Development of performance measurement systems for core plants

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Abhijna Neramballi

Sujay Suresh Babu
Abstract

Since the dawn of globalization, manufacturing companies around the world have been expanding their global footprint to stay competitive. International manufacturing network of a company consists of plants with different roles and responsibilities spread across different locations around the world. Due to this increasing geographical dispersion and competitiveness, effective co-ordination of these plants has become a priority along with achieving effective and efficient operations. This led to the development of the Core plant role. Core plants are the manufacturing plants that aims to achieve competitive and effective production, generate and transfer knowledge, while leading and coordinating the other plants within the network.

However, the core plant role varies significantly across companies and academia due to a lack of a common understanding regarding its responsibilities and objectives. Furthermore, the performance of core plants are being measured with the same generic KPIs as the other plants, even though their roles and responsibilities varies significantly. As a result, it has become difficult to measure their true performance and contribution of value to the network. The purpose of this thesis is to contribute to the development of comprehensive performance measurement system that collectively measures the true performance and value of the core plant role to its international manufacturing network. Initially, the thesis investigates and bridges the mentioned knowledge gap with a two-tier literature review, before establishing their validity and relative importance in empirical context through survey. The survey approach is also utilized to assess the current situation of performance measurement among core plants of different manufacturing companies.

The findings suggest that ‘attaining operational excellence’ has the highest strategic importance but this responsibility only extends to individual plant level not the network level. The core plant, network level responsibility ‘knowledge generation’ has the highest relative strategic importance and ‘Capability development’ has the lowest relative strategic importance. The findings also reveal that the performance measurement systems of network level core plant responsibilities are either poorly developed or non-existent. The thesis concludes with a suggestion of a conceptual framework that provides the guidelines to develop a comprehensive performance measurement system for core plants. The findings and suggestions are of practical relevance to the top management of international manufacturing companies and academia for conducting future research.

Keywords
International manufacturing networks, core plants, performance measurement, network targets, knowledge generation, knowledge transfer, operational excellence, cost effectiveness.
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1 Introduction

This chapter will introduce the concept of the thesis with a brief background, problem description, purpose and research questions, before concluding with the delimitations.

1.1 Background

Globalization has seen an increasing number of manufacturing companies expanding their network across the world to explore new opportunities for efficient and effective production (Feldmann et al., 2013). This trend has led to intense outsourcing, offshoring and expansion into new international markets. The production network of a typical international manufacturing company today consists of plants dispersed around the globe, each of them under pressure to coordinate their operations with each other and the involved supply chains, which are becoming more global and fragmented (Ferdows et al., 2016). Co-ordination of international operations in networks can improve cost and delivery performances, while also enhancing the learning from the experiences of partners within the network (Flaherty, 1996; Rudberg & West, 2008). However, it turns more difficult as the geographical dispersion of the company’s network increases (Rudberg & West, 2008). Due to this increasing trend of globalisation, focus of research on the organizational structure of multi-national companies has shifted from a narrow perspective of headquarters-subsidiaries relationships to a more holistic network perspective (Veerecke, Van Dierdonck & De Meyer, 2006).

To attain operational excellence and competitive production within this ever-expanding global network, the concept of ‘core plants’ was conceived, which has significantly evolved both in literature and in industrial context over the years. It introduces the possibilities of creating strategic advantages and to secure production within the country (Bruch et al., 2016).

One of the widely used description of the core plant concept in literature is termed as ‘lead plants’, which is considered as a global hub for product and process knowledge. The ‘lead plant’ role is one of the six strategic roles of the different plants in the network, categorized based on two factors: site competence and strategic reason for the site. It has a high degree of site competence and easy access to skills and knowledge (Ferdows, 1997b). Strategic objectives of these plants, involves in the creation of new products, processes and technologies for the company. It interacts with the research and development (R&D) department aiding in the development of new products, processes and prototypes, with the main objective being the generation and transfer of knowledge, within the network of the company (Deflorin et al., 2012; Ferdows, 1997b; Simon et al., 2008).

Enright and Subramanian (2007) describe the concept of ‘leading subsidiary’ which aims to create substantive capabilities for the international network of the company, through R&D and managerial activities, while also applying those capabilities in production, marketing, sales and other similar activities.
Introduction

The core plant has also been described as ‘main plants’ that assumes the responsibility of industrializing new products, which includes establishing and securing efficient manufacturing processes (Bengtsson, Niss & Von Haartman., 2010). In order to increase manufacturing capacity, the verified manufacturing processes are then replicated among the other plants in the network (Bengtsson et al., 2010).

To summarize the various concepts found across literature, core plants can be described as centres of excellence, involved in production development or industrialization of new products being introduced from R&D and responsible for the diffusion of knowledge, within the global manufacturing network of the company. Thus, the core plant plays a major role within the global network of international companies and has high strategic importance. If the performance, strategic importance and contribution of value by the core plants to the manufacturing network is high, they are unlikely to be closed down or offshored, even in this highly competitive global market. As a result, manufacturing plants strive to evolve into the core plant role and it is necessary to monitor their progress (Bruch et al., 2016; Meijboom & Voordijk, 2003).

Fusco and Spring (2003) suggest that role or strategies of core plants are continuously evolving, leading to a lack of common understanding regarding its contribution of value to the manufacturing network. Also, there is a significant knowledge gap regarding the development of core plant responsibilities and performance measurement.

1.2 Problem description

Multi-national companies introduce core plants which are expected to lead, guide and impart knowledge to the rest of the plants in the network (Bengtsson et al., 2010). However, the extent to which the companies can smoothly oversee these responsibilities within the network depends on the company’s ability to create, transfer and apply relevant knowledge (Tsai, 2001). This process requires the establishment of relevant manufacturing strategies, which involves in the development of strategic objectives. These strategic objectives can serve as the goals that will guide the management actions in the company. Effective action plans are designed to achieve these goals and when achieved, manufacturing competences are fostered (Feldmann & Olhager, 2013; Koufteros et al., 2002). To measure how well these plants are achieving the set strategic objectives, it is important to establish relevant Key Performance Indicators (KPIs). KPIs represent “a set of measures (quantity that directly records an observable value) that focuses on certain organizational aspects, which are deemed to be highly critical for the current and future success of the organization” (Woolliscroft, P et al., 2013). These sets of measures can provide important information regarding organizational performance enabling both top management and the other stakeholders to monitor the fulfilment of the set strategic objectives. However, the performance of the core plants is measured with the same generic KPIs that are used by the other subsidiary plants and there are few specific KPIs to measure core plant responsibilities. This proves to be a major disadvantage, as it is difficult to measure the true performance of the core plants and the value it contributes to the network, since the strategic objectives of plants with different roles in the network varies significantly (Bengtsson et al., 2010; Bruch et al., 2016; Deflorin et al., 2012;
Ferdows, 1997b; Vereecke & Van Dierdonck, 2002). As a result, the companies lack the support in the design and management of core plants, and also to utilise the strategic advantages it entails. Also as described earlier, it will be difficult for the top management of the multi-national companies to effectively monitor the progress and performance of established or evolving core plants. This reflection of progress and performance can motivate the top management to invest in the required areas in an effective manner. Hence, it is important to establish the appropriate KPIs that can effectively reflect the performance of the plants and subsequently its contribution of value in the network, ensuring that it lives up to the core plant role. KPIs are also critical for manufacturing operation management and continuous improvement processes (CI) in the plant level (Kang et al., 2016).

The importance of effective management of global manufacturing network for manufacturing companies is increasing, since it has a significant impact on their future performance and profitability (Bartlett and Ghoshal, 1989; Ferdows, 1997a; Hayter, 1997). The core plant role, offers these companies the opportunity to effectively co-ordinate their networks. However, there is an evident knowledge gap, regarding the core plant responsibilities, corresponding strategic objectives and subsequently the development of appropriate KPIs to effectively measure the performance and their value in the network. This leaves the companies with a lack of support in the design and management of core plants within the network.

1.3 Purpose and research questions

This thesis investigates and establishes the responsibilities, strategic objectives and subsequently the list of KPIs to reflect the performance of the core plant role within the networks of international manufacturing companies. The purpose of this research is to contribute to the development of a comprehensive Performance Measurement System (PMS) that can collectively monitor the progress and value of the core plant role.

The following research questions will be answered.

1. What are the important core plant responsibilities and corresponding strategic objectives?
2. What is the current situation of performance measurement of the identified core plant responsibilities and the corresponding strategic objectives?

By performing this research, a common understanding of the core plant role will be established, the current state of its performance measurement will be investigated and the guidelines to develop comprehensive PMS will be suggested. The results will be useful to both industries and academia to effectively design, develop and manage the core plant role within the global networks of manufacturing companies.

1.4 Delimitations

This study will be delimited to the internal network of multi-national manufacturing companies based in Sweden. This study will not extend to the external networks or suppliers of the involved companies. The results of this study can be generalized to the core plants of manufacturing companies with global networks.
1.5 Disposition

This section will outline and briefly describe the various chapters of the thesis.

Chapter 2 – Theoretical background
This chapter will introduce the various concepts found across different literature, which will be used to establish the theoretical background of this thesis work.

Chapter 3 – Method and Implementation
This chapter will describe the research methods and their implementation processes undertaken in the thesis work. It includes the research design, research approaches and implementation, research data analysis process and research quality appraisal.

Chapter 4 – Theoretical findings
This chapter will present the relevant theoretical findings that address the research questions.

Chapter 5 – Empirical findings and analysis
This chapter will present the empirical findings and analyses that fulfils the research purpose and addresses the research questions.

Chapter 6 – Discussions and Conclusions
This chapter will present the overview of the thesis, answers to the research questions, a conceptual framework, critical valuations and discussions of the thesis work, before the concluding remarks.
2 Theoretical background

This chapter introduces the theoretical background used in the thesis. Figure 1 visualizes the structure of the theoretical concepts and their relationships.

Initially in section 2.1, literatures regarding the need, conception and development of international manufacturing networks (IMN) are presented. In section 2.2, the descriptions of different types of manufacturing plants and their roles within IMN are presented. In the sub-section 2.2.1, literatures regarding the relationship and interaction between these plants are established. Literatures linking manufacturing strategies of IMN, network targets and plant capabilities are presented in section 2.3. In sub-sections 2.3.1 and 2.3.2, analysis in literature regarding strategic objectives and capabilities of IMN, on both plant and network level is presented. In section 2.4, literatures regarding manufacturing plant types and roles are narrowed down to the ones similar to the core plant role. An unified definition of the core plant role is established and its responsibilities are highlighted in section 2.5, based on the previous section. The theoretical background is concluded with the definition and literature regarding KPIs in section 2.6. The clouds in figure 1, represent the various knowledge gaps in focus, which will eventually be bridged by this thesis work.
2.1 Internationalization of manufacturing networks

Manufacturing has been turning more international since the 1980s as it is the single largest type of direct foreign investment in most countries (Cheng, Farooq & Johansen, 2011; Ferdows, 1997a). This increasing trend of manufacturing companies expanding their global manufacturing footprint is to find new ways for efficient and effective production (Feldmann et al., 2013). Due to the constantly increasing international trade and direct foreign investment, globalization of markets has increased, leading to the widespread restructuring of manufacturing networks (Cheng, Farooq & Johansen, 2015). Manufacturing networks can be considered as a collective body of manufacturing plants dispersed over various locations and a plant can be considered as a basic construct of the network (Cheng et al., 2011).

Figure 2. Framework describing internationalization process of manufacturing companies (Ferdows, 1997a; Reiner et al., 2008)

Figure 2 is a modified version of a conceptual framework by Reiner et al. (2008), and is also inspired by the work of Ferdows (1997a). It explores and explains the process of internationalization of manufacturing companies, based in Central Europe. It can be used to explain the strategic reasons for manufacturing companies to internationalize, decision variables relevant to the process of internationalization and also the situational factors affecting the decision variables. The reasons for internationalizing, has been
considered as a closed loop cycle since it is difficult to differentiate the initial influencing reasons for internationalization between market scenario or operation & resources. Four different situational factors that influence the decision variables has been described in the framework, including entry mode, product/process types or location of internationalization. The first factor has been described as ‘market know-how’ which includes factors such as access to customers, market risks, competition, market size and potential. The second factor has been described as ‘Technical know-how’ of products and manufacturing processes. The third factor has been described as the distance between headquarters and potential new plants. The final factor has been described as pre-existing customer-supplier network (Ferdows, 1997a; Reiner et al., 2008).

As a result of removal of trade barriers, emergence of new generations of communication and transportation technology, multi-national companies have attempted to control their geographically dispersed plants by coordinating them with a synergic network (Shi & Gregory, 1998; Cheng et al., 2015). Companies are operating in a complex environment and due to internationalization of the competition, importance of managing integrated international network is increasing (Vereecke & Van Dierdonck, 2002). Lack of vision and appropriate strategies among companies to internationalize, can lead to ineffective management of international operations (Shi & Gregory, 1998). Due to these advancements, companies have been focusing on the management of their international manufacturing networks, as it can have a significant impact on their profitability and future performance (Bartlett & Ghoshal, 1989; Hayter, 1997; Ferdows, 1997a). As a result, boundaries of manufacturing systems have adapted and extended from the localised factories to various types of international and/or inter-firm manufacturing networks. Intra-firm manufacturing networks are said to consist of independent plants belonging to the same firm (Rudberg & West, 2008).

Since, international manufacturing networks are described to be geographically dispersed, there are two levels of analysis in literature regarding the co-ordinated network of plants owned by one company, network and plant level (Cheng et al., 2015).

2.2 Plant roles within international manufacturing networks

Manufacturing plants can be considered as the ‘fundamental building blocks’ of an intra-company network, among which each plant offers different advantages and capabilities, which in turn defines its role in the network (Vereecke et al., 2006; Christodoulou et al., 2007). Various literatures classifies the different manufacturing plants based on their distinct characteristics and capabilities (Ferdows, 1997b; Vereecke & Van Dierdonck, 2002; Maritan et al., 2004; Meijboom & Vos, 2004; Vereecke et al., 2006; Feldmann & Olhager, 2013). However, the literature offer a narrow perspective on individual plant roles within the network, neglecting the interdependencies between other networks (Thomas et al., 2015). Recent research in the area of operations management, has attempted to link plant roles with a network level approach, as manufacturing plants cannot be managed in isolation (Bartlett & Ghoshal, 1989; Shi & Gregory, 1998; Colotla et al., 2003; Miltenburg, 2005, 2009; Feldmann et al., 2010; Lang et al., 2014; Thomas et al., 2015).
Theoretical background

Manufacturing plants require distinct capabilities and core competences, in order to effectively achieve the strategic objectives and competitive priorities on both plant and network level (Prahalad & Hamel, 1990; Slack & Lewis, 2002; Colotla et al., 2003).

Bartlett and Ghoshal (1989) present a model that distinguishes four different strategic roles of manufacturing plants of an international company, within its network: the implementer, the black hole, the contributor and the strategic leader. Plants with Implementer role have low levels of strategic importance and competence within the network. Their strategic objective is the maintenance of customer demands with the production and delivery of products. Black hole plants are strategically important but have levels of competence within the network. The role of these plants is to explore new markets, analyse customers and competitors. Contributor plants have low strategic importance but high levels of local resources and capabilities. Strategic leaders have high levels of strategic importance, competence and capabilities within the network. These plants coordinate the entire network, while executing the company’s international manufacturing strategies (Bartlett and Ghoshal, 1989). Effective network co-ordination can improve cost and delivery performance, while also enhancing the learning experiences within the network (Flaherty, 1996).

![Diagram](image)

Figure 3. Roles of foreign factories by Ferdows (1997b)

Ferdows (1997) identifies 6 different plant roles using two dimensions: strategic reason for site location and site competence. The 6 plant roles are termed as offshore, outpost, server, source, lead, and contributors. The levels of site competence and strategic reasons for the different sites are illustrated in the following figure 3.

Lead factory is assumed to hold the ultimate role as it serves as the global hub for product or process knowledge, within the global manufacturing network of the company (Ferdows, 1997b). Ferdows also states that the strategic roles of different plants must evolve towards the lead role, with the aim of increasing the site competence and capabilities, actively adding value to the network. Otherwise, the less successful plants might be under risk of disappearing off the map, as companies might attempt to increase their thriftiness ability, by increasing the degree of concentration of production to few plants in the network (De Meyer & Vereecke, 1996). This model has earned wide spread
recognition in both current and past research, as it has been empirically tested and has also formed the basis for many studies (Vereecke & Van Dierdonck, 2002; Fusco & Spring, 2003; Meijboom and Voordijk, 2003; Meijboom and Vos, 2004; Maritan et al., 2004; Feldmann et al., 2009; Deflorin et al., 2012; Feldmann and Olhager, 2013). Other studies on plant roles has also been performed, which offer insight on different roles of manufacturing plants within the network (Vokurka & Davis, 2004; Vereecke et al., 2006).

2.2.1 Relationship between plants with different roles
Bartlett and Ghoshal (1989) describe four different types of relationship between different plants: information flow, flow of physical goods, people/work force and financial resources. Two types of information flows have been identified: administrative information flows and knowledge flows. Manufacturing administrative information flow includes information regarding production plans, inventory levels, purchasing requirements, forecasts etc. These mainly depend on the degree of centralization of manufacturing in the network. Knowledge flow involves in the transfer of information regarding product or process development and innovation throughout the network (Gupta & Govindarajan, 1991, Vereecke et al., 2006). Three types of innovation flow have been studied in literature: development and introduction of new product, development and introduction of new processes, and implementation of new management systems (Ghoshal & Bartlett, 1988). Flow of people is regarding the movement of employees between the different plants of the network (Vereecke et al., 2006).

The way these relationships are managed, can be described in terms of network configuration and network co-ordination. Network configuration involves in the allocation of plant locations and inter-plant resource distribution, along the value chain of the network. Network co-ordination refers to process of management of networks, to integrate the different plants in order to achieve the networks strategic objectives. It concerns in achieving effective and efficient global production plans, transfer and diffusion of knowledge within the network (Cheng et al., 2011).

2.3 Manufacturing strategies of international networks
Manufacturing strategy is regarded as the link between a network’s external environment and its internal objectives, since it aims to align the company’s resources and capabilities with market requirements to achieve competitive advantage (Slack & Lewis, 2002). Strategy development is the process of co-ordinating manufacturing capabilities with the business strategy of the company through a formal planning process (Skinner, 1996). It is necessary for companies to develop manufacturing strategic objectives, as it is a measurable requirement for success since it provides competitive advantages and support to higher level corporate plans (Maruchek, A et al., 1990). Strategic capabilities and the respective objectives of a company, is its ability to renew, increase, and adapt its core competencies over a certain period of time, reflecting the company’s potential main competencies (Teece et al., 1997; Shi & Gregory, 1998).
Theoretical background

When extended to an international manufacturing network level, they can be categorised into resource accessibility, thriftiness ability (Economies of scale and scope), manufacturing mobility and learning ability and is explained in section 4.1 (Ferdows, 1989; Dunning, 1994).

![Diagram of Manufacturing Strategy and Network Targets](image)

Resource accessibility and thriftiness ability can directly decide the effectiveness of network performance. However, learning ability and mobility reflect long-term capabilities of network restructuring (Shi & Gregory, 1998; Thomas et al., 2015).

As mentioned before, there are two levels of analysis of international manufacturing in literature, the network level and the plant level (Cheng et al., 2015). Thomas et al. (2015) present a conceptual framework linking strategic objectives of international manufacturing network with the capabilities and strategic objectives of the constituting plants of the network. It is illustrated in figure 4.

2.3.1 **Strategic objectives and capabilities – network level**

The relationship of strategic objectives of the manufacturing company, with its current and future capabilities illustrated in figure 4, will be described at a network level in this
Theoretical background

sub section. Economies of scale affects the degree of concentration of the plants in the network, as it increases when manufacturing is highly concentrated and limited to one or few plants. From a network’s perspective, benefits of economies of scope are high, when certain network competences such as research and development or procurement activities are centralised and limited to one or few plants. Achieving mobility within the manufacturing networks will help achieving primary targets of products or process mobility. To achieve high degree of network mobility, degree of duplication of technologies, products or processes within the network must be high. When the different manufacturing plants have identical competencies, and are able to produce similar products, network mobility will be high. As the degree of knowledge exchange, along the internal value chain increases, learning within the network increases. This learning process can be initiated by the knowledge transfer between the plants, contributing newly developed local knowledge to the entire network (Thomas et al., 2015).

2.3.2 Strategic objectives and capabilities – plant level

The relationship of strategic objectives of the manufacturing company, with its current and future capabilities illustrated in figure 4, will be discussed at a plant level, in this sub section. The strategic objective ‘accessibility’ of the international manufacturing network of the company directly addresses the choice of site location (Cheng et al., 2011; Colotla et al., 2003). Ferdows (1997b) describes several advantages attributed to site location, but only three of them have been empirically tested: access to skills and knowledge, access to low cost production and proximity to markets (Feldmann & Olhager, 2013; Vereecke & Van Dierdonck, 2002). Economies of scale can be achieved by aggregating production volume within the network, by re-locating products into different plants (Colotla, 2003; Thomas et al., 2015). Economies of scope can be achieved by aggregating products that require similar competences. Bandwidth of competences corresponds to the variety of different competences and its reach. It depicts whether the plant performs activities for itself or other plants as well (Ferdows, 1997b; Thomas et al., 2015). From a plants perspective, mobility refers to plants being able to cope up with changes in manufacturing, offering flexibility. Flexibility is considered as a key source of competitive advantage in manufacturing (Shi & Gregory, 1998; Thomas et al., 2015). Learning involves in the transfer of internally generated knowledge and sharing of externally acquired knowledge from local markets (Colotla et al., 2003; Miltenburg, 2005). From a plant perspective, learning is initiated either by internal advancements at the plant or by learning from competitors, key customers and suppliers (Gupta & Govindarajan, 1991).

2.4 Core plant roles and descriptions

The core plant role was created by researchers and companies to attain operational excellence and competitive production within the international manufacturing networks of the companies. It also introduces the possibilities of creating strategic advantages and securing production within the country (Bruch et al., 2016). Roles or strategies of core plants have been continuously evolving both in literature and industries (Fusco & Spring, 2003). Many researchers have attempted to describe the important roles and
Theoretical background

responsibilities of such a plant. Few of those descriptions of core plants in literature are ‘lead plants’, ‘main plants’, ‘master plants’, ‘leading subsidiary’, ‘model factory’, ‘lead factory’. (Ferdows, 1997b; Enright & Subramanian, 2007; Rudberg & West, 2008; Bengtsson et al., 2010).

These descriptions are selected and presented in this section, on the basis of the situational factors for internationalization mentioned in figure 2 (section 2.1) high site competence and access to skills/knowledge, mentioned in figure 3 (section 2.2). The various concepts across different literatures that fit the above mentioned criteria are brought together to describe the different responsibilities similar to the core plant role. These roles and descriptions will ultimately aid in creating a unified definition of core plants.

Core plants are responsible for developing manufacturing systems and technologies for other subsidiary plants in the network (Ferdows, 1989). Core plants (lead plants) have high degree of site competence and strategic access to skills and knowledge. It serves as the leading plant within the manufacturing network, as it is the global hub for product and process knowledge (Ferdows, 1997b). Core plants interact with the R&D departments, aiding them in the development of new manufacturing capabilities (products and processes), with the most important task being the generation and transfer of new knowledge within the network (Deflorin et al., 2012; Simon et al., 2008).

Bengtsson et al. (2010) explain the knowledge transfer process between core plants (master plants) and its subsidiaries within the network. They suggest that core plants are responsible for the preparation of new products for volume manufacturing. They are responsible for creating secure and efficient manufacturing processes, and also for the transfer of this knowledge within the network. Core plants are expected to lead, guide and teach the other subsidiary plants (Bengtsson et al., 2010).

Rudberg and West (2008) suggest that core plants have the responsibility of transferring knowledge and information about product revisions or changes in manufacturing systems within the network, so that, they can be replicated by the other plants. Enright and Subramanian (2007) suggest that core plants are leading subsidiaries that are involved in creation of capabilities in terms of both management and technology, while also utilizing them effectively. Table 1 summarizes the different descriptions of core plants by different authors.

Table 1. Responsibilities of core plants

<table>
<thead>
<tr>
<th>Description in literature</th>
<th>Responsibilities</th>
<th>Contributors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead plants / factories</td>
<td>Development of product and process knowledge; Knowledge transfer within the network; Prototype generation.</td>
<td>Ferdows, 1989; Ferdows, 1997b; Deflorin et al., 2012; Simon et al., 2008</td>
</tr>
<tr>
<td>Master plants</td>
<td>Industrialization of new products; Prototyping; securing new processes; knowledge transfer; leading other plants in the network.</td>
<td>Bengtsson et al., 2010</td>
</tr>
</tbody>
</table>
2.5 Defining core plants

Based on the different descriptions of core plants presented in section 2.4, the term core plant has been defined in this research as “a manufacturing plant that holds the leading role, within the international manufacturing network of a company. It is responsible for various activities such as knowledge generation, knowledge transfer, attaining cost effectiveness and operational excellence, network co-ordination and configuration, in order to fulfil the overall network objectives of the company.”

2.6 Key Performance Indicators

As the competitiveness of the manufacturing industries escalates, there is an increased pressure on these industries to achieve and maintain high quality organizational operations. To evaluate the performance of these operations, different metrics have been established that can monitor the efficiency and effectiveness of manufacturing and other operations (Neely, 1995). These measurement systems, defined as Performance Measurement Systems (PMS) are created on the basis of strategic objectives of the various organizational responsibilities. Then each of these strategic objectives are supported by a set of detailed indicators designed to reflect the fulfilment of these goals/objectives and are termed as Key Performance Indicators (KPIs). It can be defined as ‘as a set of quantifiable and strategic measurements in a PMS that reflect the critical success factors of an organization’. These measures have different structures and units, which are monitored by top level management to direct the employees regarding their individual responsibilities in order to drive continuous improvement efforts (Woolliscroft, P et al., 2013; Kang et al., 2016). Continuous monitoring and measurement of KPIs can provide access to meaningful quantification and identification of different aspects of operations. These can also enable and direct continuous improvement efforts. Manufacturing companies require comprehensive KPIs that collectively measures all of their strategic objectives, rather than KPIs which measures targeted aspects such as cost, quality due to complexity of production systems (Kang et al., 2016).
An essential feature while creating performance measurement frameworks is the identification of network targets. In order to measure the network performance of the company it is essential to introduce KPIs that reflect the organizational performance of individual plants within the network, both to assess the current situation and also for future development. All of these KPIs vary based on the characteristics of the responsibilities of individual plants within the network. It is essential for organizational managers to continuously monitor and manage the performance of their corresponding plants in order to be competitively effective and efficient. Implementing relevant KPIs will reflect the strategic objectives of the corresponding plant and is considered as a standard way to focus the available resources and activities to maintain sustained improvement within the organization (Sena Ferreira et al., 2012).
3 Method and implementation

This chapter describes the research methodology undertaken in this research. The research design, approaches, implementation, data analysis process and quality appraisal are presented in this chapter.

3.1 Research design

The nature of this research is qualitative as it aims to bridge an existing knowledge gap in the area of performance measurement of core plant responsibilities and strategic objectives within the international network of manufacturing companies. An interpretivist approach, with a flexible design is undertaken in this research, as a lack of knowledge in the area of the mentioned study is evident. This research design is non-linear and iterative (Williamson, 2002).

![Figure 5. Schematic representation of research design](image)

This research design is inspired by and co-related with the basic design and working of a generic spaceship, in order to promote better understanding, see figure 5. The research questions are of ‘what’ form. Literature review is done to establish existing theories of the relevant areas of study and will attempt to establish the groundwork for the research questions, while also fuelling the entire research. Role of the literature review in this research, has been compared with the role served by the fuel system of a generic spaceship, as it establishes the relevant theories, fuelling the entire research. Survey research will be conducted with the core plants of international manufacturing companies based
in Sweden, in an effort to validate the findings and generate more knowledge regarding the area, while completely answering both first and the second research question. The role served by the survey research has been co-related with the role of a navigation system of the spaceship, as it validates the findings of the first and second research questions, established by the literature review, by comparing it with empirical evidence. It ensures that the research is progressing in the desired direction, while also contributing to the knowledge base. Two research methods are used in order to obtain a method triangulation, in an effort to increase the reliability of the conclusions.

The final section has been compared to the payload or the operational objective of the spaceship as the entire research is designed to develop a framework regarding the development of comprehensive models of KPIs to measure performance of core plants in the manufacturing networks. Similarly, the other functions of the spaceship are designed to successfully deliver the payload (satellite) into orbit and achieve the operational objective of the spaceship.

3.2 Research approaches and implementation

3.2.1 Literature review approach

Literature review approach has been used in this research, to establish the various available information and theories regarding the mentioned areas of the study. This forms the groundwork for the entire research, primarily answering the first and second research questions. It is important to establish a background and context before undertaking any study and through literature review, it is possible to create a logical framework that is essential for any research (Marshall and Rossman, 1995). Literature review is an important part of any research project as it enables the researchers to map and assess the relevant established intellectual information of the phenomenon being studied, in order to further develop the knowledge base (Tranfield, Denyer and Smart, 2003). Since there is an existing knowledge gap in the mentioned area of study, the chosen method is appropriate as this research attempts to bridge that gap and develop the existing knowledge base. The literature review process has been carried out in two separate steps: 1) Explorative literature review 2) Systematic literature review. Initially, an explorative literature review process was performed in order to identify and establish the current and past research of the topic, with the aim of building the theoretical background. The explorative review process was carried out without any restriction on time or type of publication. This step is essential since the topic being studied is dispersed across different types and time of publications. We felt the need to include the relevant information from all such publications, in order to build the theoretical background. In the proceeding step, a systematic literature review process was carried out in order to answer the research questions 1 and 2, with the latest available peer-reviewed literature, increasing the reliability of the findings. The overall literature review process is illustrated in figure 6.
Method and implementation

Figure 6. Systematic literature review process framework (Jesson et al., 2011; Rumsey, 2008.)
Figure 6 describes the framework that guided the overall literature review process. The method of systematic literature review was chosen for the second step as it follows a structured approach by initially identifying the relevant peer reviewed literature using pre-defined search terms and then it is evaluated on the basis of the pre-defined inclusion and exclusion criteria (Jesson et al., 2011). This review process is ideal when there is a specified aim and specified research questions with a targeted focus. Furthermore, use of systematic literature reviews in research has been increasing in the past decade, which further justifies its use in this context (Cresswell, 2009). Also, the quality of the literature will be assessed and the entire review process will be iterative (Jesson et al., 2011). Rumsey (2008) suggests that successful information gathering operations involves in the application of a great deal of thought and methodical way of working through each stage, hence this framework has been created by combining other existing models in order to increase the transparency and quality of the literature review process for this research (Jesson et al., 2011; Rumsey, 2008).

3.2.1.1 Data collection techniques and implementation process

Explorative literature review

This section will describe the search process and details of the explorative literature review process done on the various concepts used throughout the thesis. This initial process of literature review serves the following purposes:

- Establishing theoretical background of the thesis
- Establishing parameters for the second step, systematic literature review by establishing a common definition of core plants, highlighting its various responsibilities.
- Insight into relevant databases and publications which can potentially be used to create for the systematic review

After establishing a basic understanding of the concepts of the study as described in the previous section, the various subject areas and potential key words were listed out, to conduct the current and past literature review process. The following key words were used with different combinations to conduct the initial search process:

- International manufacturing networks, Global manufacturing networks
- Core plants, Master plants, Lead plants, Lead factories
- Industrialization, Knowledge transfer, Network co-ordination

This review process involved in the investigation of full-text databases, in the area of Industrial Engineering and Management to identify, the relevant ones that can potentially be used for the systematic literature review. The investigated databases were ProQuest Central & ABI INFORM, Science Direct and Emerald. These were selected for investigation as it included publications across all the major areas of the thesis. No limitations were used for the publication type, with the intention of identifying all relevant literature. Using the above-mentioned key words with different combinations, a search across various publications was conducted. The search yielded large number of literatures, spread across different publications. Hence, the search was refined by limiting language of the publications to English and area of study to manufacturing. However, time frame restriction was not considered, as the aim of this review is to identify
Method and implementation

both current and past literature. The different literatures were selected by choosing the relevant publications, followed by a process of relevance check, which involved in the reading of titles and abstracts. Snowballing approach was also utilized to identify relevant literature in the reference lists of the available papers (Chu, 2003).

The distribution of the selected literature across the different journals and other publications collected during the current and past research, is presented in Table 2.

<table>
<thead>
<tr>
<th>Journal publications</th>
<th>Number of articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>International journal of operations and production management</td>
<td>6</td>
</tr>
<tr>
<td>Journal of operations management</td>
<td>4</td>
</tr>
<tr>
<td>Production and operations management</td>
<td>3</td>
</tr>
<tr>
<td>International journal of production research</td>
<td>2</td>
</tr>
<tr>
<td>Strategic management journal</td>
<td>1</td>
</tr>
<tr>
<td>Omega</td>
<td>1</td>
</tr>
<tr>
<td>Journal of manufacturing technology management</td>
<td>1</td>
</tr>
<tr>
<td>Management international review</td>
<td>1</td>
</tr>
<tr>
<td>Creativity and innovation management</td>
<td>1</td>
</tr>
<tr>
<td>Tijdschrift voor economische en sociale geografie</td>
<td>1</td>
</tr>
<tr>
<td>Academy of management journal</td>
<td>1</td>
</tr>
<tr>
<td>European planning studies</td>
<td>1</td>
</tr>
<tr>
<td>Wiley</td>
<td>1</td>
</tr>
<tr>
<td>Transnational corporations</td>
<td>1</td>
</tr>
<tr>
<td>Management Science</td>
<td>1</td>
</tr>
<tr>
<td>Journal of purchasing and supply management</td>
<td>1</td>
</tr>
<tr>
<td>Production planning and control</td>
<td>1</td>
</tr>
<tr>
<td>Integrated manufacturing systems</td>
<td>1</td>
</tr>
<tr>
<td>Industrial management &amp; data systems</td>
<td>1</td>
</tr>
<tr>
<td>International journal of production economics</td>
<td>1</td>
</tr>
<tr>
<td>Academy of management review</td>
<td>1</td>
</tr>
<tr>
<td>Other publications</td>
<td>Number of articles</td>
</tr>
<tr>
<td>McGraw-Hill Companies</td>
<td>1</td>
</tr>
<tr>
<td>23rd EurOMA conference EUROMA</td>
<td>1</td>
</tr>
<tr>
<td>Springer Berlin Heidelberg</td>
<td>1</td>
</tr>
<tr>
<td>Linköpings Universitet – Doktarate</td>
<td>1</td>
</tr>
<tr>
<td>Structural equation modelling</td>
<td>1</td>
</tr>
<tr>
<td>Institute for manufacturing, University of Cambridge</td>
<td>1</td>
</tr>
<tr>
<td>Harvard Business School Press</td>
<td>1</td>
</tr>
<tr>
<td>Managing the global firm</td>
<td>1</td>
</tr>
<tr>
<td>CRC Press</td>
<td>1</td>
</tr>
<tr>
<td>Prentice-Hall</td>
<td>1</td>
</tr>
<tr>
<td>International encyclopedia of business and management</td>
<td>1</td>
</tr>
<tr>
<td>Managing international manufacturing</td>
<td>1</td>
</tr>
<tr>
<td>Harvard business</td>
<td>1</td>
</tr>
</tbody>
</table>

A total of 45 relevant papers were identified across 21 journal publications and 13 other publication. Distribution of selected literature used in the current and past research review, across a time frame ranging from 1985-2017 is illustrated in figure 7.
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It can be observed that selected literature on the area of study of the thesis work gradually increases and is the highest during the time frame 2005-2009, with 6 journal articles and 5 other publications, literature.

Following conclusion can be made from the above shown data.

- High number of relevant literature from journal publications during the time frame 2006-2016.

A library of references was created to keep track of the selected literature. These were thoroughly read through by both the authors of the thesis to prevent any possibility of bias. Using the information from the reviewed articles the introduction and theoretical background of the thesis was established (see section 1 and 2). This explorative literature review process identified the various descriptions of core plants available in literature and other relevant information. It aided in the establishment of a common definition of core plants, highlighting their responsibilities, forming the groundwork for the systematic literature review process.

**Systematic literature review**

Systematic literature review process of this research was performed in certain steps and it serves the following purpose:

- Answer research questions 1 and 2 systematically.

ABI INFORM was chosen as the database to carry out the search due to the high number of relevant scholarly journal articles found during the search carried out in the exploratory literature review. After establishing the common definition of core plants (see section 2.4), various core plant responsibilities were summarized using which the following keyword combination was selected:

("Centre of excellence" OR "Core plants" OR "lead plants" OR "master plants" OR "Main plants" OR "Model factory") AND ("Strategic objectives" OR "objectives" OR "Roles" OR "strategies") AND ("Knowledge transfer" OR "Knowledge Generation"
Method and implementation

OR "Capability development" OR "Cost competitiveness" OR "Production excellence")

Based on the results of the exploratory literature review, the following literature search strategy given in table 3 was created for systematic literature review:

Table 3. Inclusion and exclusion criteria

<table>
<thead>
<tr>
<th>Publication type</th>
<th>Language of publication</th>
<th>Time period</th>
<th>Area of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer reviewed, scholarly journal articles</td>
<td>English</td>
<td>2006 - 2017</td>
<td>Manufacturing</td>
</tr>
</tbody>
</table>

Article screening criteria:

During the search, the articles which included information regarding core plants or similar descriptions of core plants were selected for further reading, after going through the abstracts using the previously formed definition of core plants (see section 2.4) as the guiding framework. The final list of articles was selected based on their relevance, in terms of the mentioned core plant responsibilities. Also, the study was limited to international manufacturing companies excluding studies regarding Small or Medium Enterprises (SMEs).

After conducting the search using the mentioned key word combination the following search results were obtained:

Table 4. Search details

<table>
<thead>
<tr>
<th>Initial number of articles</th>
<th>Number of articles after applying Inclusion criteria</th>
<th>Relevant articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>125</td>
<td>109</td>
<td>23</td>
</tr>
</tbody>
</table>

After going through the selected articles, only 11 were selected for the systematic literature review after analysing their direct relevance to the research question 1. Following table 5 is a list of the 11 selected articles:

Table 5. Systematic literature review of core plant strategic objectives

<table>
<thead>
<tr>
<th>Journal</th>
<th>Title</th>
<th>Author</th>
</tr>
</thead>
</table>
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<table>
<thead>
<tr>
<th>Publication type</th>
<th>Language of publication</th>
<th>Time period</th>
<th>Area of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer reviewed, scholarly journal articles</td>
<td>English</td>
<td>2006 - 2017</td>
<td>Performance evaluation</td>
</tr>
</tbody>
</table>

Table 6 presents the inclusion criteria for the systematic literature review process for identifying KPIs.

Table 6. Inclusion criteria

Literature on KPIs were identified using the following key word combination:

("Key performance indicators" OR "performance measurement") AND ("Knowledge transfer" OR "Knowledge Generation" OR "capability development" OR "cost competitiveness" OR "production excellence")

Table 6 presents the inclusion criteria for the systematic literature review process for identifying KPIs.

Table 6. Inclusion criteria

**Article screening criteria:**

During the search the articles that included information regarding the performance measurement of core plant responsibilities and corresponding strategic objectives were selected for further reading after reading the abstracts.

Table 7 presents the search details for the systematic review process for identifying relevant KPIs.
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Table 7. Search details

<table>
<thead>
<tr>
<th>Initial number of articles</th>
<th>1262</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of articles after applying Inclusion criteria</td>
<td>16</td>
</tr>
<tr>
<td>Final list of articles</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 7 presents the list of the reviewed articles:

Table 8. Systematic literature review of KPIs

<table>
<thead>
<tr>
<th>Journal</th>
<th>Title</th>
<th>Source</th>
</tr>
</thead>
</table>

3.2.2 Survey approach

Survey research involves in the collection of primary data from a part of a population, to determine inter-relationships of certain variables within the population (Williamson, K, 2002). This research approach aimed to conduct ‘confirmatory surveys’ with the collaborating companies to investigate the strategic importance placed on the identified core plant responsibilities, strategic objectives and corresponding KPIs that reflect the performance, in order to validate the findings of the literature review. This type of survey is used when knowledge of the phenomenon being studied is well established in a theoretical form and is being carried out to confirm the adequacy of the concepts de-
Method and implementation

Developed in the context of the phenomenon (Forza, 2002). Also, some elements of ‘Explanatory Survey’ was incorporated, as we attempted to discover new information of the phenomenon being studied (Forza, 2002).

3.2.2.1 Selection of companies
A purposive sampling process was utilized to select the companies, as the study is limited to core plants of manufacturing companies with international networks based in Sweden. In each of the sample companies, snowball sampling approach was utilized to identify relevant employees who could participate and contribute with their knowledge in the survey (Williamson. K, 2002). The unit of analysis is core plant of a manufacturing company with international network. Table 9 provides the description of the participating companies.

Table 9. Description of participating companies.

<table>
<thead>
<tr>
<th>Company</th>
<th>Manufacturing sector</th>
<th>Official core plant role</th>
<th>Number of plants under core plant coordination</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Aerospace</td>
<td>No official role</td>
<td>-</td>
</tr>
<tr>
<td>B</td>
<td>Automotive (Planes and Trains)</td>
<td>Operations lead industrial site</td>
<td>6</td>
</tr>
<tr>
<td>C</td>
<td>Pharmaceutical products</td>
<td>Introduction/ Launch site for tablets and capsules</td>
<td>-</td>
</tr>
<tr>
<td>D</td>
<td>Automotive (Cars)</td>
<td>Global manufacturing office</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>Automotive (Trucks)</td>
<td>Centre of excellence – Product specific</td>
<td>-</td>
</tr>
<tr>
<td>F</td>
<td>Automotive (Construction equipment)</td>
<td>Centre of excellence – Product specific</td>
<td>1</td>
</tr>
<tr>
<td>G</td>
<td>Bearing and seal manufacturing</td>
<td>No official role</td>
<td>-</td>
</tr>
</tbody>
</table>

From the above given table it is evident that the participating companies are from different manufacturing sectors. Some of them have an official core plant role and some don’t. Also, some of these core plants are responsible for coordinating subsidiary plants within their network.

3.2.2.2 Data collection techniques and implementation process

Document analysis
Certain documents which are a part of previously done research, regarding KPIs being utilized by core plants of the involved companies were analysed in order to build the
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last part of the framework and is presented in the theoretical findings (see section 4.3). This document is not revealed for confidentiality purpose.

**Questionnaire**

Questionnaire was chosen as the research technique to carry out the survey research with the identified companies, as they are useful in identifying information from potential users of the system (core plants) being studied, especially when there is a large sample, across different locations (Williamson, 2002).

The topics for the questionnaires are as follows:

- Background information (Position, work experience, roles at core plant)
- Core plant responsibilities
- Corresponding strategic objectives of core plants
- KPIs used to measure the performance of those objectives

These blocks were established based on the findings of the literature review. Using this information, a questionnaire guide was created to categorize and frame the appropriate questions. The guide also included information regarding instructions to answer the questionnaire for the respondents. The questionnaire was created using an online survey tool (esMaker), consisting a blend of factual, open, closed, and opinion questions addressing different target areas. The chosen blend of questions is appropriate in this context since a combination of confirmatory and explanatory survey had to be conducted as described before. Instructions and definitions of important concepts were also attached. The finished questionnaire contained 76 questions with 3 blocks, spread across 15 pages and it contains the following blocks of questions:

**Table 10. Content of Questionnaires**

<table>
<thead>
<tr>
<th>Block number</th>
<th>Page number</th>
<th>Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Introduction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background questions</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Responsibilities &amp; Strategic objectives of core plant role</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Knowledge generation</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Knowledge transfer</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Capability development</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>Cost effectiveness</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Operation excellence</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Corresponding Key Performance Indicators</td>
</tr>
</tbody>
</table>

The questionnaire had three types of questions: 1) Open ended questions 2) Ordinal questions with a Likert scale ranging from 0-5 3) Nominal questions with three options Yes/No/Don’t know. Block 1 of the questionnaire contained open ended questions aimed to extract background information regarding the respondent and the unit of analysis - core plants. Block 2 contained a blend of open ended and ordinal questions with
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the following Likert scale: 0 – Not relevant, 1 – Very low strategic importance, 2 – Low strategic importance, 3 – Average strategic importance, 4 – High strategic importance, 5 – Very high strategic importance. The ordinal questions aimed to confirm the findings as described previously and the open ended questions aimed to extract additional information from the respondents. Block 3 included nominal questions and aimed to investigate the current situation regarding the use of KPIs in core plants. These questions had three options: Yes/No/Don’t know.

Devised questionnaire was sent to the key personnel of the collaborating companies using the survey tool. It can be found in its entirety in the appendix 1. Statistics regarding the questionnaire can be found in table 11.

Table 11. Questionnaire Statistics

<table>
<thead>
<tr>
<th>Statistics regarding questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Companies (#)</td>
</tr>
<tr>
<td>7</td>
</tr>
</tbody>
</table>

The questionnaire titled ‘Core plants survey’ was sent to 20 key personnel of manufacturing plants, which are either formally established core plants or are fulfilling certain core plant responsibilities of the participating multi-national companies, using an online survey tool ‘esMaker’. The respondents were chosen carefully in order to represent the personnel of their core plant, who held key knowledge regarding the topics being investigated. Their roles at the plant are very diverse, including the following: process development technical leads, lean directors, heads of manufacturing, operations directors, head of industrialization, director of manufacturing research and concepts, senior advisors and an industrial PhD student among other roles.

The work experience of 11 of the 14 the respondents in their current roles is illustrated in table 12. 3 respondents chose not to reveal this information.

Table 12. Total number of respondents and their experience

<table>
<thead>
<tr>
<th>Experience in the current role (years)</th>
<th>1 - 5</th>
<th>5 – 10</th>
<th>10 - 15</th>
<th>15 - 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of respondents</td>
<td>8</td>
<td>1</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

Gender and age of the respondents has not been considered since it is irrelevant to this study. Majority of the respondents are relatively new to their current position, with 72% having only 5 or less than 5 years’ experience in their current roles.

3.3 Research data analysis process

The data analysis was performed in four different phases and the details are given in table 13
3.3.1 Literature review

The literature review process as explained before was done in two phases, exploratory literature review and systematic literature review. The process of data analysis was the same for both the phases. Initially the collected literature was thoroughly read through by both researchers to identify patterns of recurrence and this information was then funnelled down through themes under the various core plant descriptions and responsibilities identified during the exploratory literature review process. The recurring information found in the reviewed articles, were summarized as the strategic objectives and KPIs under the respective core plant responsibility.

3.3.2 Document analysis

The documents taken from a previously done study regarding core plant KPIs of the participating companies were in Swedish language. Initially they were translated into English, then the information was categorized and indexed. The relevant KPIs were used in the findings.

3.3.3 Questionnaire

All the responses were summarized and analysed using the online survey tool esMaker and Microsoft Excel. The names of the companies and individual participants will not be disclosed due to confidentiality reasons. The responses for the open ended questions which are qualitative in nature are categorized and presented in the empirical findings. The responses for the ordinal questions were analysed in two steps, assessment of the content validity of the theoretical findings, a relative comparison of strategic importance of the measures. To measure the content validity the responses on the Likert scale was categorized as illustrated in the following table 14.

<table>
<thead>
<tr>
<th>Likert scale</th>
<th>Confirmatory criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – Not relevant</td>
<td>Not important</td>
</tr>
<tr>
<td>1 – Very low strategic importance</td>
<td></td>
</tr>
<tr>
<td>2 – Low strategic importance</td>
<td></td>
</tr>
<tr>
<td>3 – Average strategic importance</td>
<td>Important</td>
</tr>
<tr>
<td>4 – High strategic importance</td>
<td></td>
</tr>
</tbody>
</table>
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5 – Very high strategic importance

The responses falling within the range of 0 – 2 was categorized into ‘not important’ and 3 – 5 was categorized ‘into important’. This categorization was done to assess the content validity of the information regarding core plant responsibilities and strategic objectives using Lawshe’s (1975) content validity ratio (CVR_i) measure. It is computed as follows:

\[ CVR_i = \frac{n_e - N/2}{N/2} \]

i – Confirmatory criteria
n_e – Number of Subject Matter Experts (SMEs) indicating the item ‘i’ being measured is essential.
N – Total number of SMEs

In this case, the SMEs are the questionnaire respondents who are the key personnel of the core plants (unit of analysis). They confirmed whether the information found in the literature is empirically valid in the context of their core plants. The value of ‘n_e’ is the total number of responses within the ranges 0-2 and 3-5 respectively, using which the CVR_i value was calculated for both criteria mentioned in table 14. According to Lawshe (1975) for the content being measured to be considered valid, CVR_i value should at least be 0.54 or 0.51, when value of N is 13 or 14 respectively. Using this technique the content validity of both the criteria was measured for each core plant responsibility and corresponding strategic objective. If CVR_i of either criteria met the minimum requirements set by Lawshe (1975), it was considered statistically valid and thus was included in the answer of research question 1. An example of the calculation is presented in appendix 2.

A relative comparison of the strategic importance of the core plant responsibilities and corresponding strategic objectives has been done by the weighted scoring analysis of the responses. The values on the Likert scale were assigned weights as shown in the following table 15.

Table 15. Weighted ratings

<table>
<thead>
<tr>
<th>Rating</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1</td>
</tr>
</tbody>
</table>

Based on the number of responses received for the different ratings of the core plant responsibilities and corresponding strategic objectives, weighted score was evaluated.
Method and implementation

The average weighted score for each core plant responsibility and the objectives were calculated to establish their relative strategic importance.

The responses of the nominal questions in block 3 of the questionnaire were analysed systematically for the KPIs of each corresponding core plant responsibilities. The total number of responses under each of the three options (Yes/No/Don’t know) for each KPI were calculated. The percentage of responses under the three options for all the KPIs under the different core plant responsibilities was then calculated. This was done to determine the current scenario of performance measurement of the various core plant responsibilities with the identified set of KPIs.

3.4 Research quality appraisal

This section will address the trustworthiness of the thesis by considering the reliability and validity of the chosen methods and techniques.

A thorough, transparent and systematic approach has been taken throughout the thesis, in order to increase the trustworthiness. A two-fold literature review process, was done in order to increase the reliability of the findings. A modified framework (see figure 5) was created to clearly describe the different steps taken in a systematic manner. Survey research (questionnaires) was conducted, in order to obtain a method triangulation in an effort to increase the internal validity of the collected data. The data was collected from multiple sources across different literatures and companies, in order to increase external validity (Williamson, 2002). Also, widely used technique such as Lawshe’s (1975) content validity ratio measurement was used to further increase the construct validity. The questionnaire received a 70% response, making the findings reliable.
4 Theoretical findings

This chapter presents theoretical findings of the research. It includes the analysis and findings of explorative literature review, systematic literature review and document analysis.

4.1 Network targets

Manufacturing strategies of multi-national manufacturing companies are built around the targets set for the entire network. Strategic network targets are the bridge between manufacturing strategies and the individual plant capabilities and characteristics. Since the focus of this research is on core plants, the strategic network targets will be aligned with the core plant capabilities. Thomas et al. (2015) present a conceptual framework (see figure 7) linking manufacturing network targets to individual plant capabilities and is described in section 2.3. Their research identifies and summarizes the network targets into accessibility, economies of scope, and economies of scale, mobility and learning ability. The network targets are defined as follows (Thomas et al., 2015):

i. Accessibility

The term ‘accessibility’ in this context refers to the location of the different plants of the network. It addresses the choice of the plant location and the various advantages it entails. Some of the advantages are proximity to markets, access to low cost production and access to knowledge and skills.

ii. Economies of scale

It refers to the economic implications based on the scale of business, technology, and other related competences of the network. It involves in changing the scale of business and production to achieve cost advantages. It includes increasing the scale of operations such as production, purchasing and marketing. It influences the degree of concentration of those operations within a manufacturing network. From a network perspective, economies of scale are highest when concentrating and increasing production or other operations at a few plants.

iii. Economies of scope

It refers to the economic implications based on the scope of technology, engineering, manufacturing, developmental and other competences, for different products within the network. It provides efficiency benefits and competitive advantages to the company. To attain high economies of scope, products that require similar manufacturing or technological competences must be bundled together, since average costs of production decreases as variety of products that can be manufactured with same competences increases.

iv. Mobility

The term ‘Mobility’ in this context refers to the networks ability to transfer products or processes among the plants in the network enabling it to react flexibly to environmental changes. It is highest when plants have identical competences and
Theoretical findings

The term ‘learning’ refers to transfer of knowledge between manufacturing plants within a network. It involves in the process of transferring internally generated and externally acquired knowledge at external markets. It begins with the development of new processes, technologies or new applications of existing technology. From a network perspective, learning can be increased by increasing the degree of knowledge exchange in terms of newly developed technologies, products or processes among the plants of the network. From an individual plant perspective, learning increases as the plant learns from suppliers, competitors or key customers.

4.2 Core plant responsibilities and strategic objectives

Based on the formulated definition of core plants (section 2.5), five main core plant responsibilities have been identified and they are: Knowledge generation, Knowledge transfer, Capability development, Achieving cost competitiveness and Attaining operational excellence. Systematic literature review regarding each of these responsibilities has been performed in order to identify various activities that can be quantifiably measured as strategic objectives and are listed out in the following table 16.

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Strategic objectives</th>
<th>Contributing authors</th>
</tr>
</thead>
</table>
| Knowledge Generation      | 1. Introduction of new tech - products, processes, info sharing  
2. Product prototype  
3. Design of full scale manufacturing process for new products  
4. Verification of tech  
5. Collaboration with R&D  
Mauri, A. J. (2009)  
Mendes Borini, F., & Tereza Leme Fleury, M. (2011)  
Deflorin et al., 2012; Feldmann & Olhager, 2013 |
| Knowledge transfer/exchange | 1. Adaptation of product design with manufacturing systems of subsidiary plants  
2. Assistance in the preparation of new products for volume manufacturing  
3. Transfer of product and manufacturing technology to subsidiary plants  
Suh, Y. (2016)  
Mendes Borini, F., & Tereza Leme Fleury, M. (2011)  
### Theoretical findings

<table>
<thead>
<tr>
<th>Capability development</th>
<th>Ability</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Communication with other plants via employee movements</td>
<td>Dalgleish, D., Mauricio, R., &amp; Williams, T. (2013)</td>
</tr>
<tr>
<td></td>
<td>Mauri, A. J. (2009)</td>
</tr>
<tr>
<td></td>
<td>Kuhn, J. (2006)</td>
</tr>
</tbody>
</table>

### Cost competitiveness

| Cost reduction by adaptation of new products and processes to local manufacturing requirements | Mauri, A. J. (2009) |
| Cost reduction by aggregating products that require similar processes                     | Kuhn, J. (2006) |

### Operational excellence

| Meeting customer demands and requirements                                                | Dalgleish, D. et al., (2013) |
| Reduced product/process defects                                                          | Boehe, D. M. (2010) |
| Reduced average manufacturing/lead time                                                  |                                  |
| Optimum manufacturing inventory levels                                                   |                                  |
| Increased productivity in terms of manufacturing processes                               |                                  |
| Increased productivity in terms of employee contributions                               |                                  |
| Improved safety and environmental standards                                             |                                  |

4.3 Corresponding list of KPIs

The findings of the analysis of a previously done survey document and systematic literature review regarding KPIs that can mirror the performance of the above mentioned strategic objectives, has been listed out in *table 17*.  

35
Table 17. Responsibilities and corresponding KPIs

<table>
<thead>
<tr>
<th>Responsibilities</th>
<th>KPI</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4. Adaptation time for manufacturing processes during new product introductions</td>
<td>Reiner, G et al., 2008</td>
</tr>
<tr>
<td></td>
<td>3. Average adaptation time for subsidiary plants during product/process knowledge transfer</td>
<td>Daghfous, A., Belkhodja, O., &amp; C. Angell, L. (2013)</td>
</tr>
<tr>
<td>Capability Development</td>
<td>1. Measure of employee training - Average number of training hours/Number of employees</td>
<td>Tan, L. P., &amp; Wong, K. Y. (2017)</td>
</tr>
<tr>
<td></td>
<td>2. Measure of employee competence - Based on education, experience and contribution</td>
<td>Wooliscroft, P et al., 2013</td>
</tr>
<tr>
<td></td>
<td>3. Number of employee participation programs (Platforms for employees to provide their ideas, solutions, to contribute to the growth of the company/Bottom up perspective)</td>
<td>Szwejczewski, M., Sweeney, M. T., &amp; Cousens, A. (2016)</td>
</tr>
<tr>
<td></td>
<td>4. Number of subsidiary plants under the direct control of core plants - Indicates reach of competence of core plants</td>
<td>Daghfous, A., Belkhodja, O., &amp; C. Angell, L. (2013)</td>
</tr>
<tr>
<td></td>
<td>5. Number of localized R&amp;D departments of subsidiary plants - coordinated by core plants</td>
<td></td>
</tr>
<tr>
<td></td>
<td>6. Level of technical resources: Measures the technical competences in terms of equipment, IT systems, infrastructure etc.</td>
<td></td>
</tr>
<tr>
<td>Cost Competitiveness</td>
<td>1. Measure of adaptation time - Time for plants to start full scale production of new product introductions or product improvements. Directly proportional to adaptation costs.</td>
<td>Sena Ferreira, P et al., 2012</td>
</tr>
</tbody>
</table>
Theoretical findings

| Operational Excellence | 3. Measure of product heterogeneity among the different plants: Measures the extent of similarities in terms of product type, between core plants and subsidiaries. Directly proportional to adaptation costs.  
4. Level of subsidiary plant autonomy: Measures the extent of autonomy provided to subsidiary plants being coordinated by the core plants  
5. Number of introductions of standardized products and processes within the network |
|---|---|
| | 1. Deliverability indicators: Metric that measures the delivery time of products to customers  
2. Manufacturing lead time: Measures time from point of order to point of delivery of final product.  
3. Number of customer rejects/returns  
4. Number of product defects  
5. Work in progress: Measures inventory levels  
6. Product/Process changeover time: Measures flexibility  
7. Overall Equipment Effectiveness: Comprehensive KPI that measures availability, performance and quality of production processes  
8. Number of safety incidents |
Sena Ferreira, P et al., 2012  
Szwejczewski, M., Sweeney, M. T., & Cousens, A. (2016) |

4.4 Linking network targets and core plant responsibilities

Based on a qualitative analysis of the strategic objectives of the different core plant responsibilities (section 4.2) and the description of network targets (section 4.3) and its relationship to plant capabilities (section 2.3.1), the following relationships are established. The core plant responsibility knowledge generation involves in the creation of new products, processes and technologies by collaborating with R&D and other knowledge creating institutions, providing the network access to knowledge and contributing to its learning ability. It also increases the economies of scope as knowledge generation responsibility is concentrated in the core plants of the network. The core plant is also involved in the process of transfer of generated knowledge throughout the network increasing the learning ability. Fulfilling knowledge transfer increases economies of scope by sharing technology, engineering and other competences and also increases the mobility, as it enables the network to react to changes flexibly. Capability development increases the learning ability and mobility by developing R&D capabilities, human and technological competences of the subsidiary plants within the network. Focusing on cost competitiveness will increase the thriftiness ability of the network by providing cost advantages and also increases the mobility of the network by having identical competences, enabling the plants to react flexibly to changes. The core plant responsibility operational excellence is only applicable on individual plant level. The relationship between these constructs is illustrated in table 18.
Theoretical findings

Table 18. Relationship between network targets and core plant responsibilities

<table>
<thead>
<tr>
<th>Responsibilities</th>
<th>Knowledge Generation</th>
<th>Knowledge Transfer</th>
<th>Capability Development</th>
<th>Cost Competitiveness</th>
<th>Operational Excellence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network targets</td>
<td>Accessibility</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Economies of scale</td>
<td>-</td>
<td>-</td>
<td>✓</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Economies of scope</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Mobility</td>
<td>-</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Learning ability</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>-</td>
</tr>
</tbody>
</table>

Network level

Plant level
5 Empirical findings and analysis

This chapter presents the empirical findings and analysis collected from the questionnaire.

5.1 Block 1 – Introduction

This section will present the findings of the first section of the questionnaire that addresses the core plant roles and descriptions of the manufacturing plants represented by the respondents and also regarding their influence over the network.

5.1.1 Core plant roles and descriptions

The current official designated core plant roles of the participating manufacturing plants were investigated in the first section of the questionnaire. Only 12 out of 14 participants responded with 5 respondents stating that their manufacturing plant does not have an official core plant role. The other respondents gave the following descriptions of the core plant roles of their manufacturing plants:

- Product specific – centre of excellence
- Operations lead site
- Lead industrial site
- Global manufacturing engineering office
- Introduction site or Launch site (Product specific)

Some of the respondents explained that their core plant is a product specific centre of excellence, which is a knowledge base for developing core competences in key product specific manufacturing processes and is a key participant in the Product or Process Design (PPD) process for certain products. One respondent explains further that the core plant is responsible for consolidating manufacturing requirements from all manufacturing locations of a certain product and reflecting them on the PPD process. These core plants are also responsible for start-up of new products and product specific manufacturing processes, supporting product localization programs, sourcing of non-localized parts and also for securing and maintaining the same high quality standards at the Hub plant. Some respondents state that their core plant role refers to the launch or introduction of certain products.

5.1.2 Co-ordination of subsidiary plants in the network

The level of network co-ordination of the core plants over the subsidiary plants was investigated. Only 11 out of 14 participants responded, with 5 respondents stating that their core plants are not responsible for co-ordination of subsidiary plants. Some core plants are responsible for other plants both within and outside Europe. One core plant does not formally manage the subsidiary plants but leads the development forward in an informal capacity. Another co-ordinates with other plants only for product transfer. Another plant is responsible for 12 other plants, eleven manufacturing offices and one engineering office.
Empirical findings and analysis

5.2 Block 2 – Responsibilities & Strategic objectives

This section will present the findings regarding section 2 of the questionnaire, which investigates core plant responsibilities and strategic objectives of the manufacturing plants of the respondents.

5.2.1 Content validity analysis

Content validity of the theoretical findings of core plant responsibilities and strategic objectives will be presented in this section, based on the analysis of the questionnaire responses. Detailed explanation regarding the data collection process is described in section 3.2.2 and the data analysis process is described in section 3.3.3.

 ✓ - Valid; × - Not valid

Core plant responsibilities

The findings regarding the content validity of the core plant responsibilities are presented in table 19. Based on the CVR_i values received for the ‘important’ criteria, all the measures are valid in empirical context.

Table 19. Content validity of Core plant responsibilities

<table>
<thead>
<tr>
<th>Core plant responsibilities</th>
<th>Content Validity Ratio (CVR_i)</th>
<th>Content Validity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not important</td>
<td>Important</td>
</tr>
<tr>
<td>Knowledge Generation</td>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>Knowledge transfer</td>
<td>-0.85</td>
<td>+0.85</td>
</tr>
<tr>
<td>Capability development</td>
<td>-0.69</td>
<td>+0.69</td>
</tr>
<tr>
<td>Cost competitiveness</td>
<td>-0.85</td>
<td>+0.85</td>
</tr>
<tr>
<td>Operational excellence</td>
<td>-0.85</td>
<td>+0.85</td>
</tr>
</tbody>
</table>

Strategic objectives of knowledge generation

Table 20 presents the content validity ratio values and the content validity of the strategic objectives of the core plant responsibility ‘knowledge generation’. It can be observed that CVR_i value for ‘important’ criteria for all the measures meets the requirements (see section 3.3) to be considered empirically valid.

Table 20. Content validity ratio and content validity of knowledge generation

<table>
<thead>
<tr>
<th>Content Validity Ratio (CVR_i)</th>
<th>Content Validity</th>
</tr>
</thead>
</table>
Empirical findings and analysis

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Knowledge Generation and corresponding strategic objectives</th>
<th>Not important</th>
<th>Important</th>
<th>Not important</th>
<th>Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction of new technologies</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>2. Generation of product prototype during new product development</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>3. Product improvements</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>4. Design of full scale manufacturing processes for new products</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>5. Manufacturing process improvements</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>6. Verification of technologies</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>7. Collaboration with R&amp;D during new product development</td>
<td>-1</td>
<td>+1</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>8. Collaboration with universities or other research institutes</td>
<td>-0.69</td>
<td>+0.69</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Knowledge transfer and corresponding strategic objectives

Table 21 presents the content validity ratio values and the content validity of the strategic objectives of the core plant responsibility ‘knowledge transfer’. It can be observed that CVR_i value for ‘important’ criteria of all the measures meets the requirements (see section 3.3) to be considered empirically valid.

Table 21. Content validity ratio and content validity of Knowledge Transfer
Empirical findings and analysis

**Capability development and corresponding strategic objectives**

Table 22 presents the content validity ratio values and the content validity of the strategic objectives of the core plant responsibility ‘capability development’. The CVR<sub>i</sub> value of the ‘important’ criteria of only the first strategic objective meets the pre-defined requirements (see section 3.3) to be considered empirically valid.

Table 22. Content validity ratio and content validity of Capability development

<table>
<thead>
<tr>
<th>Core plant responsibility Capability development and corresponding strategic objectives</th>
<th>Content Validity Ratio (CVR&lt;sub&gt;i&lt;/sub&gt;)</th>
<th>Content Validity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Employee training programs</td>
<td>-0.57 +0.57</td>
<td>× ✓</td>
</tr>
<tr>
<td>2. Managerial training programs</td>
<td>-0.42 +0.42</td>
<td>× x</td>
</tr>
<tr>
<td>3. Introducing small R&amp;D departments and liaison systems</td>
<td>0.28 -0.28</td>
<td>× x</td>
</tr>
<tr>
<td>4. Implementation of continuous improvement programs</td>
<td>-0.42 +0.42</td>
<td>× x</td>
</tr>
</tbody>
</table>
Empirical findings and analysis

Cost competitiveness and corresponding strategic objectives

Table 23 presents the content validity ratio values and the content validity of the strategic objectives of the core plant responsibility ‘cost competitiveness’. The CVR_i value of the ‘important’ criteria for only the first and second strategic objectives meets the pre-defined requirements (see section 3.3) to be considered empirically valid.

Table 23. Content validity ratio and content validity of Cost competitiveness

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Content Validity Ratio (CVR_i)</th>
<th>Content Validity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not important</td>
<td>Importance</td>
</tr>
<tr>
<td>Cost competitiveness and corresponding strategic objectives.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Adapting new products and manufacturing processes</td>
<td>-0.57</td>
<td>+0.57</td>
</tr>
<tr>
<td>2. Product and manufacturing process standardization</td>
<td>-0.71</td>
<td>+0.71</td>
</tr>
<tr>
<td>3. Aggregating products that require similar manufacturing processes</td>
<td>-0.38</td>
<td>+0.38</td>
</tr>
</tbody>
</table>

Attaining operational excellence

Table 24 presents the content validity ratio values and the content validity of the strategic objectives of the core plant responsibility ‘attaining operational excellence’. The CVR_i value of the ‘important’ criteria for all the strategic objectives meets the pre-defined requirements (see section 3.3) to be considered empirically valid.

Table 24. Content validity ratio and content validity of Attaining operational excellence

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Content Validity Ratio (CVR_i)</th>
<th>Content Validity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not important</td>
<td>Important</td>
</tr>
<tr>
<td>Operational Excellence and corresponding strategic objectives.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

43
In order to determine the relative importance of the core plant responsibilities and the corresponding strategic objectives, their weighted scores based on the responses received in the questionnaires were calculated and the findings are presented in Table 25. The strategic objectives of each responsibility are indexed, please refer to Section 4.2 for more information regarding each measure. The data analysis process is described in detail in Section 3.3.

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>5 - rating</th>
<th>4 - rating</th>
<th>3 - rating</th>
<th>2 - rating</th>
<th>1 - rating</th>
<th>0 - rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge Generation</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.4</td>
</tr>
<tr>
<td>Strategic objective -1</td>
<td>8</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.6</td>
</tr>
<tr>
<td>Strategic objective -2</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.05</td>
</tr>
<tr>
<td>Strategic objective -3</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.15</td>
</tr>
</tbody>
</table>
### Empirical findings and analysis

<table>
<thead>
<tr>
<th>Strategic objective</th>
<th>5 - rating</th>
<th>4 - rating</th>
<th>3 - rating</th>
<th>2 - rating</th>
<th>1 - rating</th>
<th>0 - rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4</td>
<td>6</td>
<td>3</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.35</td>
</tr>
<tr>
<td>-5</td>
<td>2</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>-6</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.35</td>
</tr>
<tr>
<td>-7</td>
<td>7</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3.6</td>
</tr>
<tr>
<td>-8</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2.85</td>
</tr>
</tbody>
</table>

**Average score:** 3.26111111

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>5 - rating</th>
<th>4 - rating</th>
<th>3 - rating</th>
<th>2 - rating</th>
<th>1 - rating</th>
<th>0 - rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
<td>0.3</td>
<td>0.25</td>
<td>0.2</td>
<td>0.15</td>
<td>0.1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Knowledge transfer</td>
<td>4</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3.3</td>
</tr>
<tr>
<td>Strategic objective -1</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>2.65</td>
</tr>
<tr>
<td>Strategic objective -2</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3.15</td>
</tr>
<tr>
<td>Strategic objective -3</td>
<td>3</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3.35</td>
</tr>
<tr>
<td>Strategic objective -4</td>
<td>2</td>
<td>6</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3.2</td>
</tr>
<tr>
<td>Strategic objective -5</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3.1</td>
</tr>
</tbody>
</table>

**Average score:** 3.125

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>5 - rating</th>
<th>4 - rating</th>
<th>3 - rating</th>
<th>2 - rating</th>
<th>1 - rating</th>
<th>0 - rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
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<td>0.25</td>
<td>0.2</td>
<td>0.15</td>
<td>0.1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Capability development</td>
<td>1</td>
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<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>2.9</td>
</tr>
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<td>5</td>
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<td>1</td>
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<td>2.8</td>
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<td>7</td>
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<td>1</td>
<td>1</td>
<td>2.55</td>
</tr>
<tr>
<td>Strategic objective -3</td>
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<td>2</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>1.7</td>
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<td>2</td>
<td>0</td>
<td>2.75</td>
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<td>Strategic objective -5</td>
<td>1</td>
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<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2.65</td>
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</table>

**Average score:** 2.558333333

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>5 - rating</th>
<th>4 - rating</th>
<th>3 - rating</th>
<th>2 - rating</th>
<th>1 - rating</th>
<th>0 - rating</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weights</td>
<td>0.3</td>
<td>0.25</td>
<td>0.2</td>
<td>0.15</td>
<td>0.1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cost effectiveness</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3.25</td>
</tr>
<tr>
<td>Strategic objective -1</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3.1</td>
</tr>
<tr>
<td>Strategic objective -2</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>3.2</td>
</tr>
<tr>
<td>Strategic objective -3</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>2.7</td>
</tr>
</tbody>
</table>

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The strategic objectives which were deemed to have low content validity in section 5.3.1 are not considered for analysis in this section and thus are cut out from the table.

### 5.3 Block 3 – Corresponding KPIs

This section presents the findings based on the responses received in section 3 of the questionnaire that investigates the use of identified lists of KPIs (see section 4.3) in empirical context.

#### 5.3.1 Performance measurement of core plant responsibilities and strategic objectives

This sub-section presents the findings and analysis of the questionnaire regarding the evaluation of current situation of performance measurement of core plant responsibilities and the corresponding strategic objectives using the identified set of KPIs. Please refer to section 4.3 for more information regarding the indexed list of KPIs given in this section. The data analysis process is described in detail in section 3.3.

**Knowledge generation**

Table 26 reveals that only 30% of the core plants measure the performance of identified responsibility knowledge generation and its corresponding strategic objectives with the identified set of KPIs. Some respondents suggested that specific KPIs for this core plant responsibility has not been implemented as of yet. Other respondents suggested that the
Empirical findings and analysis

The following KPIs are currently being used to measure the performance of knowledge generation.

- Needed hours for learning (start-up) of assembly
- Total number of non-recurring hours (one time investments in all areas to get started)
- Time, cost, technique and competence related KPIs

Table 26. Performance measurement of Knowledge generation

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge Generation</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>KPI 1</td>
<td>7</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>KPI 2</td>
<td>1</td>
<td>10</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>KPI 3</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>17</td>
<td>27</td>
<td>12</td>
<td>56</td>
</tr>
<tr>
<td>%</td>
<td>30%</td>
<td>48%</td>
<td>21%</td>
<td></td>
</tr>
</tbody>
</table>

Knowledge transfer

Table 27 reveals that only 17% of the core plants measure the performance of the responsibility knowledge transfer with the identified set of KPIs. One respondent suggested that no specific KPI for knowledge transfer has been implemented and that product knowledge transfer is only seen as project execution in individual delivery projects, with no aggregated KPI measurement.

Table 27. Performance measurement of knowledge transfer

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge transfer</td>
<td>3</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>KPI 1</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>KPI 2</td>
<td>2</td>
<td>9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
<td>27</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>%</td>
<td>17%</td>
<td>64%</td>
<td>19%</td>
<td></td>
</tr>
</tbody>
</table>

Capability development

The data in table 28 suggests that only 12% of the core plants measure the performance of capability development and its corresponding strategic objectives with the identified list of KPIs. One of the respondent suggested that some of the identified KPIs are measured locally and not on a network level.

Table 28. Performance measurement of capability development

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capability development</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Empirical findings and analysis

| KPI 1 | 3 | 4 | 7 |
| KPI 2 | 4 | 6 | 4 |
| KPI 3 | 1 | 10 | 3 |
| KPI 4 | 1 | 9 | 4 |
| KPI 5 | 0 | 9 | 5 |
| KPI 6 | 1 | 8 | 5 |
| Total | 10 | 46 | 28 | 84 |
| % | 12% | 55% | 33% |

**Achieving cost competitiveness**

The data in *table 29* suggests that only around 20% of the core plants measure the performance of the responsibility ‘achieving cost competitiveness’ and its corresponding strategic objectives with the identified list of KPIs. One respondent suggested that several of the mentioned KPIs would be in focus during the next 6 months.

*Table 29. Performance measurement of cost competitiveness*

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KPI 1</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>KPI 2</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>KPI 3</td>
<td>1</td>
<td>5</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>KPI 4</td>
<td>1</td>
<td>6</td>
<td>7</td>
<td>14</td>
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<tr>
<td>KPI 5</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>28</td>
<td>27</td>
<td>69</td>
</tr>
<tr>
<td>%</td>
<td>20%</td>
<td>41%</td>
<td>39%</td>
<td></td>
</tr>
</tbody>
</table>

**Attaining operational excellence**

The data shown in *table 30* suggests that 86% of the core plants measure the performance of responsibility ‘attaining operational excellence’ and its corresponding strategic objectives with the identified list of KPIs. The respondents indicated these measures are being implemented locally; per plant and has not been implemented on a network level. Another respondent stated that the following list of KPIs are implemented at the core plant to measure operational excellence:

- Injury occurrences
- Health frequency rates
- Waste and resource reduction
- Stock availability
- Plan adherence
- Stock tolerance
- Lead time norms
- Health & well being
- Resource flexibility
## Table 30. Performance measurement of operational excellence

<table>
<thead>
<tr>
<th>Core plant responsibility</th>
<th>Yes</th>
<th>No</th>
<th>Don't know</th>
<th>Total responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPI 1</td>
<td>12</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>KPI 2</td>
<td>13</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>KPI 3</td>
<td>13</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>KPI 4</td>
<td>12</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>KPI 5</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>KPI 6</td>
<td>11</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>KPI 7</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>84</td>
<td>8</td>
<td>6</td>
<td>98</td>
</tr>
<tr>
<td>%</td>
<td>86%</td>
<td>8%</td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>
6 Discussions and conclusion

In this chapter, discussions regarding the methods and findings are presented with the aim of answering the research questions and fulfilling the purpose of the research.

6.1 Overview

The purpose of this thesis was to contribute to the development of comprehensive performance measurement systems to monitor the performance and value of the core plant role to the global network of international manufacturing companies.

An explorative literature review was done to establish the relevant theoretical background. Initially, literature regarding the internationalization of manufacturing companies was investigated and established, in order to understand the process and reasons for internationalization. The various plant roles within international manufacturing networks and their relationship were later described before introducing the literature regarding manufacturing strategies of international networks. This section introduced a framework that links network objectives with individual plant capabilities, which aids in the formulation of manufacturing strategies of international networks. Since core plants are the focus of this thesis work, various literature regarding the core plant role is established in the next section. In this section, the various descriptions of plant roles which are similar to the core plant role are described and their responsibilities are highlighted. Based on these descriptions, an unified definition of core plants was formulated. The theoretical background concluded with information regarding performance measurement and KPIs.

In order to fulfil the purpose of this thesis, the following two research questions were framed and aimed to be answered:

1. What are the important core plant responsibilities and corresponding strategic objectives?
2. What is the current situation of performance measurement of the identified core plant responsibilities and the corresponding strategic objectives?

The research approaches taken to address the research questions are a two tier literature review and survey. The data collection and analysis process has been described in detail in sections 3.2 and 3.3 respectively.

6.2 Answering research question 1

The first research question aimed to address the lack of a common understanding of the core plant role among international manufacturing companies and in academia, by establishing the important core plant responsibilities and corresponding strategic objectives. It has been addressed by using systematic literature review and survey approach, utilising the findings of the explorative literature review as the basis. After defining core plants in section 2.5 based on its various descriptions found in literature (section 2.4), core plant responsibilities were established. Using these responsibilities as part of the key word combination, systematic literature review has been done to identify the corresponding strategic objectives under each responsibility as shown in section 4.2.
Discussion and conclusion

Confirmatory survey with the core plants of the participating companies was performed using a questionnaire to validate the theoretical findings in empirical context, and the corresponding findings are presented in section 5.2.1. Based on the survey data, analysis of relative strategic importance of core plant responsibilities and their corresponding objectives has been done (section 5.2.2) using weighted scoring technique. The overview of the findings is presented in figure 8.

Following is the ranking of the core plant responsibilities and the corresponding strategic objectives based on the average weighted scores.

1. Attaining operational excellence – 3.32
2. Knowledge generation – 3.26
3. Cost competitiveness – 3.18
4. Knowledge transfer – 3.125
5. Capability development – 2.85

It can be observed from the above findings that ‘attaining operational excellence’ is considered as the most important core plant responsibility with the highest weighted score and ‘capability development’ is the least important with the lowest weighted score. However, it is important to note that attaining operational excellence is only applicable in the individual plant level, not the entire network. Hence, ‘knowledge generation’ can be considered as the most important core plant responsibility that extends to the entire network.

Other related qualitative, empirical information regarding core plant roles, descriptions and network co-ordination are presented in section 5.1. These findings suggest that few core plants are already fulfilling the network targets (section 4.1). They have the exclusive role of knowledge generation contributing to the network targets accessibility to knowledge and skills, learning ability and economies of scope. They are also responsible for one or few product types increasing economies of scale. They also transfer knowledge regarding development of required products or processes increasing economies of scope and mobility.
6.3 Answering research question 2

The second research question aimed to investigate the current situation of performance measurement of the core plant role in empirical context. A list of KPIs that quantify and reflect the identified strategic objectives of the different core plant responsibilities were established after reviewing relevant literature in section 4.3. Confirmatory survey approach has been used to investigate the level of performance measurement of the identified objectives among the core plants of the participating companies by using the same questionnaire. The corresponding qualitative and quantitative empirical findings are presented in section 5.3.1. The overview of the findings is presented in figure 9.

![Figure 9. Graphical representation of the current situation of performance measurement among core plants](attachment:figure9.png)

The findings suggest that the core plant responsibility ‘operational excellence’ is well established in terms of performance measurement. 84% of the responses indicate that the corresponding strategic objectives are being reflected with the identified list of KPIs. Rest of the core plant responsibilities are poorly established in terms of performance measurement. These findings are consistent with the theoretical evidence described in the introduction (section 1.2). Few core plants have additional KPIs which are presented in section 5.3.1.

6.4 Holistic analysis

After the answering of both research questions, a holistic analysis of the findings will be presented in this section. Figure 10 visualizes the overview of the findings and highlights the relationship between the relative strategic importance of core plant responsibility with that of the current scenario of performance measurement of the corresponding responsibilities and objectives.
The findings reveal that ‘Attaining operational excellence’ has the highest relative strategic importance and majority of the core plants have well implemented KPIs to measure the performance of its strategic objectives. However, both theoretical and empirical findings suggest that this core plant responsibility is only applicable to the individual plant level and not the entire network of the companies. ‘Capability development’ has the lowest relative strategic importance and has the lowest percentage of implemented KPIs that can reflect the performance of its corresponding strategic objectives in the core plants.

![Figure 10. Graphical representation of relationship between relative strategic importance of core plant responsibilities and implemented KPIs.](image)

The figure also reveals that even though the relative strategic importance of core plant responsibilities ‘knowledge generation’, ‘cost competitiveness’ and ‘knowledge transfer’ are high, the percentage of core plants that have implemented KPIs that mirrors the performance of their corresponding strategic objectives are very low. This empirical finding is consistent with the previously stated theoretical findings (section 1.2).

The findings and analysis suggest that the core plant responsibilities that are applicable to the network level are not being measured effectively with relevant KPIs in comparison to the individual plant level objectives. This proves to be a major challenge for the top management of the multi-national manufacturing companies to assess the true performance and contribution of value of core plants to the network. The reason can be attributed to the previously mentioned knowledge gap in the area of core plant responsibilities and corresponding performance measurement. Also, some of the qualitative findings suggest that they are already fulfilling network targets, but it is unclear whether they have implemented PMS to measure the network level performance as this survey analysed the general consensus, not an individual core plant/company specific analysis. The following framework is suggested with the aim of fulfilling the purpose of this thesis work.
6.5 A conceptual framework

As described earlier, there is a lack of system that measures the performance and contribution of value of core plants to the network of the company, leaving the top management of the company with a disadvantage during strategy formulation. Strategies of the multi-national companies are formulated based on the set network targets and their level of performance. Literature on network targets of multi-national manufacturing companies are summarized and explained in section 4.1. Based on the various literature regarding core plant role and its descriptions (section 2.4) a unified definition of core plants and its responsibilities has been established in section 2.5. Systematic literature review has been performed on the identified core plant responsibilities and several corresponding activities that can be quantified into strategic objectives are listed out in section 4.2. Section 4.4 describes the relationship between the network targets and the core plant responsibilities. A list of KPIs that mirrors the performance of the strategic objectives is listed out in section 4.3. These KPIs can reflect and quantify the performance of the identified strategic objectives of the core plants under the corresponding core plant responsibilities. The empirical validity of the findings is presented in chapter 5. Figure 11 presents the conceptual framework that shows the relationship between the established constructs.
The listed out KPIs can be utilized by the core plants to reflect the performance of the respective strategic objectives. Measurement of the performance of strategic objectives can reflect the performance of the respective core plant responsibilities. Based on the previously established network targets and their relationship with core plant responsibilities, performance and contribution of core plants to the network of the company can be reflected. This framework can be utilized as the guidelines to create a comprehensive performance measurement system using computerized tools such as Microsoft Excel.

6.6 Discussion of methods

The research process consisted of two different approaches: literature review and survey, undertaken in four different phases. Explorative literature review has been done in phase 1 and systematic literature review in phase 2. Analysis of a document consisting a list of the currently implemented KPIs in core plants of the participating international manufacturing companies is conducted in phase 3. Survey approach has been taken in the final phase with the key personnel of the core plants of the participating companies. The research design is explained in section 3.1 with an original model and is shown in figure 5.

A two-tier literature review process has been conducted with the aim of covering all the related literature across different time periods to establish a strong theoretical background, before answering the first research question with the latest literature. This vastly increased the reliability and quality of the process. Furthermore, a modified framework has been presented in figure 6, that clearly outlined and guided the overall literature review, increasing the transparency of the process. These steps were taken to achieve increased reliability.

Questionnaire was utilized for the confirmatory survey approach using the theoretical findings to create the questionnaire guide. The planning stage of the survey approach has been well thought and the participants were briefed earlier regarding the questionnaire. It was sent to 20 key personnel of core plants of different companies and 70% of the participants, responded making the findings valid enough to generalise (Forza, 2002). Construct validity and method triangulation was achieved using the questionnaire as it confirmed the empirical validity of the findings by analysing the data with Lawshe’s (1975) technique for measuring content validity. External validity was achieved as the empirical findings were based on different theoretical findings from different literatures and the respondents of the survey were employees of core plants of different companies. These findings can be generalized to core plants of all international manufacturing companies. In addition, the employees held diverse roles within their core plants and had relatively varying experiences in their current positions providing different perspectives to the questionnaire data increasing the reliability of the findings.

A relatively small sample size of 20 participants has been utilized due to a lack of available companies who are aware of the core plant concept, which might not be representative of a larger population, making the reproducibility of the findings questionable.
Discussion and conclusion

However, the entire research process is well described with original frameworks, allowing future research to be conducted seamlessly with larger sample sizes. Furthermore, the survey participants all held top level positions and held key knowledge of the area being investigated in the thesis, increasing the quality of the findings. Individual plant level analysis of the participating companies was not pursued as it did not serve the purpose of the thesis, however is encouraged for future research. Hence a general consensus regarding the findings was aimed for in the survey, rather than individual plant or company perspective. Another drawback of the thesis is that the relationship between network targets and core plant responsibilities is not subjected to empirical validation. Quality of the research could have been vastly increased by conducting surveys with larger sample size and case studies at core plants of the participating companies, providing deeper insights to the thesis work. These approaches were not considered due to time restriction, however are recommended for future research.
Discussion and conclusion

6.7 Conclusion

The purpose of this study was to provide guidelines for the development of comprehensive performance measurement systems to reflect the progress and contribution of value of core plants to the network of the respective international manufacturing company. After developing a common understanding of the core plant role, first research question was answered by establishing its responsibilities, strategic objectives and corresponding KPIs. Also, qualitative findings indicate that some of the core plants are fully established and are already contributing to one or more network targets.

Answer of the second research question provided insight into the current situation of performance measurement of the core plant role among the international manufacturing companies. It revealed that even though the strategic importance of the network level core plant responsibilities is high, the performance measurement system is either poorly developed or non-existent. It serves to be a major disadvantage for the top management of the companies, as they do not have a clear picture of the performance and contribution of value of core plants on a network level. This finding is consistent with the limited theoretical evidence presented in the introduction of the thesis work. The suggested conceptual framework, provides detailed guidelines to develop comprehensive performance measurement systems by identifying core plant responsibilities, corresponding strategic objectives and respective KPIs that reflect the performance, thereby fulfilling purpose of the thesis.

This research work is useful for both academia and industry. The extensive and detailed literature reviews provide a library of relevant references for future researches. The research design and approach can also be used for other similar researches. The results of the thesis are useful for top management of international manufacturing companies in designing performance measurement systems for their core plants. Also a similar approach can be taken to develop performance measurement systems of manufacturing plants with other roles.

Further research including case studies at the companies to investigate more strategic objectives and corresponding KPIs would be of great interest. In addition, there is a scope for creating a functional model of the comprehensive performance measurement system using the conceptual framework established in the thesis and tested in the case companies.
7 References


References


References


References


References


Turner, R., Pinto, J. and Bredillet, C., 2011. The evolution of project management research.


References

8 Appendices

8.1 Appendix 1: Questionnaire

Questionnaire

Section 1 – Background questions

The first section of the questionnaire will include background questions, in order to acquire the required basic information. This section will have a mix of factual and open ended questions. Please answer Yes/No for the factual questions and answer briefly in words for the open ended questions.

1. Does your manufacturing plant have an official designated core plant role within the network of the company? If yes, please state the designated role.
A: ……………………………………………………………………………………………

2. What is your official designated role at the plant?
A: ……………………………………………………………………………………………

3. For how many years have you been operating under this role?
A: ……………………………………………………………………………………………

4. Is your plant responsible for coordinating other subsidiary plants? If yes, please state the number of plants under control.
A: ……………………………………………………………………………………………

Section 2

Responsibilities and Strategic objectives of the core plant role

This section will aim to investigate, which of the following responsibilities and strategic objectives are being performed by your core plant. Please rate the mentioned objectives on a scale of 0-5, based on their strategic importance placed at your core plant using the following scale for reference.

0 – Not relevant, 1 – Very low strategic importance, 2 – Low strategic importance, 3 – Average strategic importance, 4 – High strategic importance, 5 – Very high strategic importance.

Example:

If the main responsibility of your core plant is knowledge generation and has very high strategic importance, please rate as follows:
A: 0 -- x- --; 1 -- -- --; 2 -- -- --; 3 -- -- --; 4 -- -- --; 5 -- x- --

If one of the main strategic objective under this responsibility is introduction of new technologies, and has very high strategic importance at your core plant, please rate as follows:
A: 0 -- x- --; 1 -- -- --; 2 -- -- --; 3 -- -- --; 4 -- -- --; 5 -- x- --

If collaboration with universities and research institutes is not a strategic objective of your core plant, please rate as follows:
A: 0 -- x- --; 1 -- -- --; 2 -- -- --; 3 -- -- --; 4 -- -- --; 5 -- -- --
1. Core plant responsibility: Knowledge Generation:

The responsibility of knowledge generation within the network addresses the process of generation of knowledge in terms of new products, processes and technologies, by collaborating with R&D or other research institutes. Please rate the strategic importance of this responsibility, placed in your core plant on a scale of 0 – 5, as described earlier.

A : 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Strategic objectives of knowledge generation:

The following is a list of the strategic objectives under the core plant responsibility of knowledge generation. Please rate each of the objectives based on their strategic importance placed in your core plants on a scale of 0-5 as described earlier.

Introduction of new technologies (product, process, information sharing)
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Generation of product prototype during New Product Development (NPD)
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Product improvements – changes in product specifications during NPD
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Design of full scale manufacturing processes for new products
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Manufacturing process improvements – changes in manufacturing process specifications during new product development
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Verification of technologies (Verifying the functionality of new products and manufacturing processes)
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Collaboration with R&D during new product development
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Collaboration with universities or other research institutes
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Please state and briefly describe, if there are any other additional strategic objectives under this core plant role category:

A: ...........................................................................................................

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Core plant responsibility: Knowledge transfer/exchange:

The core plant responsibility of knowledge transfer/exchange addresses the transfer process of generated knowledge among the other subsidiary plants within the network. This responsibility
of core plant is relevant at both the core plant level and the network level. Please rate the strategic importance of this responsibility, placed in your core plant on a scale of 0 – 5.

A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

**Strategic objectives of knowledge transfer/exchange:**

The following is a list of the strategic objectives under the core plant responsibility of knowledge transfer/exchange. Please rate each of the objectives based on their strategic importance placed in your manufacturing plants on a scale of 0-5.

Adaptation of product design with manufacturing systems of plants
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

Assistance in the preparation of new products for volume manufacturing in other plants
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

Transfer of product and manufacturing technologies to subsidiary plants (Tools such as equipment, IT, Infrastructure)
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

Communication with subsidiary plants using media (such as teleconference, emails, and databases)
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

Communication with other plants via employee movements (Managers, line operators, specialists etc. are sent to subsidiary plants to oversee the knowledge transfer.)
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

Please state and briefly describe, if there are any other additional strategic objectives under this category of core plant responsibilities:

A: …………………………………………………………………………………………………………………………

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**Core plant responsibility: Capability development:**

This core plant responsibility refers to the ability to renew, increase and adapt the core competencies of the plants. It is also used to aid in the evolution of the subsidiary plant roles into the core plant role. This responsibility of core plant is relevant at both the core plant level and the network level. Please rate the strategic importance of this responsibility, placed in your core plant on a scale of 0 – 5.

A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -

**Strategic objectives of capability development:**

The following is a list of the strategic objectives under the core plant responsibility of capability development. Please rate each of the objectives based on their strategic importance placed in your core plant on a scale of 0-5 as described earlier.

Employee training programs Programs to develop and improve the various technical and overall competences of employees (manufacturing processes, company values, proactive contribution, innovation, language skills or any other relevant competence.)
A: 0 -- - -; 1 -- - -; 2 -- - -; 3 -- - -; 4 -- - -; 5 -- - -
Managerial training programs

Programs to develop and improve the various technical and overall competences of managers (manufacturing processes, company values, proactive contribution, innovation, language skills or any other relevant competence.)

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Introducing small R&D departments and liaison systems in different subsidiary plants to increase their autonomy and decrease the dependence on core plants.

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Implementation of continuous improvement programs

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Implementation of new management/production systems (ex: Total quality Management, Company specific production systems XPS)

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Please state and briefly describe, if there are any other additional strategic objectives under this category of core plant responsibilities:

A:

Core plant responsibility: Cost competitiveness:

This core plant responsibility refers to the ability to reduce the costs of knowledge generation, transfer and production within the manufacturing network, increasing the cost competitiveness. This responsibility of core plant is relevant at both the core plant level and the network level. Please rate the strategic importance of this role, placed in your core plant on a scale of 0 – 5, as described earlier.

A : 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Strategic objectives of cost competitiveness:

The following is a list of the strategic objectives under the core plant role of cost competitiveness. Please rate each of the objectives based on their strategic importance placed in your core plant on a scale of 0-5 as described earlier.

Reducing the costs for adapting new products and manufacturing processes to local requirements of subsidiary plants for volume manufacturing

A : 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Reducing costs through product and manufacturing process standardization: Standardization of products and manufacturing processes in subsidiary plants, tightly managed and co-ordinated by core plants to ensure efficiency.

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Costs reduction by aggregating products that require similar manufacturing processes.

A: 0 -- - - ; 1 -- - - ; 2 -- - - ; 3 -- - - ; 4 -- - - ; 5 -- - -

Please state and briefly describe, if there are any other additional strategic objectives under this category of core plant responsibilities:

A:

5. Core plant responsibility: Operational excellence:

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This responsibility refers to the day to day activities performed at the plant level in order to enhance the operational excellence of the core plant. This responsibility is usually applicable only within the core plant. Please rate the strategic importance of this responsibility, placed in your core plant on a scale of 0 – 5, as described earlier.

A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

**Strategic objectives of operational excellence:**

The following is a list of the strategic objectives under the core plant role of operational excellence. Please rate each of the objectives based on their strategic importance placed in your core plant on a scale of 0-5 as described earlier.

Meeting customer demands and requirements
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Reduced product/process defects
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Process flexibility: Refers to the ability of changing processes to adapt to new products being introduced.
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Reduced customer rejects/returns
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Reduced average manufacturing lead time
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Increased productivity in terms of manufacturing processes
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Optimum manufacturing inventory levels
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Increased productivity in terms of employee contributions
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Improved safety and environmental standards
A: 0 -- -- -- ; 1 -- -- -- ; 2 -- -- -- ; 3 -- -- -- ; 4 -- -- -- ; 5 -- -- --

Please state and briefly describe, if there are any other additional strategic objectives under this category of core plant responsibilities:
A:

**Section 3**

**Corresponding Key Performance Indicators**

This section will aim to establish the suitable KPIs that can be utilized by core plants to measure their performance and value to the network. Please state Yes/No/Do not know, to indicate if the given KPIs are used to measure the above mentioned strategic objectives at your core plant. If
there are additional KPIs being used to measure the strategic objectives under their respective core plant responsibility, please state and describe them in the provided space.

1. **Knowledge Generation**

Rate of new product introductions
A: 

**Time for Industrialization** – (Start of a project to full scale production)
A: 

Number of collaborations with students, universities and research institutes
A: 

**Adaptation time for manufacturing processes during new product introductions**
A: 

Please state and briefly describe, if there are any other additional KPIs under this category of core plant responsibility:
A: 

2. **Knowledge transfer**

Rate of transfer of product/process technologies
A: 

**Rate of knowledge exchange via managerial movements** (Movement of employees with technical know-how between core plants and subsidiaries)
A: 

**Average adaptation time for subsidiary plants during product/process knowledge transfer** (new introductions/improvements)
A: 

Please state and briefly describe, if there are any other additional KPIs under this category of core plant responsibility:
A: 

3. **Capability development**

Measure of employee training - Average number of training hours/Number of employees
A: 

Measure of employee competence - Based on education, experience and contribution
A: 

Number of employee participation programs (Platforms for employees to provide their ideas, solutions, to contribute to the growth of the company/ Bottom up perspective)
A:
Number of subsidiary plants under the direct control of core plants - Indicates reach of competence of core plants
A: 

Number of localised r&d departments of subsidiary plants - coordinated by core plants
A: 

Level of technical resources: Measures the technical competences in terms of equipment, IT systems, infrastructure etc.
A: 

Please state and briefly describe, if there are any other additional KPIs under this category of core plant responsibility:
A: 

4. Cost competitiveness

Measure of adaptation time - Time for plants to start full scale production of new product introductions or product improvements. Directly proportional to adaptation costs.
A: 

Measure of process heterogeneity among the different plants: Measures the extent of similarities in terms of production processes, between core plants and subsidiaries. Directly proportional to adaptation costs.
A: 

Measure of product heterogeneity among the different plants: Measures the extent of similarities in terms of product type, between core plants and subsidiaries. Directly proportional to adaptation costs.
A: 

Level of subsidiary plant autonomy: Measures the extent of autonomy provided to subsidiary plants being co-ordinated by the core plants
A: 

Number of introductions of standardized products and processes within the network
A: 

Please state and briefly describe, if there are any other additional KPIs under this category of core plant responsibility:
A: 

5. Production/Operational excellence

Manufacturing lead time: Measures time from point of order to point of delivery of final product.
A: 

Number of customer rejects/returns
A:
Number of product defects

A:
Work in progress: Measures inventory levels

A:
Product/Process changeover time: Measures flexibility

A:
Overall Equipment Effectiveness: Comprehensive KPI that measures availability, performance and quality of production processes

A:
Number of safety incidents

A:
Please state and briefly describe, if there are any other additional KPIs under this category of core plant responsibility:

8.2 Appendix 2    Content validity ratio analysis

Content validity ratio

CVR=(N_e - N/2)/(N/2)

N_e – Number of Subject Matter Experts (SMEs) indicating the item ‘i’ being measured is essential.

N – Total number of SMEs

Example- The ratings for the criteria ‘Low strategic importance’ of Knowledge generation, N. within 0-2 range (i.e, low strategic importance) is 0 and N is 13

So, CVR of low strategic importance for knowledge generation= (0-13/2)/(13/2) = -1