has a very essential role in sustaining the strategic capability. This is because it sets the long plans for production which is the main purpose of our assets.

According to the strategic goals that are usually set by the top management, PP&C develops long and short plans as well as schedules for operations of the continues processes of the production lines in all the plants of the company.
These plans are developed based on coordination with other plans. The marketing plan is first to be defined to confirm the continual demand and the expected increase in demand of the various products of the company. Such demand is usually compared to the most probable achievable capacity and the associated risk with it. Plans are made in terms of products to be produced and all requirements such as raw materials, consumables, water supply, and electric supply and scheduled with time constraints.
In developing these plans, PP&C is in direct coordination with all related departments such as purchasing, marketing, quality control, MP&C. While these PP&C offices at the plants provide the performance information on the production processes of each plant.
The performance indicators measured and analysed by PP&C are process indicators of each production line as one process or system. I have provided a copy of the annual report as you asked which provides a total view of the whole performance measurements and analysis done by PP&C department. The main KPIs as you know are: utilization rate, availability rate, yield rate, production rate and productivity. Also we use the stoppages categories that are part of the utilization rate. Most of these are measured and compared to planned and designed figures to serve in developing plans.
The PP&C has developed its performance indicators and KPIs for each production process and maintain a database for these indicators for producing periodic reports (monthly, quartile, semi annual and annual).
The performance analysis serves in developing the long plans and foreseeing the possibilities for improvements or identifying the factors causing unachieved plans. These indicators can be further studied with the operation and maintenance people at the specific plant and analyzed in details to avoid the cause or find the remedy.

5. What do you mean by factors causing unachieved plans or can you give an example of that?

For example, if the utilization rate is low in one of the production lines, the line production manager would be asked for explanation and reasons. The indicator is an indication of high stoppages. The high category of stoppages would identify the area of the problem. For example, the production manger of steel melt shop-1 (SMS1) responded to reasoning of decreased yield rate by demonstrating that the pour back is the main factor and he asked for the development to ladle furnace to get red of this problem.

6. How does your department handle the data integration?

In the absence of a comprehensive information system, PP&C department has developed its information networks and programming to handle the huge amount of data from all these plants or other departments.

7. Who uses your reports?

The PP&C department's reports have become the database for the whole company. They are used for planning budgets, used as basis for improvement or development projects and most importantly are the main tools for top management to observe how the company is progressing.

8. You have said early that top management sets the strategic objectives, so you only implement the required change in strategy or how does it work?

Top management makes strategic decision based on many inputs from inside and outside the company. In our company, I think most of changes related to strategy are driven externally by customer demand or quality satisfaction and internally by lowering products' unit cost. The decision of top management in the past has involved expansion projects of the production assets, developing new production lines for new products. The PP&C performance indicators provide basis for taking analysis to arrive at such decision. There are also other important reports with indicators for top management to take decision such as finance, accounting and marketing or sales. But the PP&C is always consulted in aiming at changing strategy because it has a role in coordinating with other departments and defining if such a strategy can be implemented successfully with the existing assets and the requirements for achieving such targets.

9. How do you make the production plan?

We study the trends of actual indicators, planned figures of past years and identify the actions taken to avoid low achievement, and then we establish our future plans. To develop a production plan we have to have the sales plan, maintenance plan, development or innovation plan and any expectation or risk such as those resulting from delaying shutdown maintenance or power stations.

10. Finally, do you think PP&C department have an impact on asset management for sustaining the capability for strategic change?

Yes, I think it has a important role in coordination with those departments dealing directly with the assets to defining the basis for undertaking any strategic change. It identifies what can be achieved with current assets, give indication of the need for expansion or development of assets to achieve new goals and provides the performance indicators to lead for changes and improvement.

Interview -10
9:00, 17th January, 2009

Participant-10 has been a manager for a long time and considered an expert in a relevant field to the company.

1. What is your view of the slit-rolling modification and rod mill expansion projects that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

At the time of slit-rolling in 1994 or 1993, I was working with quality department and this research and development (technical support and development) department did not exist then. This department was introduced in 1998 but still limited in size and resources. From quality performance perspective, slit-rolling did not serve its purpose. I recall that there were many quality losses that also disturbed the operation. At that time we did not have the experience and the team members tried to do their best but it was the wrong choice. If they did the right analysis then a large expansion in production could have served in avoiding the shortage n production for the market demand along all these past years. The performance of the rod mill has been very good all along but its capacity was not enough to

cope with the demand. Again, I think the decision was not based on good analysis of the need; in particular the expected demand increase.
Most of projects in the past were initiated through managers meetings and studied by appointed teams that usually do detail studies and/or give issues to consultants. Currently this department plays an important role in investigating problems or looking for ways of improvement and making initiatives toward such objectives. We still use teams usually led by this department members to analyse and study matters because of the limited size and resources of this department. However, we have gained a lot of experience since then and found that the team work and involvement of those dealing with the matter in the plants is important for arriving at the right solution. But this was realized after a long time of dealing with situations improperly. The other important requirement was the Industrial Research Centre (IRC) which was established lately in 2004. This IRC took care of a lot of the initiatives that we have proposed and done the required studies for making the decisions. For example, now we have a strategic plan for expansion and development that even has been revised twice before implementation started.

2. What about other expansion projects like HBI and G&C Line that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

These two were undertaken to introduce new products and gain a share in the international market. There decision was taken by the chief executive based on a study of the international market. The study was focused on what products should be introduced but overlooked the internal factors. As a result, the HBI was a success but the G&C Line was a disaster. The HBI increased the export dramatically, on the other hand, the G&C Line was a major loss in terms of a capital cost that not did payback but caused other losses and was not good for the reputation of the company.

3. What projects, developments or any asset related actions did this department take part in for improvement? I mean improvement toward achieving the organisational strategy and how did this department contribute to the business and strategic objectives of the company?

After this department establishment in 1998, it took a while to build a procedure and a data base for conducting analysis of the practice in these plants. The department first focused on reviewing current development in the world relative to these processes and technologies used in our plants. It also maintained contacts with those related suppliers, customers, manufacturers, universities and government institutions. Then, we started studying the current situation in these plants and find possible ways to improve the practice for the benefit of the organisation. But we found that the amount of data to be collected and studied is huge and the company lacked the proper computerized information system for collecting organizing and reporting and most importantly missing the computerized systems for conducting analysis. We had to start the available manual reporting system and concentrating on certain plants at a time. For example, we started with steel melt shops as the most critical upstream process. In doing so, reporting on certain problems from operations or maintenance in these plants was given priority. The earliest work done by this department was done on some of the problems in the steel melt shops. This department for example did the study and analysis for the developments of ladle furnace. It also did the

analysis for the replacement of external cooling rolls by internal cooling rolls and transferring liquid steel between the two steel melt shops.

4. What triggered the study of these? I mean for example, was it the intention to make cost saving for the company that triggered the ladle furnace development? How was the decision made for adoption of ladle furnace development?

It was not the thought of saving that triggered starting the analysis and evaluation to adopt the ladle furnace. It was these complaints from the rolling plants and operation in steel melt shops from the disruption of production schedules caused by pour back. This department studied the process in terms of all performance indicators and obtained all required data for the analysis. At first we were thinking of putting more control on operation process procedure but reviewing the latest technology in the field highlighted the opportunity for improvement by the ladle furnace solution. So, there was the analysis to define the problem and the different ways of approaching its solution and defining the ladle furnace as one of the alternative or opportunity for improvement relative to the problem defined. Therefore, before even thinking of the saving made by the ladle furnace, there was the work to determine that the ladle furnace was an alternative solution. When it was realized as an alternative, we focused on gathering all information about its acquisition, installation and the viability and flexibility of its integration within the steel melt shops. This led us to the cost and benefit analysis for adopting the ladle furnace for improvement of the steel melting and casting processes. After we became aware of all these ideas and process indicators, it was not hard to establish the right analysis and make the decision about adopting the ladle furnace. It was realized that introducing the ladle furnace will contribute to increasing the utilization and therefore the productivity as well as enhancing the final product quality by reducing the out of specification percentage. But its main advantage is elimination of pure backs. It also eliminates other losses caused by these pure back including energy, time, utilities, labor hours. By conducting the analysis it was clear that the saving by eliminating pure back is high comparing to the investment in ladle furnace. The analysis done showed that payback for this project can be obtained in less than 2 years.

5. What about the replacement of rolls? How was it triggered? Why was it selected and how did it contribute to improvement?

It was triggered by the scale formation problem that causes a lot of problems in the later rolling processes. Many complaints were reported by rolling operation regarding stoppages and breakdown maintenance cased by scales on billets or slabs. Steel melt shops were contacted regarding the matter as it originates there. Coordination with operation and maintenance personnel in the steel melt shops provided the required information to make the analysis done regarding the adoption of the internal cooling rolls instead of the external cooling ones. In fact, the maintenance people have requested these internal cooling rolls but the purchasing turned down this request due to the huge difference in purchasing price. The analysis done by this department showed the saving in repair and replacement time and cost by adopting the internal cooling rolls. It was shown by the analysis that in addition to eliminating the formation of scales there is saving maintenance and replacement costs as well as increasing the availability and utilization of the steel melt shops. The cost benefit

analysis was reported to the chief executive committee and we got approval for changing the purchasing policy regarding these rolls.

6. What about the EAF refractory replacement and repair model development? How was it triggered? Why was it selected and how did it contribute to improvement?

This department was just established when the EAF refractory replacement and repair model development was initiated for analysis. This department coordinated a project to study the issue in conjunction with [IND-university]. However, the department has all related documents to this research analysis. The project was initiated for the intension of reducing product unit cost by optimizing the replacement and repair practice in the steel melting process. This model was developed to determine the optimum replacement time and optimum use of repair. The research document in this department records, contains all the information regarding this model.

7. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and the model fitness and need in your company? And to what extent do these activities in the model exist in your company?

Your model seems to look at the whole enterprise optimization kind of thing and I am not sure if I can be of any help in viewing the role of these different activities in your model but I can explain what we do in our technical support and development department which I think is related to your model. The activities done by this department are related to the management of the equipments and play an important role in forming the strategy. This is because its activities are concerned with upgrading or developing capabilities or capacities of these production lines for more production, better quality or new steel alloy production.

What we are doing now is to contact all plants to report to us if there is any problem that might be considered for development solution and review these and see what we can study by our limited resources and submit to technical director those problems that we think have influential impact on the cost, safety and benefit or improvement in general, for discussion. We also contact all firms and organisations that are potential customer and see if their need or specifications can be produced in our company or see how our production process can be altered for such specification. We are in direct contact with new development in the world related to steel industry and provide related departments in our company with the latest. We also deal with universities, research institutes and regulatory organisations.

In brief, this department coordinates with all other departments to study their problems, concerns or any proposed idea for improving the practice and achieving better performance. Based on these things found or submitted from plants or from customers, the department studies the matters and then decides on:

a. The importance and criticality to the organisation
b. The possible alternatives for the solution and the impact of and opportunities offered by each for the organisation objectives.
c. The need to further study either in conjunction with universities or consultants.
d. The possibility for providing a solution with existing resources.
e. Making a proposal for a solution.

8. How do you see this department doing its obligation in the best way? For example, is it best to perform tasks by integrated teams formed from this department and the technical people at the plants or by having independent professionals working in the department?

The current staff is not enough, so the department capability is limited. I think the team work is essential because these technical people are very familiar with the nature of the problems and it would be impossible for the department to have experts on all the different processes and their equipments. The department should have enough professionals to carry the investigations and analysis or feasibility studies to provide higher management with the best solutions. This should replace the current committees and also should have direct link to performance parameters that can be used to indicate the need for investigation before problems are really experienced. This requires providing fully integrated IT system in the company which is not available now.

Based on many requests from different departments for the need of an integrated IT, an initiative was submitted to the technical director for contracting with the appropriate consultants. In fact, the company has already decided on ERP system and has formed the project team for implementation. My only worry is that the implementation is starting in a top down direction; emphasizing the financial system and going down. This may take a while before we get the technical system links in place and these links may be designed for the purpose of serving the financial control. My advice to the committee was to have a system that emphasize and start with technical need but that is what has been approved.

9. Bringing the issue of financial control, how is it affecting your practice or the practice in general in the company and in particular the strategy making and implementation?

The company has been enforcing product unit cost reduction for a while and also growth in terms of capacity and new products. The company started 25 years ago with 1.3 million ton per year of final products and aiming to reach 4 million ton per year by 2012. This is in parallel to the main quality improvement strategy of the final products. However, the implementation toward cost reduction in my view is not going well. The fact that every department is forced to reduce it budget or cost, has resulted in many unexpected problems in the operation processes of the various plants. Complains of unavailable spares, low quality material and spares are evident. Experienced employees leaving especially from steel melt shops because of the heavy work load with no extra payment. There is also alerting indication of increased breakdown maintenance and struggling to reach targets. Also those capital investment solutions are not easily approved. This is why I do not like this kind of financial control thinking. I rather, have the strategy set in purely technical terms, for example, higher quality, higher productivity and less stoppages with what ever cost required because these technical strategies will always pay back from increased sales but this cost reduction would always end up reducing sales in the long run.

Interview -11
9:00, 13th January, 2009

Participant-11 has been a head of one of the important section for a long time.

1. What is your view of the slit-rolling modification and rod mill expansion projects that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

In the early 90s when first operated with slit rolling in the bar rolling mill. The defect rate was high after the modification of that line and there were many events of stoppage because of quality and adjustments or calibration on the equipments was required. It took very close monitoring and many quality stoppages and this was going on through the whole period of slit-rolling operation. The irregularity defect was not lowered to an acceptable rate but severity of the defect was minimized to a level that does not affect the functionality of the product but still considered as minor service defect. So, this indicates that slit rolling was not the right decision because its performance was not good enough. The rod mill has been excellent and I think it was a good decision.

2. What about other expansion projects like HBI and G&C Line that took place in the company? I mean were they the right decision at the time and how did they contribute to the business and strategic objectives?

I do not think I can help you with this because I have been working in the quality inspection of bar and rod and I was not involved in quality inspection of any of these projects.

3. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? And to what extent do these activities in the model exist in your company?

From our view in the quality control department, the capability and good condition of the assets or process in general are very essential avoiding defects and therefore achieving high level of quality. The better the conditions of the assets, the more uniform the process and less variation in specifications. So, yes; good care of the assets would result in quality improvement which is one of the strategies of our company. However, we do not leave any chance of passing defects to customers by having very tidy inspection. I would think good asset management, will help process quality and reduce defect rate, and increase good production. This would reduce defect and reject losses as well as reduce inspection cost. This will consequently reduce the product unit cost which is also another strategy of our company.

I do not know how our company deal with the management of assets, but I can assure you the majority of non-conformance to quality is usually caused by faults in equipments such as not precisely calibrated, deteriorating condition and the like. Of course, these things depend on the human action but the missing action or not properly performed action end up in bad conditions that are usually reflected as quality deficiencies.

4. How are these performance measures or indicators that you produce used in the company in general and for strategic purpose in particular?

We monitor the production of all plants and have indicators that if they reach certain level we have the authority to stop the production process. Therefore, operation people are very sensitive to quality indicators and take the matter seriously and stop when ever required to make the adjustment. For the strategic purpose, our indicators are used to monitor the quality improvement by parameter such as defect rate, out of specification and rejected orders. They also are used for production planning and prediction of quality rate.

Interview -12
9:00, 18th January, 2009

Participant-12 has been in many operation management positions and has a very long experience with the company.

1. Can you describe how the introduction of HBI and G&C Line were initiated in 1997? And how did they impact the business performance and contributed to the organisational strategy?

Both of these projects were initiated and imposed by the chief executive of the company at that time and we had nothing to do with their initiation. We only were told that such projects were going to be implemented and teams to handle these projects were appointed. I know that these two projects were in response to the strategy of growth and introducing new products to allow our company to compete in the international markets. As a business decision it was based on the study done by Dastur Limited International but no body from the plants was consulted for decision of undertaking these projects. The decision was undertaken by the chief executive alone based on the study and recommendation by Dastur. I can not tell you much about HBI project except that it is beneficial to the company according to my colleagues' managers.

On the other hand, being one of the top managers in the flat rolling mills the G&C Line is of direct concern to me. This is because the operation and maintenance of these lines became part of our responsibility. However, no one of the flat mills managers was consulted regarding taking the decision of these projects. The decision was simply a business driven decision with no consideration to adoption, applicability or integration with the existing plants. I think this is why the G&C Line project was unsuccessful.

2. Can you clarify what you mean by adoption, applicability and integration?

There were problem with the design; specifically it was not possible to process our coils as an input in these lines. So, it was realized at the commissioning stage that more investment in rewinding our coils before using them as input to these lines. Commissioning was done by importing some suitable input coils and operation continued by importing coils until the extra development for rewinding our coils was established. However, after starting using our coils our production capacity of these coils was not enough for covering the increase in market demand and the input for these lines. Above all these problems, shortly after cracks were shown in the concrete structure of these lines. That was a complete disaster in my view that led to shutdown of these lines and reconstructs the whole concrete bases. Although the supplier was responsible for the reconstruction, it took a long time before the lines were back in operation.

3. How was the performance of these lines afterwards?

Okay, but these problems in the design, implementation and shutdown delay have imposed many limitations on the performance. The resulting capital cost became very high. Production rate has been low due to less ordering from customers in the international market and shortage of input coils. This has resulted in low utilization of these lines. The production has been less than 50% of their design capacity, a matter that most likely lead to not cover even the fixed cost.

4. How did it impact the business performance and contributed to the organisational strategy?

It is a great loss for the company financially and bad reputation for the company in terms of not keeping commitment to customers and loss of those customers relative to these

products. The results are opposite to the intended strategy. Instead of gaining share in the international market the project caused bad reputation and a great financial loss.

5. What do you think was the cause of all of these problems with G&C Line project?

As I have said the decision was singly taken by the chief executive as a business driven decision. It was certainly based on analysis of the market but no analysis was done in terms of its design, acquisition, and integration with existing plants or the associated risks with it. The improper decisions that were taken by the chief executive and assisted in worsening the results are the selection decision and contracting with the supplier and the decision of selection of the supervision project team. The supplier was selected on the low cost basis and the project supervision team members had no experience what so ever.

6. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? And to what extent do these activities in the model exist in your company?

Many of these activities in your model are reflected in the discussion of the *G&C Line* case. Other issues that you presented in your model as activities and relationships represent the real factors that are limiting us from keeping up with our operation targets. Most of the operation stoppages are due to unexpected components failure that some time further delays the operation because of the unavailability of spares. This matter requires monitoring of the equipments conditions and performance for analysis and prediction of failure to eliminate stoppages and minimize repair time. Not only that but also under some equipments condition it is hard to achieve certain level of product quality and some specification may not be achieved because of some component deteriorating condition for example. In fact, in many occasions by experience we diagnose certain equipment condition from the production quality pattern instead of monitoring the condition to avoid out of specification production.

7. In carrying operation, do you experience any problems in coordination with other departments?

We carry operation according to the production schedule and quality specification and have no problem with that but stoppages are worrying us of not achieving the production plans or quality.

8. From your view how do you think these stoppages that you talked about affect the strategy?

In a production company like our company, any strategy in based on achievement of production and quality targets. Therefore, these factors that disturb operation are important to consider for achieving the strategy.

9. How do you think these activities of the model should be implemented for the purpose in your company?

I do not really know what the best way to do that is, but the maintenance people may have views to help you with that.

Interview -13
12:00, 19th January, 2009

Participant-13 has been a maintenance Manager in one of the plants for a very long time.

1. Can you describe how the introduction of HBI and G&C Line were initiated in 1997? And how did they impact the business performance and contributed to the organisational strategy?

I can only make some comments relative to the G&C Line. It was initiated by the chief executive of the company for approaching the European market. It did not achieve its objective because of many design and implementation problems.

2. What are these problems?

There were several problems:

   a. The supplier design did not account for the specification of our input coils and therefore they could not be used and required extra development.
   b. Not following the construction specification led to cracking in concrete that required reinstallation of all equipments after it was in operation.

These led to very high cost and low performance that resulted in not serving the intended objective of the project. In fact, the project became an extra cost that lowered the profitability of the company.

3. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company?

The emphasis in our company is on production achievement and the final products quality. This has created a culture that over look the importance of the good care of assets. Your model looks at what should be done on the assets to maintain their ability and condition to achieve objectives. As a maintenance manager, I really like to see this concept of asset management understood in our company because it serves in the long run instead of pressuring the short term targets by overloading assets and overlooking maintenance. Maybe the innovation and development department should have a big role in this but it seems like it is following the production culture and concentrating on expansion and development of new projects.

I do not think we have the integrated system or mechanism in place as you presented in the model, however; some of the elements are in place or the activities are carried out by different departments but are not properly linked for the purpose. For example, with reference to maintenance we do not have activities and the links to collect the data or information about the various assets and do the analysis to predict things or to do maintenance in different ways so that assets will not break down suddenly. The information is there but the maintenance people are too busy to even think of doing such analysis or provide indicators per asset for managing its condition. I think there is a realization all over the company for an integrated information system and a decision have been made to adopt the ERP to handle the situation but I do not know how valuable will it be for the maintenance matters we are discussing here.

4. How about the MP&C department, does it assist with this situation?

Not really, its people are handling the procurement of spares and maintenance planning bud they depend on us for providing all the information and advice. They do not have the experience with our assets or can do any analysis, because they do not have the IT technology to hand all assets in all plants. Even when we report to them on some of our

problems we do not get feed back, they just report the same thing to higher management in the technical affair division.

5. To what extent do these activities in the model exist in your company?

I do not know but in terms of some part of the model, I think we do not know who is responsible for these activities indicated in your model for example analysis and evaluation. Some technical activities exist such as performance measurements but may not be adequate. Others do not exist such as condition monitoring and analysis and prediction or reliability analysis. There is also a lack technology tools and professionals, maybe contracting with those who are specialized in the field could solve such a problem. In this regard I have raised the issue of instrumentation for condition monitoring in several meetings and the technical division general manager is arranging for adopting such concept. What I like about this concept of asset management is that it looks into getting information and analysing it to clarify requirements for avoiding breakdown or in other words, for achieving targets.

6. How do you deal currently with the situation?

The best we can do is to use the time based maintenance as provided by the CMMS which conflict some times with production plans and hard to fit into shutdown maintenance. In addition, the CMMS has its problems such as incomplete information or not enough historical data. We found our selves increasing replacements and repair during shutdown as a preventive measure but we could be concentrating on the wrong equipments. This also has increased maintenance cost dramatically, a matter that is not welcomed by top management? We lack the performance measurement system that handles assets individually to assist in defining things and enhancing the mills performance. As I mentioned at the start, our company has production culture, so every thing is directed to serve the production process. For example the only performance indicators system we have is produced by PP&C to serve the production plans for achieving targets. I know it is a good system and it provides many indicators that we use such as stoppages, availability and utilization but it is designed to serve production planning. I mean there is no indications why are these stoppages occurring, what components are causing them or what action has resulted in or was not taken to avoid such stoppages, there are no indicators generated for such purpose. It is very hard to sense or predict the assets conditions or reliability through our current practice. However, we are doing a good job based on experience of maintenance people. And so far, we are handling things but fearing the unexpected.

7. So, you saying you do not have the proper way of monitoring the assets performance, condition or doing the analysis, but in your view, how does this impact on the strategy?

The lack of these things results in stoppages that require breakdown maintenance and consequently reducing the utilization of these mills. In return the targets are not achieved, the maintenance cost is higher and all plans are disturbed. This for example, works in reverse of the cost reduction strategy in our company. It also affects delivery of products to customers and work against our quality strategy. All of these affect the profitability and the ability to compete in the market. In the past we were doing a good job but as demand increased the production targets have exceeded the design capacity in some cases and the utilization and availability indicators are alerting. There is also the age of equipments which could be a factor too. I think our company should be looking seriously into asset

management to be able to define the maintenance requirements in the future; otherwise we may not be able to achieve targets and therefore strategies.

8. Do you have any thing to add about the G&C Line?

I think one thing to mention is that we did not have the experience and we were not aware enough to have the responsibility for development allocated to the experience people. Therefore, a group of inexperienced people were selected somehow as an ad hoc team for the G&C Line project. The technical support and development department was established late but after its establishment, it helped us make decisions about several matters such as the replacement cooling pipes in the heating furnace in flat mill and we still working with them to resolve several other matters. Perhaps if we had this department earlier we could have avoided some of the problem we had with G&C line.

Interview -14

14:30, 20th January, 2009

Participant-14 has bee the head of one of the important maintenance sections for a long time.

1. Can you describe how the introduction of HBI and G&C Line were initiated in 1997? And how did they impact the business performance and contributed to the organisational strategy?

I am not the person to ask about these projects because I was not in direct contact with the details of these. But what is generally realized in the company that the HBI is a very successful project and the *G&C Line* had many problems and resulted in big losses for the company.

2. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company?

In this section we basically execute the maintenance activities and from what I can see in your model, these maintenance related activities are the responsibility of the MP&C. We have been submitting all the information to them but unfortunately we are not getting any help from them to make the decision that allow us to achieve objectives.

3. What do you mean by these related activities?

I mean the analysis and evaluation of the performance of equipments which we have no time to look into but we do provide information on events and execution of work and also they have the information form the CMMS. For example, there are reoccurring breakdowns but they have not analysed this information or investigated why this is reoccurring.

4. How did you handle things like that before when the MP&C did not exist?

The MP&C department was introduced to handle these kinds of things that we were complaining to higher management to do some thing about it. But it seems that we are getting more headaches from this department rather than solutions. We use to depend on our experience to make decisions regarding the required maintenance without real review of all information but what ever seems rational by intuition as we remember pattern of events with some use of the CMMS.

5. Are you saying that in maintenance you have realized the need for such activities but you are not sure how the situation can be managed?

It is not that we did not know how to manage the situation, we have reported the need for the IT tools and the assistance of professionals and the monitoring technology but the company has decided to allocate this to a central department instead of letting every plant develop its maintenance department for the purpose. And I do not think this is working because activities such as performance monitoring and analysis require the experts or those with the maintenance and operation experience. It is logical to have central department to handle IT system and facilitate its use in the various plants but the monitoring and analysis should be done by those familiar with the equipments in the plant.

6. How about other activities in relation with production planning, operation or Technical support and development?

In this section we do not deal with production planning but the operation seems to be coordinating well with the PP&C department. On the other hand, I think the technical support and development is not doing its job right. It is acting just like a project management concentrating on new development projects with no attention to the development or innovation of the existing assets. I mean these IT requirements and condition monitoring technology and how they should be introduced is a task that requires study by technical support and development department but such task in our company is usually discussed by managers at different levels and decisions taken without real study to select the proper solution.

7. In your view, how all of these activities affect the strategy?

If these activities are not properly managed, then the maintenance practice will become totally breakdown maintenance and production targets will not be achieved. And I think achieving production targets is the key to success of any strategy.

Interview -15
12:30, 21th January, 2009

Participant-15 has been in many production and operation manager in one of the critical plants in the company.

1. In steel melt shop-1, what actions that you think were asset related and were taken for improvement toward achieving the organisational strategy?

Many things, such as the development into ladle furnace, the cooling and replacement of rollers in casting, the billets coding problem. And the quality of spare parts as a result of purchasing policy, the high planning targets that cannot be achieved based on current conditions, the quality of raw material and additions and many others. Some of these problems have been solved but could have been done a long time ago. There was also the project of transferring liquid steel between the two steel melt shops. We have also organized testing of samples of spares and materials so we can select what is best for our assets and operation conditions and indicate those that do not withstand conditions as the one we selected. But with current overloaded crew of operation and maintenance it is hard to get the practice reset to a better level. Also there was the development of the EAF refractory lining replacement and repair optimization models in 1998-99.

2. How initiatives were made about these projects or actions? And how did they impact the business performance and contributed to the organisational strategy?

We have been doing a lot of coordination with the technical support and development department to resolve some of the issues but all issues were reported to the technical support and development by managers in the steel melt shops. We have been reporting some of problems and issues for long time through the hierarchy to top management but we did not get any answer. But when the technical support and development department was established we were directed to report these sorts of issues to it. The technical support and development requested a lot of information from us and studied these issues and did the required analysis to resolve several issues. There were many issues analysed and resolved in coordination with the technical support and development department. For example, the development of the ladle furnace was a response to resolve the pure back problem that was reported to the technical support and development department. The replacement of the external cooling rolls by internal cooling rolls in the cooling bed in the continuous casting was a response to the scale formation problem due to difficulty in sustaining uniform thin layer cooling. The development of the transporting vehicle for sharing liquid steel between melt shops was a response to an idea made by steel melt shop manager that made into reality by the technical support and development department.

3. Can you tell me what triggered the need for developing the EAF refractory lining replacement repair optimization models and can you describe how the models were developed? And how did they impact the business performance and contributed to the organisational strategy?

The pressure toward lowering cost led to a tendency to reduce budgets for operation and maintenance in the steel melt shops. This created conflicts between operation or maintenance in the steel melt shops and those finance, accounting and purchasing departments. When we request from purchasing department to purchase lining material from a specific supplier we were told that our request conflicts with purchasing policy. The purchasing policy was to purchase based on our requested specifications of materials but their role is to find the cheapest supplier with the requested specification. We knew that there was a difference in the use but we did not know how to distinguish between the advantages and disadvantages of these materials from the different suppliers. At the time the technical support and development did not exist. We had realized that the best practice relative to our replacement and repair of lining need to be defined to support our argument. We contacted those suppliers of EAF furnace lining and repair material to provide us with the optimization indicators of replacement and repair practice. But these suppliers indicated that such indicators depend on the operating conditions, parameters and other context factors. They explained that some plants achieved high lining life while others operated at lower life because of various operation and other context factors. We had to initiate a research study on our own to develop decision support models for refractory lining practice. The aim was to contribute toward cost minimization and achieving competitive products unit cost. It was necessary to do the required research and analysis to determine the optimum practice. Our department did not have the expertise to do such analysis but made available all the required data for the research study. The matter was reported to the

technical support and development which allocated the work to one of our engineers to do the research study in conjunction with [IND-university]. The research study concentrated on EAF's lining replacement and repair optimization. The development of decision support models for refractory lining, it was meant to contribute toward cost minimization and achieving competitive product unit costs.

4. In reviewing the model presented in the sheets and illustration with it, give your view of the role of these activities in strategic changes and their fitness and need in your company? Or to what extent do these activities in the model exist in your company?

What you are representing as asset management and it is role in strategy making, can be easily understood from my experience in the refractory department. I gauss the refractory department can be considered part of the asset management or a very important system for managing EAFs, ladles and CMS because refractory is the most important part of these assets. Because the refractory department is dealing with only these specific assets, it easily recognized that these activities shown in your model are very essential such as monitoring the conditions, optimizing replacement cycles, measuring performance and so on. But even when these are done, there is a need for experts to carry analysis to clarify the best way of carrying activities such as maintenance, replacement or operation to achieve the best performance or the optimum practice. The refractory department did not have the appointed experts to do such analysis, so in many cases we did not know what is the best practice? or what is optimum?. For example, we were unable to convince top management that the cost reduction strategy or in particular for our department case the purchasing strategy of lower procurement cost of the same specification material is having a reverse impact on the production cost. We were only saying thing like it causes us a lot of stoppages, deterioration or defects in quality, but had no manpower or time to do any analysis to provide prove in terms of dollar value of the things we were saying.

5. What about your experience in production process of steel melt shop-1?

With respect to the production process as a whole in the steel melt shop-1, these concepts of asset management are not thought of in terms of all assets because nobody is assigned the responsibility of such activities. These decisions are arbitrarily taken by operation and maintenance because they do not have the structure and size that would allow them to make the right decisions. The situation has resulted in a disturbed practice; where operation people are too worried about achieving these high targets but experiencing many stoppages and the maintenance people are too busy handling unexpected breakdowns. At the end the production management is blamed for not achieving the targets which resulted in not providing the required input to these new rolling lines that have been introduced. It is good thing that this world financial crisis gave us a break, this may sound unusual but it reflect the relieve form high target achievement pressure. When making these expansions and developments in the final products, thoughts should have been given to expansion of the steel melt shops instead of overloading them.

I think these activities that have been highlighted under the concept of asset management in your model are very essential for our company to achieve the targets in the long run even though that they may require some upfront investment especially on these critical assets such as EAFs and on manpower upgrading or recruitment of experts. For example, the EAFs are very critical because all of the rolling plants depend on the output of the steel

melt shops, and are a consumption cost centre, it is very critical to keep the EAFs, ladles and casting machines (CMS) in good condition for operation and at the same time reduce the liquid steel or the billets, blooms and slabs production cost. I think defining the right way to manage these assets, has a very big impact on achieving production targets of other plants and therefore directly impact the strategy of the company. In fact, any change in the final products is limited by the capacity and quality of the liquid steel produced by melt shops. Hence the capability of the process in terms of humans and their utilization and care of EAF, CMSand other equipments (what you call assets) is fatal for achieving any strategic objectives and essential to consider for setting the strategic objectives as well.

6. How do you think the model can be applied or tailored for implementation in your company?

In the whole company, I do not know but on the steel melt shops level I think we need to introduce a department call it asset management or any other name but must have experts and do these activities that you illustrated in your model. If we have such thing we can know what our assets need in terms of the right maintenance, replacement, developments and can control their conditions for availability and maximum utilization. The department can provide the right analysis for decisions to be taken and work can be done on planned basis instead of reactive manner. Maybe these experienced maintenance people can fill this positions and train new people for maintenance execution tasks.

7. Why do you think the current maintenance department cannot be developed into an asset management department?

They are overloaded with breakdown maintenance, have no time for rethinking what to be done in terms of preventive maintenance or planned maintenance. The asset management department should be structured in terms of separate sections that should have no responsibility of the maintenance execution. These section can be taken from your as, for example maintenance planning, asset performance and condition monitoring, asset replacement and life cycle or analysis section. These section must design what to be done and how things be done such as maintenance, replacement, inspection or procurement or logistics. They also can report with evidence to other departments such as accounting, production planning or innovation and developments.

Interview -16
9:00, 22nd January, 2009

Participant-16 has an operations manager in on of the plants for a very long time.

1. In steel melt shop-2, what actions that you think were asset related and were taken for improvement toward achieving the organisational strategy?

Many actions were undertaken to enhance performance to result in lower overall cost and consequently serve toward achieving competitive products unit cost. Example of these include the study to optimize EAF refractory lining replacement during 1998-99, the introduction of ladle furnace in year 2001 and the replacement of external cooling rollers by internal cooling rollers in continuous casting in year 2001 as well. Also, there were many other actions that contributed to cost reduction and better output quality such as improving purchasing policy to enhance the quality of spare parts, the quality of raw material and additions to molten metal.

2. How initiatives were made about these projects or actions? And how did they impact the business performance and contributed to the organisational strategy?

Regarding the lining refractory replacement and repair optimization in 1997-98, we had a feeling that we were not doing the best actions but we had to establish the facts about it. There were the safety factors, the hesitation in taking the decision and the conflicts with purchasing on the best material to get. It was necessary to do the required research and analysis to determine the optimum practice. The study was done in coordination with [IND-university] involving engineers from the company. We were pleased that the study had proved with no doubt that the most expensive lining material in terms of purchasing is actually the cheapest in use or its use results in less lining life cycle cost. The study represented dollar value comparison between suppliers and showed the optimum replacement and repair cycle based on life cost analysis. It also gave us basis to estimate the lost value do to stoppages. As an output of the study, models for establishing the decision criteria regarding several operational and strategic management decisions were developed. The application of these models served in determining decision criteria relative to the optimum replacement cycle and hot repair sequence and cold repair limit based on life cycle cost analysis. Another outcome of the study is the dollar value comparison between suppliers. It also gave us basis to estimate the lost value do to stoppage time. Overall there was contribution from its application to increasing availability, reliability and utilization of EAF as well as lowering liquid steel unit cost that consequently resulted in lowering all final products unit cost.

Regarding ladle furnace in 2001, analysis for development was done by the technical support and development department in response to resolving the pure back problem. Coordination between technical support and development and steel melt shops resulted in studying the possible alternatives and adopting the ladle furnace solution. The solution was established in terms of acquisition and installation of a $17 million ladle furnace. The reason for introducing ladle furnaces was eliminating pour backs that cause waste or scraps, downtime or delays and energy losses. This increased process yield, utilization and helped reduce production cost by eliminating such losses. In my view this development was a dramatic push toward performance improvement. For example in one year the pour back reached about 40,000 tonnes in SMS2 alone. It is usually 50% less in SMS1due to the less complexity of steel grades produced but still a great loss.

The Technical support and development also worked with steel-melt shops and other relevant department on developing an automobile for carrying ready to cast liquid steel between the two steel-melt shops (SMS1 and SMS2). The development was done in-house by modifying the slag removal automobile. The transportation process was designed to take less than ten minutes which is the allowed duration for transporting the liquid steel. The transporting of liquid steel between SMS1 and SMS2 allows for supplying the shortage of liquid steel if there is a surplus in the other steel-melt shop. Such case is evident in practice due to the stoppage for repair or replacement of EAF lining and trend demand of output of either steel melt shop.

Another study by the Technical support and development department in coordination with the operation and maintenance departments of steel-melt shops proved that it was more

economical to use internal cooling rolls in the continuous casting process. The cost factors that made the difference were fewer stoppages for replacement, elimination of scales formation and less maintenance cost.

Interview -17
12:00, 23rd January, 2009

Participant-17 has been in many operation manager and head section positions in the company.

1. Can you tell me about how initiatives were made and decision taken to adopt the replacement external cooling rolls by internal cooling rolls in the continuous casting? And how did that impact the business performance and contributed to the organisational strategy?

These rolls we had before were externally cooled and we experienced either rolls damage due to uninformed cooling or scale problems due to high cooling water flow rate. We had to deal continuously with the balance to avoid these problems. Based on our reports, the technical support and development studied the problem and proved that cost can be reduced and losses can be avoided by replacing them with internal cooling rolls. These are very expensive compared to external cooling ones but they last much longer than external cooling ones. The external cooling rolls also require more frequent replacement or repair of worn ones. In addition to all of this, they result in problems that are caused by scales in the rolling mills.

2. Can you tell me about how initiatives were made and decision taken to adopt the ladle furnace? And how did that impact the business performance and contributed to the organisational strategy?

The investment in ladle furnace was proven to be worth it by the analysis done by the technical support and development department. Based on that, decision was made to adopt the ladle furnace that helped the operation process significantly. The ladle furnace helped us avoid pour backs by keeping the temperature as wanted and testing the liquid steel for specification and quality and making the addition of materials to obtain the required steel grade. It is hard to precisely control additions to the furnace and with normal ladles we are constrained by time to make the adjustment before the temperature drop to certain level. Pour backs affects the yield and impact on cost of liquid steel produced as well as lowering the productivity resulting in not achieving our production target.

Interview -18
10:00, 24th January, 2009

Participant-18 has been a manager of one of the important departmets for a very long time.

1. Can tell me about the importance of EAF refractory lining replacement and repair practice for A-Steel? And how does that impact the business performance and contributed to the organisational strategy?

Before talking about its replacement or repair, we should define it within its process in our company. The electric arc furnace (EAF) refractory lining is one of the most critical assets in the EAF-steel making process. In A-Steel, the steel melting process is maintained by six electric arc furnaces (EAF) each SMS has three EAFs. The life of the EAF lining is usually measured in term of liquid steel production or heats; each heat is 90 ton of liquid steel. The refractory lining of the EAF is composed of two layers of lining: the permanent lining and the working lining. The manufacturer recommended replacement of the permanent lining is after 5000 to 6000 heats. While, the manufacturers provided no specific data as to when a working lining layer should be replaced and advice that the working lining life is a function of the operating conditions which defer depending on many operation's factors. The working lining in the EAF interfaces with the melting metal, gases that causes interaction and erosion. Due to such conditions, the working lining requires repair and replacement at certain periods. There are two types of repair used in the EAF refractory lining: hot repair and cold repair. Cold repair is done by cooling down the furnace and then repairing damaged areas. On the other hand, hot repair is done while the furnace is hot by a combination of gunning and fettling. Gunning is used for hot spot on the walls and fettling is used for hearth. Actual Practice within A-Steel has revealed that depending on the operation conditions, the working lining life ranged from less than 200 to more than 500 heats; that is about 20,000 to 50,000 ton of liquid steel production.

2. How was the practice done in terms of replacement and repair? And why did you require the development of models to improve the practice or performance?

Due to safety factors, inspection and hot repair were required after every heat and the repair or replacement decision was judgmental depending on the inspector view of the conditions of the working lining. The replacement practice was carried this way until early 1997 when the furnaces availability became vital for achieving the ever increasing target of the annual production plans. According to the refractory department, at that stage the strategy was to utilize the working lining for as long as possible but there was the safety issue and later realized that repair cost can be very high for longer life. There was also two other issues: whether to use cold repair or replacement when the furnace is cooled down and which supplier's refractory is best to use, as the practice involved the use of 3 suppliers refractory sets on the furnaces. These issues required analysis and evaluation to decide on the best working lining replacement or repair strategy. Although the data was available, the refractory department was busy doing the operational work of repair and replacement and had no expert to do any analysis.

3. What triggered the thought of determining these optimum criteria for this lining practice?

Due to the demand of higher availability of furnaces and the interest to lower the unit cost of products, attention was focused on reducing the cost of steel making process in the steel melt shops because it is an upstream process that contributes to the unit cost of all products. When the refractory department was faced with such a challenge, the manager demanded from the production director to provide means to undertake several studies for such purpose. Neither the operation manager nor the refractory manager was ready to take the responsibility of delaying the replacement or reducing the repair because the matter involved a safety risk and it was not clear how the practice could be optimized.

Consequently, the production moved the issue to the technical support and development department which coordinated with us and sent issue to the [IND-university] and a joint study was undertaken involving some of our engineers. The study was based on the total life cycle cost which included replacement verses repair and stoppage cost taken in consideration the worst and best operation conditions. The results were:

5. Defining the optimum replacement of the lining to be within a specific range (e.g. 300 to 350 heats for one lining supplier material). This showed that it was more costly to operate with lining over this life range with the amount of repair done.
6. Defining the limit for using cold repair based on remaining life estimation; that is at what age of life is cold repair economical to use.
7. Defining the optimum range of using hot repair as a function of the lining life; that is when to start hot repair, periods of doing it and what amount of repair should be used at each period.
8. Defining the best supplier of refractory based on the life cycle cost per unit produced e.g. per heat or per ton of liquid steel.

Furthermore, the study served in uncovering the wrong decision regarding the lining acquisition strategy. The acquisition strategy of the company at first was based on maintaining continuous supply of the lining by purchasing an equal number of sets from three main suppliers. There was a difference in the purchasing cost of the lining set between these three main suppliers. In response to the cost reduction policy, a decision was made to purchase lining sets from one supplier (cheapest). The decision was based on only purchasing cost and not comparing the life cycle cost of each. The consideration of the repair cost (hot and cold repair) associated with each supplier set was hidden because the furnaces were working with the different sets simultaneously and there was no body responsible for doing the total life cycle cost analysis of the different lining sets separately at the time. Data or information was available for each supplier set but no analysis was done.

4. How did these models or their use contributed to the business performance and organisational strategy?

The finding of the study showed that the annual refractory lining life cycle cost increases by a percentage ranging from 10 to 15%, (2,000,000 ELD) as a result of changing the purchasing strategy to the cheapest supplier of the lining sets. The increase of cost is mainly the contribution from lost production due to stoppages and delays and not really much from refractory lining capital cost or repair material cost. Before the development of these models there was a conflict with the purchasing department regarding the purchasing policies of lining and repair materials. The decision process within the purchasing department follows the overall cost reduction strategy and therefore purchase the lining and repair material with our specification but selects the cheapest supplier. The purchasing department requests recommendation from our refractory and other departments before making purchasing decision. However, in the case of lining purchases their reply to our request for purchasing the expensive refractory lining was that we lacked the reasoning for purchasing the expensive lining.

Interview -19
12:00, 25th January, 2009

Participant-19 has been a manager of one of the most important maintenance section in the company.

1. How does this department contribute to the business performance and contributed to the organisational strategy?

I want assure you that the maintenance planning and control department in our company has an influential impact on the availability and utilization of equipments in the production lines in the various plants.

I should give a view of how maintenance has been managed and the organisational structure of its management. Since 1989; the starting of operation, maintenance was carried through separate departments and section in each plant. In year 2000, this maintenance planning and control department was establish based on the need for central supervision that can assist in organizing maintenance work and in particular the shutdown maintenance and plan with coordination with production planning to avoid production stoppages and major delays.
Our department is central in planning by having offices in each plant with 8 or more planners and supervisors. In coordination with operation in each plant they participate in meetings, collect information, report to us and schedule maintenance work according to our plans which are made in coordination with production planning and control department. They also report to us on the spare parts requirements and logistics to set scheduled maintenance and keep track of spares wit the inventory department. They also provide us with information to organize and plan maintenance activities for shutdown which is usually done every 16 month. We use CMMS which is useful in carrying out maintenance activities but its information has not been utilized to serve the analysis for strategic decisions.

The control section of this department in my view is still not fulfilling the purpose of providing indicators on each asset that can be used to guide in managing the maintenance activities according to the most appropriate policy. However, the section collects information and establishes some performance indicators in periodic reports. These may include indicators such as downtime, repair duration and spares consumption for each production line but not equipment wise.

2. In your view, does this department play any role in the strategy making?

Well maintenance is an important activity in terms of the care of the assets and planning and control are the means to organize activities for achieving production goals. I think its relation to strategy is dependent on the guaranteeing the required reliability and availability for the optimum utilization of the equipments. These provide the ability for achieving the goals of the company and keeping equipments in good conditions. I think, in this respect, this department can provide information and analysis that can help in strategic decisions. For example, if the right information and analysis are provided on equipments, then these can facilitate the way to choose the proper maintenance strategy for each equipment e.g. preventive, breakdown and etc or on making the repair/replace decisions or the replacements and repair periods of equipments.

3. How well is your department doing in playing such role?

We still have a long way to go for establishing the right practice. In the time being we are relying on planned maintenance using CMMS and preventive maintenance to provide good results in terms of production lines availability; however, we seem to spend a lot on preventive maintenance but still having faults causing operation stoppages and delays. We rely on manufacturers recommendations but because of the huge number of different equipments and the difference in replacement and repair time of the parts of these, we have difficulty in maintaining the right schedule for maintenance. Further more; we have difficulty on deciding the shutdown intervals and what should be done during the shutdown. In every shutdown maintenance done, there is something overlooked that causes breakdown. It was always unclear, in terms of what should be done and who is responsible for taking the decision for example on replacing some thing before its due time or repairing it and delaying its replacement to the next shutdown or even deciding on extending the shutdown intervals.

4. So, how your decisions are taken putting in mind the strategic goals?

The decisions are usually taken based on the production plans; satisfy the production plans while taking some risks of breakdowns. To prepare the maintenance plans we consult with all the maintenance and operation departments of all plants through our offices in these plants and plan to avoid conflicts with production achievement plans.

5. How well is the task of these decisions handled by this department?

It is hard, we lack the fully automated information system to provide information or database assist in making decisions.

6. How about the CMMS, isn't used to facilitate such data?

It is used but we are updating now for utilizing its data base for such purpose. It was adopted in 1991 and it took a long time to feed data into it. In fact, the data feed in some plant has not been completed yet. We also suspect incorrect data feed in the system. It is being updated now and it needs to be integrated with the appropriate IT system to facilitate its data base for our purpose. I think we need such system to provide information to all concerned department such as operation, planning, inventory and maintenance.

7. In cases where major changes in production or quality goals took place, what actions or measures did this department take? Or what changes in maintenance were required?

The main focus in such cases was on preventive maintenance. But preventive maintenance alone was not enough to handle the change requirement. We also realize that equipments need more care, so we increased repair, replacement items during shutdown and more extensive overhauling. I think we need to be fully aware of the various impact of such change as a function of time and schedule the required maintenance activities accordingly to avoid breakdown maintenance. But this has resulted in more maintenance cost .This why our company is investing now in consulting contracts for updating CMMS.

8. Do you do any condition monitoring or performance measurements of the individual assets and the life management of these assets?

It is only done on critical equipments where safety is a major factor such as the furnaces lining. But the practice of monitoring the conditions to trigger the need for maintenance is not present in our company. We mostly do time based maintenance, except for the inspections techniques which are part of the preventive maintenance.

9. As a final comment, what do you think are the important factors that your department should consider to contribute to the strategic success of the company?

From my view, I think we need to do some criticality analysis and define priority of critical equipments to closely monitor them for availability and reliability for enhancing the overall utilization. We also need to know our weakness, losses and high cost and manage accordingly. But we are in need of the right information system first to assist in such task.

Interview -20

11:00, 26th January, 2009

Participant-20 has been a manager of many departments with long experience with the company.

1. In relation to the management of assets, how did this department contribute to the business performance and the organisational strategy?

The role of this department in relation to the concept of your model is providing the proper IT or information system to allow the good management by having the right information in the proper form for operation or strategic purpose. In the early establishment of the company the manpower and computer system project with (IBM main frame) was not implemented because embargo on our country to have such technology due to political reasons. Due to that the company had no choice but to start manually and build and develop its activityal networks and programs for the purpose. So, there were and still are constrains on us to have the proper IT systems which are in my view the most critical assets to have for success nowadays. From this perspective asset management (IT) is a limiting factor for strategic change or transformation. That was the background of the problem; nowadays we have realized that it is a must to integrate our systems in terms of information to facilitate the proper action from these different systems such as operation, maintenance, marketing, finance and so on. The company is now in the early stage of implementing ERP as recommended the consultant evaluation of our situation. They have also recommended the upgrading of our CMMS to facilitate better utilization for our objectives. They have also recommended the implementation of TPM to minimize our process losses. I think these are related to what you are presenting as AM.

2. In your view, does this department play any role in the strategy making?

I was in Austria, Lens to get some views of Vosta Alpine working systems, as a training tour in preparation for establishing the MP&C department. Interestingly, they had a system called ‘investment and Technical support and development in which they where doing a good job on the performance measurement and analysis for providing the development alternatives for strategic decision. These reflect these elements in your model and the need in this company to have these elements in place. In our case, I think we need to introduce a system that is a new department (call it strategic planning or strategic asset management) to handle these activities denoted in your model and use the ERP as a tool for managing the relationships and other appropriate tools for analysis and provide clear basis for strategic decision making. However, these performance measurement, condition monitoring and reliability monitoring activities should be established as sections in each maintenance

department depending on the criticality of the assets to provide good indicators for analysis in the strategic asset management or planning.

3. How well is your department doing in playing such role?

My previous experience in the technical affair division showed me that the incomplete coordination between storing and material control department and the purchasing department and the effect on the maintenance and operation is due to the lack of proper integrated information system. The point is that there was and still is a real lack of information system. Also, the application of TPM on one of the plant in this company showed that it could change the way we manage our assets. It works on overcoming barriers and lead to the team work if culture permit. Even our company has declared adopting TPM, it is not getting any where and I think that is because our systems need to be restructured to include an integrated information system.

Interview -21A and 21B

10:00, 27th January, 2009

Participant-21a and 21b have been in many head section positions in one of the important departments in the company.

1. In relation to the management of assets, how did this department contribute to the business performance and the organisational strategy?

We can only discuss things from the purchasing point view. In relation to your model, the purchasing department as a system deals with two types of relationships: the relationships with suppliers and relationships with various departments at the various levels inside our company. We do procurement of any thing needed by the company from assets, their spares and materials and the input materials for operation to the administrative needs and so on.

2. What departments do you deal with inside the company? And how do you make your decisions?

In doing our tasks we deal mainly with the inventory department which issues all orders and we obtain technical opinions and any additional specification or information from end user to help us make certain decisions. For matters that exceed certain amount of value (dollars), we have a committee that involves experienced members from our company and deals with these matters as strategic decisions and get approval from chief executive committee. We depend mainly on our experience in making decisions and also constrained by certain policies of the company. For example, if the technical opinion from end user department did not provide prove of his preference in terms of dinars savings, damage or safety threat, our policy will set for the lower purchasing price of any thing ordered. Unfortunately, most technical opinion lack evidence or prove of their preference.

3. How do you maintain your relation with suppliers and how do you select one over the other when purchasing?

In relation to suppliers, we have a register of all potential suppliers that we may contact. We make a list of our preferred suppliers of items or materials. We also continuously revaluate these suppliers and update our order of preference. We have different policies depending on the material or spare. Usually we keep purchasing supplies from more than

one supplier and set percentage of purchase for each depending on certain factors of our relations with suppliers.

4. Do you base your decision on performance analysis or just specification and cost of items you purchase?

In general we deal with specification and purchasing cost because technical opinions are not usually submitted with clear evidence. However, there are cases where performance indicators or analysis provided basis for our decision. If evidence of cost saving by the technical opinion from end user in terms of use in operation is provided then we have to consider that in the decision process. For example, there was evidence provided to us that certain type of tiers of slap carriers last much longer than others. Another example is information provided on the life cycle cost of refractory sets for EAF. There is also some evidence in reports on some spares that caused problems. But even those were performance indicators were not really done by end user but based on research studies done by technical support and development or individuals. The end users have not been able to provide us with good information to use for decision such as comparison of different spares in use with numbers or a pattern of indication of failure of certain item or the like. Therefore, we need to have people who can do analysis of things and provide indicators with evidence or clear criteria for making decisions. Maybe the technical support and development department can do this.

5. Is your information system directly linked to other systems such inventory and finance?

No, each of these is developed separately and the links are usually maintained manually by paper work. We are now toward agreement to get SAP which should provide us integration with others.

Interview -22

15:00, 27th January, 2009

Participant-22 has been in many manager positions in the company.

1. In relation to the management of assets, how did this department contribute to the business performance and the organisational strategy?

In our company when we started installation more than 30 years ago, we had no experience and therefore we did not take consideration of so many factors that resulted in damaging our buildings, steel structures and infrastructure of the plants. Now, we are putting so mush capital into repairs and replacements of so many things. This could have been avoided if we had planned the sort of preventive action at the start. For example, the selection of structure or building materials could have been selected to resist corrosion in many situations or the cathode protection method could have been used with some infrastructure. These are strategic decisions which could make a lot of difference if they were considered at the design or installation stage. As a result the maintenance cost is very high now and in many situations such as leakages in pipes the consequences may be interrupt operation and cause damage of other things. Inspection some times is not easy or possible and the risks of not replacing things can catastrophe. Therefore, certainly asset management has a gig role in strategy development and implementation in my view.

We use to have a department called the projects departments that supervise the implementation of various projects but we had no experience that could have assisted us in altering those contracts for better implementation and we depended on consultants who are not here today to see the results of some of their advices. Therefore, I think we should have those activities in your model done in our Technical support and development department. I know the Technical support and development is not as it should be but emphasis on restructuring it for this purpose is essential for our company to make sure that any future strategies are built on good basis.

Interview -23

11:30, 28th January, 2009

Participant-23 has been a manager in the company for a long time.

1. In relation to the management of assets, how did this department contribute to the business performance and the organisational strategy?

This department coordinates with all departments in the company to get information for budget planning. For example, getting the production plan, raw material plan, maintenance plan, and spare parts plan and so on. Then it studies previous budgets, financial capability of the company and decide on the next year budgets. The department also determines the unit cost of all products, annual returns and profitability.

2. How investment initiatives are developed and decisions are made in your company?

I am not aware of any formal way of making initiatives for investment projects. However, initiatives or decisions for investment are usually dealt with by the chief executive committee. Proposals are usually developed and sent to the ministry of industry if funding is required. Feasibility studies are usually done by consultants.

3. In relation to the management of assets, what activities are done by the asset accounting department or section? Does it have full data on these assets such as design, condition and maintenance data?

It is simply an asset register holding account of all assets and their depreciation and face book value. It lacks the information system that can allow it to collect such details on the conditions or the cost data of these assets. It only serves the accounting purposes and its connection with departments in the plants is lacking or not existing.

4. In relation to the management of assets, does the department play a role in controlling cost such as the cost of operation or maintenance?

We prepare an annual report that present all cost elements of all the plants but it represent the previous year costs. It is usually used as basis for accounting to plan next year budget.

Interview -24

14:00, 28th January, 2009

Participant-24 had been a manager in the company and has experience in maintenance with the company and working with the ministry of industry.

1. From your experience in A-Steel and in relation to the management of assets, can you tell us how AM can contribute to the business performance and the organisational strategy?

From my experience in the maintenance department of the hot rolling mill, I think one of the important things for asset management is to have the ability to do the analysis required for making the decision regarding several things:

a. Select the appropriate maintenance strategy for the need. That is usually a mix of different types of maintenance policies or types for the different type of assets.
b. Determining the criticality of assets to the overall performance (availability, productivity, utilization, quality and the like).
c. Having clear criteria a bout replacement and overhauling periods of assets or spars. For example, when we were dealing with the repair verses replacement of skid-pipes in the furnace in the hot mill we had no clear basis for deciding on repair or replacement of these pipes. Until a study in coordination with the technical support and development provided the optimum criteria for the repair verses replacement practice.
d. Having the right information and inventory system to guarantee the need of spares, tool and materials when needed.
e. Having the right maintenance plan and program for each asset that can guarantee the required availability of assets. Including inspection, monitoring, scheduling, work orders, and repair requirement and so on.
f. Having the right training programs for maintenance.
g. Abiding by the safety measures.

By having these in place the adequate performance for the production targets can be assured to fit the business plans and the strategic objectives.