Strategic Performance Measurement and Management in Manufacturing Networks –
A Holistic Approach to Manufacturing Strategy Implementation

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St. Gallen, May 19, 2015

The President:

Prof. Dr. Thomas Bieger

For my parents and brothers

DANKSAGUNG

Diese Dissertation entstand im Rahmen meiner Tätigkeit am Lehrstuhl für Produktionsmanagement der Universität St.Gallen in den Jahren 2011 bis 2014. Während dieser Zeit als Forschungsassistent war es mir erlaubt, in über 20 Industrieprojekten Einblicke in die Managementaktivitäten zahlreicher Unternehmen zu gewinnen und diese mitzugestalten. Die so gesammelten Erfahrungen und Erkenntnisse dienen als Basis für diese Dissertation und haben meine Perspektive massgeblich geformt. Ermöglicht wurde der Aufbau dieses Erfahrungsschatzes durch die Unterstützung und Mitarbeit zahlreicher Mitmenschen, bei denen ich mich im Folgenden bedanken möchte.

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Nicht unerwähnt lasse ich an dieser Stelle die zahlreichen studentischen Mitarbeiter, Bachelor- und Masterarbeiter und Industriepartner, die einen wichtigen Beitrag zum Entstehen dieser Dissertation geleistet haben.

St.Gallen im August 2014 Fabian Liebetrau

MESSAGE TO THE READER

Dear reader,

I hope you find as much pleasure in reading this dissertation as I had in writing it. Although the time as a PhD student might seem stressful and unbearable at times, in the end it is most definitely a time that was worth taking. Please use the findings and ideas in this thesis freely but do not forget to quote correctly. If you have any questions regarding this thesis feel free to contact me through Linkedin or Xing. I am always more than happy to discuss my findings. Although I no longer work in an academic setting, I am greatly interested in spreading my ideas and hope that other people, researchers or practitioners, can greatly benefit from my research.

I hope you find what you are looking for in this dissertation.

Best regards

Fabian Liebetrau

ZUSAMMENFASSUNG

Produzierende Unternehmen agieren und produzieren zunehmend global. Das Management der so entstehenden globalen Produktionsnetzwerke im Einklang mit den heterogenen und dynamischen Anforderungen der belieferten Märkte stellt Unternehmen vor grosse Herausforderungen. Die zielgerichtete strategische Weiterentwicklung der Produktionsnetzwerke und somit die Erhöhung der Leistungsfähigkeit ist dabei unabdingbar. Die praktische Umsetzung dieser Weiterentwicklung ist allerdings problematisch, da die Definition und somit die Bewertung von Leistungsfähigkeit bzw. Performance abhängig von externen und internen Faktoren ist und nicht abschliessend und einheitlich für verschiedene Standorte oder Netzwerke definiert werden kann. Performance kann dabei auf strategischer, taktischer oder operativer Ebene bewertet werden. Unternehmen haben meist weitreichende Erfahrung in der Bewertung einer operativen, prozess-orientierten Performance in der Produktion. Die Bewertung der strategischen Performance eines Produktionsnetzwerks oder Standorts findet aber praktisch nicht statt, da im Produktionsumfeld operative Fragestellungen das Tagesgeschäft bestimmen und die strategischen Werkzeuge zur zielgerichteten strategischen Weiterentwicklung und Bewertung fehlen.

Diese Arbeit adressiert diese praktische und wissenschaftliche Lücke indem sie ein generisches strategisches Performance Measurement und Management System (SPMMS) für Produktionsnetzwerke entwickelt, welches es Managern aus der Praxis erlaubt ein netzwerkspezifisches SPMMS zu implementieren und so die strategische Performance ihres Produktionsnetzwerks zu überwachen.

Diese Arbeit liefert dazu zunächst eine umfassende Definition von strategischer Performance für Produktionsnetzwerke. Diese wird genutzt, um eine Übersicht aller relevanten Performancedimensionen auf Netzwerk- und Standortebene und deren Verknüpfung zu entwickeln. Das so entstandene strukturelle Framework soll von Managern zur Identifikation relevanter Performancedimensionen und der Zielsetzung für Netzwerke und Standorte genutzt werden.

Die firmenspezifische Entwicklung und Implementierung eines SPMMS wird durch ein Prozessframework gestützt, welches existierende Herangehensweisen an Performancemessung und –management vereint und um die Spezifitäten und Bedürfnisse eines Produktionsnetzwerks erweitert. Beide Frameworks werden mit ergänzenden Erkenntnissen untermauert. Die Verifizierung der Anwendbarkeit beider Frameworks erfolgt mit Hilfe von detaillierten Fallstudien. Abschliessend werden die Resultate dieser Dissertation kritisch diskutiert.

SUMMARY

Manufacturing companies increasingly act and produce globally. Managing the resulting global manufacturing networks in unison with the heterogeneous and dynamic requirements of supplied markets is a very demanding task for companies. In this, the goal-oriented, strategic development of manufacturing networks and thus the increase of performance is inevitable. However, putting this strategic development into practice is problematic as the way performance is defined (and evaluated) will greatly depend on external and internal factors and thus cannot be defined consistently for different sites or networks. Generally, performance can be evaluated on a strategic, tactical or operative level. Usually, companies are very experienced in evaluating operative, process-based performance in manufacturing. The strategic performance of a manufacturing network or site, however, is seldom evaluated since manufacturing management is often occupied with operative questions and day-to-day business and the strategic tools for a goal-oriented strategic development and evaluation are missing.

This thesis addresses this practical and scientific gap by developing a generic strategic performance measurement and management system (SPMMS) for manufacturing networks which enables practitioners to define and implement a network-specific SPMMS and monitor the strategic performance of their manufacturing network.

To do so, the presented work develops a comprehensive definition of strategic performance in manufacturing networks. This definition is then utilised to provide an overview of all relevant performance dimensions on network level and site level and identify their interconnection. The resulting structural framework can be used by manufacturing managers to identify relevant performance dimensions and define targets for their manufacturing network and sites accordingly.

The company-specific development and implementation of an SPMMS is further supported by a procedural framework which merges existing approaches to performance measurement and management and extends them to accommodate the specificities of manufacturing networks.

Supporting findings for the successful implementation of an SPMMS are corroborating both frameworks, and the frameworks' applicability is validated with detailed case studies. The thesis closes with a thorough and critical discussion of the findings.

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List of Abbreviations

Abbreviation	Explanation
Bn.	Billion
BPM	Business Performance Measurement
BSC	Balanced Scorecard
BU	Business Unit
CAD	Canadian Dollar
CC	Cable Company (case)
CEO	Chief Executive Officer
cf.	Confer (compare)
CFO	Chief Financial Officer
CHF	Swiss Francs
CoC	Centre of Competence
CoE	Centre of Excellence
COGS	Costs of Goods Sold
COO	Chief Operating Officer
CSR	Corporate Social Responsibility
CTC	Chassis Technology Company (case)
EBIT	Earnings before Interest and Taxes
ed.	Edition

Abbreviation	**Explanation**
EFQM	European Foundation for Quality Management
e.g.	Exempli gratia (for the sake of example)
EHS	Environment, Health and Safety
EMEA	Europe, Middle East and Africa
EPC	Electronic Packaging Company (case)
ERP	Enterprise Resource Planning
et al.	Et alii (and others)
FDI	Foreign Direct Investment
FPE	Finished Piece Equivalent (Strategic Performance Measures of the SPC)
FPY	First Pass Yield
FTE	Full-Time Equivalent (used to measure amount of employees)
GDP	Gross Domestic Product
GM	General Manager
GMN	Global Manufacturing Network
h	Hours
HSG	Hochschule St.Gallen (University of St.Gallen)
IC	Insulation Company (case)
i.e.	Id est (that is)

Abbreviation	Explanation
IfM	Institute for Manufacturing, University of Cambridge
IMF	International Monetary Fund
ISIC	International Standard Industrial Classification
ITEM-HSG	Institute for Technology Management, University of St.Gallen
JIT	Just in Time
kWh	Kilowatt Hours
l	Liters
LF	Lead Factory
Mio.	Million
MN	Manufacturing Network
MRQ	Main Research Question
MPS	Master Production Schedule
MTC	Materials Technology Company
NC	New Contribution
NOK	Norwegian Crowns
NW	Network
OEE	Overall Equipment Effectiveness
OPEX	Operational Excellence
OPMS	Operational Performance Measurement System
PAC	Process Automation Company (case)

Abbreviation	Explanation
PC	Packaging Company (case)
PFC	Pet Food Company (case)
PM	Performance Measurement
PMM	Performance Measurement and Management
PMMS	Performance Measurement and Management Systems
PMS	Performance Measurement System
PC	Pharma Company (case)
PPC	Pharma Packaging Company (case)
ppm	Parts per Million
RADAR	Results, Approach, Deployment, Assessment and Review
ROCE	Return on Capital Employed
ROI	Return on Investment
S.A.	Société Anonyme
SC	Supply Chain
s.l.	Sine loco (without place [of publication])
SMART	Strategic Measurement And Reporting Technique
SME	Small and Medium Enterprise(s)
SMED	Single Minute Exchange of Die
SPC	Sanitary Products Company (case)

Abbreviation	**Explanation**
SPMS	Strategic Performance Measurement System
SPMMS	Strategic Performance Measurement and Management System
SQ	Sub-Question
t	Tons
TdB	Tableau de Bord
TPM	Total Productive Maintenance
UNCTAD	United Nations Conference on Trade and Development
US(A)	United States (of America)
USD	United States Dollars

1 Introduction

This chapter will first introduce the motivation for the current research and highlight its relevance from both a practical and scientific perspective. Secondly, the basic constructs discussed in this thesis are defined. Thirdly, the underlying scientific theory and understanding will be set out. Fourthly, the research objectives and questions will be stated. The chapter closes by laying out the structure of the dissertation.

1.1 Motivation and Relevance

The importance of manufacturing for the global economy is undisputed. In 2012, the manufacturing of physical goods attributed 16 % of the overall global gross domestic product (GDP) (Manyika *et al.*, 2012). The manufacturing share of global trade was estimated at 70 % and with every US dollar of manufacturing output another 19 cents of service input were generated (Manyika *et al.*, 2012). Various studies have illustrated a global growth in overall international production activities (cf. Harre and Moya-Quiroga, 2012; United Nations, 2012). In 2011, employment at foreign subsidiaries of manufacturing companies accounted for 63 million jobs while generating 27 trillion US dollars in sales (an increase of 450 % since 1990) (United Nations, 2012). The United Nations Conference on Trade and Development (UNCTAD) projected a further increase in foreign direct investments (FDI) for 2013-2015 (United Nations, 2013). Over the last 20 years, an increasing amount of corporations have developed and continue to maintain a global footprint (United Nations, 2012). By expanding this global footprint, companies not only strengthen their position in new markets, they also reduce their overall sensitivity to market volatility (Mauri, 2009; Taticchi *et al.*, 2012b). However, as companies further develop their global footprint, the challenge of managing said global footprint increases.

1.1.1 Research Motivation

Fierce global competition forces many companies to search for new opportunities to realise competitive advantages. Managing the global manufacturing footprint from a network perspective and streamlining those networks can lead to cost-savings of up to 45 % (Jacob and Strube, 2008). Often, however, this potential is not realised as it requires a fundamental understanding of the various markets and customers and the diverse technologies and processes involved, which is often not centrally available (Colotla *et al.*, 2003; Jacob and Strube, 2008; Dossi and Patelli, 2010).

Manufacturing networks are understood as globally dispersed manufacturing sites which influence each other and are interconnected in various organisational forms; hence these sites cannot be managed in isolation (Shi and Gregory, 1998; Rudberg and Olhager, 2003). Such networks can be organised in a variety of ways (cf. Schmenner, 1982). Manufacturing sites within a network often differ in their set-up, strategic purpose or competence. These differences can be described in so-called site roles (e.g., Ferdows, 1997; Vokurka and Davis, 2004; Vereecke *et al.*, 2006; Feldmann and Olhager, 2013). To date, only a few companies have undertaken efforts to define a manufacturing strategy that steers the different sites according to their individual roles to a network-wide orchestrated optimum. But even those companies that do define a network strategy can face problems when it comes to implementing and controlling strategies, especially so as the network level optimum might be contradictory to site-level optima. As Wahlers and Cox (1994) point out:

> *"Complexity of technology and the specialization of disciplines in today's business environment have caused increasing separation between the various functions within each organization. Without an overall global linkage of goals and measures the different functions that are part of a typical organization may have very disparate organizational goals and strategic objectives. These differences in goals and objectives have been exacerbated by the traditional organizational performance measurement systems. The lack of coordination of the flow of information, products, or services across functional organizational boundaries has become a subject of growing concern.*" (Wahlers and Cox, 1994, p. 229)

Strategic Performance Measurement and Management Systems (SPMMS) are tools to put strategy into action and monitor the degree of strategy-achievement (Micheli and Manzoni, 2010; Bititci *et al.*, 2012). However, SPMMS described in the scientific literature currently are not designed for manufacturing functions and do not incorporate a network perspective or a differentiated perspective on manufacturing site performance in accordance with site roles (Bititci *et al.*, 2012). As a result, most SPMMS are of little use in the context of manufacturing networks. This gap is further observed by Dossi and Patelli (2010):

> *"Headquarters need to employ management control systems that take into consideration the variegated mix of dependence, independence and interdependence characterising modern relationships between headquarters and subsidiaries. The variety of subsidiaries' roles and of the control systems employed to manage relationships suggests that subsidiary performance is the result of complex combinations of several elements related to international strategies, environmental embeddedness and local entrepreneurship. Therefore, headquarters*

> *face significant challenges in measuring the performance of subsidiaries, which are semi-autonomous entities, capable of making their own decisions but constrained in their actions by the demands of corporate offices and by the opportunities of local environments."* (Dossi and Patelli, 2010, pp. 500–501)

As Gomes *et al.* (2004) point out, there is currently no SPMMS that is broadly accepted in a manufacturing environment. Gomes and colleagues identify a general lack of practical, integrated and realistic PMMS (Gomes *et al.*, 2004). One reason for this striking gap is the fact that performance measurement literature has always followed business trends, and has thus failed to adapt to the emergence of globally dispersed manufacturing networks (Taticchi *et al.*, 2012b).

This thesis aims to close this gap. The goal of this thesis is two-fold. Firstly, it strives to provide frameworks that allow practitioners to implement a strategy and monitor this implementation. This requires the use of a state-of-the-art manufacturing strategy as well as an evaluation of intra-organizational strategic performance all whilst considering the complex environments manufacturing organizations act in. Secondly, it will expand the scientific understanding of performance in the context of manufacturing sites and networks.

1.1.2 Practical Relevance

The global importance of manufacturing in general has already been discussed at the beginning of this chapter. In a study of German manufacturing companies, Zanker *et al.* (2013) showed that companies that manufacture outside of Germany conduct an average share of 39 % of their manufacturing activities abroad. While global manufacturing has been on the rise, it continues to presents companies with difficulties - managing a network of interlinked sites striving for common goals remains challenging (Rudberg and West, 2008). The task of manufacturing managers is complex: They need to decide on the overall vision for the network and derive goals and objectives for each plant (Vereecke *et al.*, 2008). To do so, they have to understand the environment, customers and regions the company operates in. To complicate the matter, the vision and goals of today might prove to be outdated or wrong tomorrow: Managers of global operations also need to understand the dynamism of manufacturing on a global scale. They need to be able to reconfigure manufacturing networks in response to new circumstances or arising business opportunities (cf. Vereecke *et al.*, 2008; Deflorin *et al.*, 2012).

Another challenge for manufacturing networks lies in their origin. More or less autonomous, regionally responsible full scale manufacturing sites have been developed into an interwoven network of focused plants with unique knowledge that are required to work together closely. This trend is expected to further increase as companies need to utilise their intellectual capital wherever it resides (Harre and Moya-Quiroga, 2012). In these interlinked networks, the focus and understanding of manufacturing site performance shifts from an operative and output-oriented understanding with a strong cost focus towards a networking understanding that requires multiple non-financial performance measures to capture the diverse aspects of manufacturing network performance (Dossi and Patelli, 2010). However, not all manufacturing sites within a network are able to contribute equally to the achievement of network level goals; their contribution will depend on their size, competences, equipment and resources (Dossi and Patelli, 2010). To fully realise the potential of a manufacturing network, it should be managed as a whole, in accordance with its site roles (Ferdows, 1997; Blomqvist and Turkulainen, 2011). In general, managers frequently use performance measurement systems (PMS) to put strategy into action (Neely *et al.*, 1994; Micheli and Manzoni, 2010). However, contemporary business management and performance measurement literature often fail to take into account two important facts (Wathen, 1995; Busi and Bititci, 2006): Firstly, manufacturing sites can adopt different roles within a manufacturing network. Secondly, within a business organisation, different types of manufacturing processes, which may yield different results, might be in use at the same time. This makes existing PMS somewhat unsatisfactory, as they do not support a proper implementation of strategy in the manufacturing environment and are unsuccessful in translating a network strategy to the operational level (Busi and Bititci, 2006). Thus, practitioners who base their corporate performance evaluation systems on existing PMS are unable to implement the latest aspects of manufacturing (network) strategy.

This claim can be supported by the following anecdotal case. At the **Chassis Technology Company** (**CTC**), site managers used to be incentivised based on the financial performance (ROCE) of the entire company and their division, and based on the operational performance of their respective division, business unit and site. Goals were only set in those dimensions as well. However, the company had grown from a few manufacturing sites in central Europe to a network of 121 producing companies world-wide and the need for implementing a network perspective in their manufacturing activities became apparent. To manage the manufacturing activities from a network perspective, it was decided that from 2014 on, site managers' performance will be evaluated based on financial performance (40 %), operational performance (40 %) and the achievement of individual strategic goals (20 %), which can incorporate a strategic network perspective. In 2015, the importance of the achievement of individual strategic goals will be increased to 30 %, while the importance of the financial performance will be reduced to 30 %. In general, the introduction of a third performance dimension for site managers shows that the previously existing PMS had to be adjusted and that the sole focus on financial and operational measures had been unsatisfactory. Another example will further illustrate the problem with financial and operational measures in a manufacturing context.

The **Packaging Corporation** (**PC**) produces packaging machines for the pharmaceutical and food industries. The footprint is set up globally and manufacturing follows a local for local strategy meaning that products for a local market are preferably manufactured locally. The reason for this is that the served markets often differ fundamentally. Customers for packaging machines in the food market in Europe are mainly big multi-national companies (e.g., Nestlé S.A., Unilever, Procter & Gamble). These companies mostly have large scale production that requires complex packaging machines which can handle a high product flow. Specialists of **PC** in Europe produce these knowledge-intensive machines with the latest technology. Another market the **PC** serves, India, works very differently however. The Indian government prevents big multi-national food companies from flooding the Indian market. Instead, food is mainly produced by local companies that are mostly SMEs. These companies do not have the massive production volume that would require a complex and high-tech packaging machine. Instead, they want simple machines that are inexpensive and can be maintained by untrained staff. Additionally, many packaging tasks are done manually since labour costs are low. Therefore, the machines in India are simple, low-tech machines that are designed and built locally. It is evident that customer requirements greatly differ between these two markets. This also has implications for the way the goods are produced. Using operational and financial performance measures to evaluate the performance without incorporating the special local market requirements and manufacturing characteristics might work on a business level (e.g., a sales increases by 5 % would mean for both regions they are doing well) but will not work on a manufacturing level. For example, the general comparison of stock levels will show that India has higher stock levels than the European sites. The goal to reduce the stock level might work for the European manufacturing sites as their suppliers are highly flexible and deliver just in time (JIT), but might show to be detrimental for the Indian site. A lower stock level can lead to a production halt since local suppliers cannot deliver quickly and reliably enough. Using financial and operative level performance measures for the performance comparison of the manufacturing sites is also difficult. Many financial performance measures are completely or partially outside of the responsibility areas of the site managers (e.g., Sales and Return of Sales). And comparing manufacturing costs or cost structures too will fail to provide any satisfying results as the different manufacturing concepts vary greatly. Using the annual output of manufactured machines as an operative performance measure in the comparison of sites is also difficult as the Indian site produces more machines than the European sites. However, the machines in India are less complex and easier to manufacture. Therefore, it is not possible to say which site performs better solely based on financial and operational performance indicators - site roles need to be incorporated in the assessment of performance, and backed by an understanding of the local environment.

In a study conducted by the University of St.Gallen[1], network managers were asked in what dimensions goals for manufacturing sites managers were set. The result showed that the main foci were put on financial and operational performance. Only roughly 28 % of the participants stated they also incorporate the achievement of strategic goals in the site-specific performance evaluation of manufacturing sites. The same is true for the contribution to corporate learning.

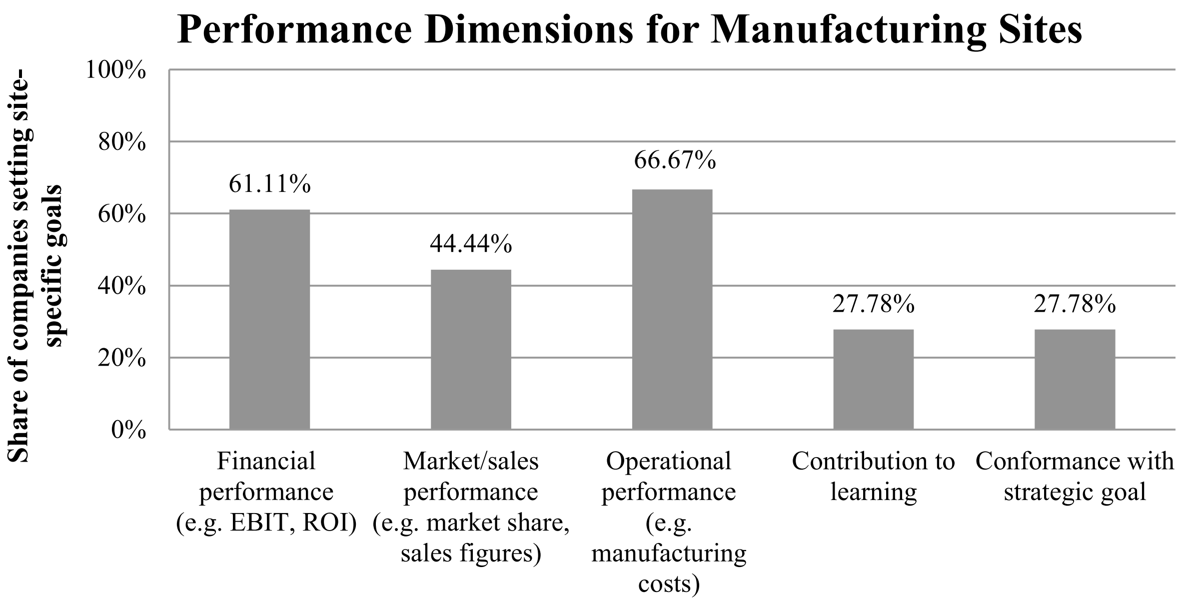

Figure 1 – Performance Dimensions for Manufacturing Sites

This supports the conclusion that although managers in manufacturing networks are aware of the shortcomings of traditional financial and operational performance measures in a manufacturing network environment, few are able to overcome the focus on financial and operational performance measures imposed by traditional PMS.

These and other experiences from various industries support the notion that the understanding of manufacturing performance currently fails to incorporate network-related dimensions and other long-term strategic aspects. Managers of manufacturing networks have difficulties incorporating a long-term network strategic perspective in

[1] The study was conducted by the Institute of Technology Management between April and November 2012. A total of 36 companies participated in the study.

existing PMS and therefore often in the incentive systems of corporations. This leads to the self-optimization of manufacturing sites based on the financial and operational performance measures imposed by traditional PMS. Furthermore, the neglect of site roles in existing PMS makes it difficult to compare site performance and derive any sort of recommendations based on traditional performance measures in a manufacturing environment.

1.1.3 Theoretical Gap

Previous research on performance measurement and management has been extensive to say the least (cf. Marr and Schiuma, 2003; Bititci *et al.*, 2012). However, none of these studies has yielded a broadly accepted PMS that is also valid for manufacturing networks (Gomes *et al.*, 2004; Richard *et al.*, 2009; Bititci *et al.*, 2012). The reason for this is that academics in PMS research often are more focused on scientific rigour than practical results (cf. Bourne, 2008). In the context of performance measurement this has led to the discussion of minutiae and oversimplified models instead of fundamental and complex real-world problems (Bourne, 2008). Researchers in PM therefore seldom create new practices (Bourne, 2008). Chapter 2 will discuss the overall development of the scientific coverage of performance measurement in manufacturing networks and the resulting gaps. In general, the following gaps will be guiding for the current research:

- Firstly, to date there is no common understanding of strategic manufacturing performance, neither on a network nor on a site level. In particular, a multi-dimensional understanding regarding performance is lacking (cf. Hon, 2005; Nguyen, 2011; Pekkola and Ukko, 2011; Bititci *et al.*, 2012). This is also supported by the fact that in a manufacturing environment strategic performance is rarely distinguished from operational performance (measures) (Gunasekaran and Kobu, 2007).
- Secondly, there is a general lack of strategic performance measurement and management systems that are suitable for manufacturing networks as the current systems do not incorporate network thinking and fail to connect network level goals and performance to the site level (cf. Dangayach and Deshmukh, 2001; Colotla, 2003; Pekkola and Ukko, 2012; Thomas, 2013).
- Thirdly, existing Strategic Performance Measurement and Management Systems (SPMMS) neglect the dynamism of the business environment, the variance of strategies and the general complexity of manufacturing in multinational corporations (cf. Wathen, 1995; Medori and Steeple, 2000; Busi and Bititci, 2006; Dossi and Patelli, 2010; MacBryde *et al.*, 2012).

- Fourthly, existing SPMMS lack the integrativity and interactivity towards all manufacturing network levels that is needed for defining strategic performance in a network context (Dossi and Patelli, 2010). SPMMS-research of the future should support practitioners in the implementation and development of performance management rather than performance measurement (cf. Neely, 2005; Bourne, 2008; Dossi and Patelli, 2010).

1.2 Basic Definitions, Research Background and Foundation

The literature on performance measurement and manufacturing networks is diverse and spans many scientific disciplines and topics. This has led to the emergence of a variety of terms, concepts and definitions that are partly overlapping and sometimes contradictory. Thus, this section defines the basic concepts and constructs used in this thesis. These definitions are based on exhaustive literature work in Chapter 2 and hence comprise conclusions which will only be later developed. Thus, some findings and definitions are given more than once in the course of this thesis. This was considered necessary, as the early presentation of definitions is crucial to create a thorough initial understanding of the topic while the detailed derivation of definitions was part of the research process.

1.2.1 Definitions Related to Manufacturing Networks

Manufacturing

Manufacturing describes processes and methods used to transform tangible (raw materials, semi-finished goods etc.) and intangible (ideas, information etc.) inputs into goods and services (cf. Stevenson, 2010). The words “manufacturing” and “production” are often used synonymously; however, “production” can also refer to creative processes such as writing a book. Manufacturing in the context of this thesis exclusively describes large-scale industrial processes which require machinery and specialised knowledge.

Manufacturing Function

A company is typically divided into organisational units (functions) which take over different tasks for the organisation (e.g., marketing, finance, human resources). The functions can be responsible for the activities of the entire company or for a division or business unit only. This depends on the organisational set-up of the organisation. The manufacturing function is typically responsible for the management of physical resources (raw materials, equipment, labour and working capital) in order to provide physical products or services in accordance to customer demands (Panneerselvam, 2007). The manufacturing function decides where which manufacturing steps are conducted with what equipment and what focus. It further decides how the manufacturing activities are interlinked.

Manufacturing Site

For this thesis, a manufacturing site is defined as a physical entity (building) where manufacturing takes place. Synonyms for a manufacturing site are "factory", "plant" or "subsidiary". A manufacturing site is embedded in a manufacturing network and plays a distinctive role within the network which is connected to the manufacturing strategy of the network (cf. Gupta and Govindarajan, 1991; Ferdows, 1997; Vereecke and van Dierdonck, 2002; Meijboom and Vos, 2004; Vereecke *et al.*, 2006; Ferdows, 2008; Miltenburg, 2008; Vereecke *et al.*, 2008; Kretschmer, 2008; Miltenburg, 2009). Manufacturing sites can also add value through activities in R&D, process and product engineering, customer support/service and other activities connected to manufacturing.

Manufacturing Network

A manufacturing network is a network of manufacturing sites which belong to a single company (cf. Shi and Gregory, 1998; Slack, 2005; Mundt, 2011; Thomas, 2013). According to the typology provided by Rudberg and Olhager (2003), a manufacturing network is a so-called intra-organisational network. An often-used synonym is the term "production network". The manufacturing sites within manufacturing networks are often geographically dispersed. Such networks are understood as scattered nodes (sites) with matrix connections where each node affects the other and cannot be managed in isolation (Shi and Gregory, 1998; Rudberg and Olhager, 2003; Rudberg and West, 2008).

Manufacturing Strategy

Based on the literature review in Section 2.1, the following definition was adopted: A manufacturing strategy is the strategy revolving around the manufacturing function of a company and is connected to the overall corporate strategy. Thus, it needs to be aligned with other aspects of the corporate strategy and other functional strategies within a company. The manufacturing strategy describes how structural and infrastructural levers are utilised to realise the strategic focus regarding manufacturing and network capabilities in the manufacturing of goods. The goal is to develop a competitive advantage based on the manufacturing function and support corporate goals and objectives.

1.2.2 Definitions Related to Performance Measurement

Performance

Literature on performance measurement provides a wide array of definitions for the term "performance". The scope varies from the unit performing in a given task (e.g., single person, department, division, business unit or company), the addressed stakeholder (e.g., suppliers, customers, shareholders, employees) and the perspective the performance is evaluated against (e.g., inside vs. outside, financial, sustainability, operational, marketing, human resource, manufacturing) (cf. Neely *et al.*, 1996b; Hilgers, 2008; Lebas and Euske, 2008; Meyer, 2008; Richard *et al.*, 2009; Pekkola, 2013).

In general, Neely *et al.* (1995; 1996b) define performance as the efficiency and effectiveness of action (also cf. Bourne *et al.*, 2003). "Efficiency" can be understood as the concept of doing things right which means that a certain product is created supported by processes while utilising needed resources as economically as possible (Müller-Stewens and Lechner, 2005). "Effectiveness" refers to the concept of doing the right things (Müller-Stewens and Lechner, 2005). In the context of manufacturing networks, effectiveness incorporates the strategic decisions of what manufacturing steps will be done where and with what resources, whereas efficiency describes how well given processes exploit needed resources while generating output (products, components etc.).

However, whether an action is actually effective or efficient can only be determined against a point of reference. Grüning (2002) and Kretschmer (2008) define performance as the degree of goal achievement. This rational goal approach does not specify which goals are chosen (Kretschmer, 2008). In general, goals can be set by 1) using past action as a reference, 2) using comparable action as a reference or 3) simply defining a desired outcome (cf. Lönnqvist, 2004; Kretschmer, 2008; Pekkola, 2013). In the context of companies, the top management defines goals based on corporate strategies, the corporate environment and past experiences in the organisation (cf. Bartlett, 1989; Kretschmer, 2008). It is further important to note that performance is a multi-dimensional concept and cannot be evaluated by focusing on one isolated performance measure or dimension (e.g., financial dimension) (Krause and Mertins, 2006). Performance is also dependent on the context it is evaluated in (Lebas, 1995; Krause and Mertins, 2006; Kretschmer, 2008).

In the context of manufacturing networks, goals for production sites and the entire network are derived from the overall corporate strategy and the environment of the manufacturing function. The strategic performance of a manufacturing network or a manufacturing site is therefore defined as the degree of fulfilment of the manufacturing strategy set for the site or the network while considering the influence of contextual factors. This is illustrated in Figure 2.

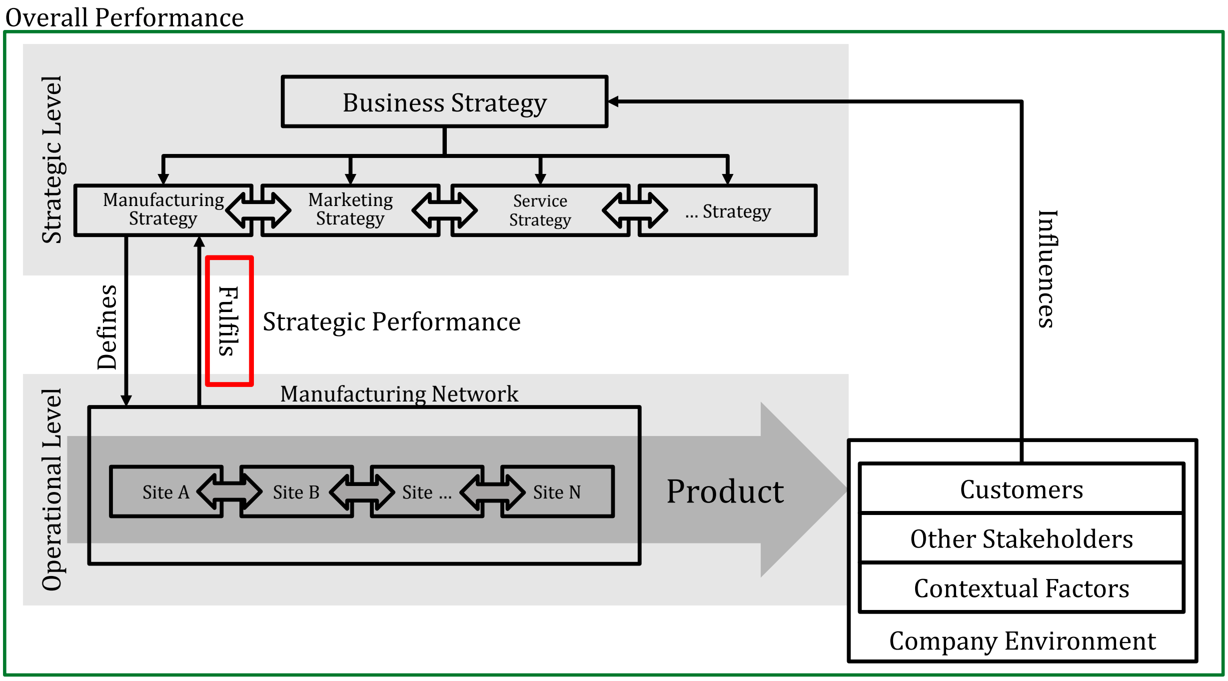

Figure 2 – Strategic Performance of Manufacturing Networks

Performance Measures

A performance measure is a metric used to capture the efficiency and/or effectiveness of action (e.g., Neely *et al.*, 1996b; Bourne *et al.*, 2003; Neely *et al.*, 2005). Performance measures can be financial or non-financial, internal or external, quantitative or qualitative and lagging or leading (e.g., Eccles, 1991; Gregory, 1993; Neely *et al.*, 1997; Epstein and Manzoni, 1998; Bourne *et al.*, 2000; Gomes *et al.*, 2004; Meyer, 2008). They should be connected to strategy (e.g., Neely *et al.*, 1994, 1996b; Neely *et al.*, 1997; Neely, 1999; Bourne *et al.*, 2000; Bendoly *et al.*, 2007; Bhasin, 2008; Micheli and Manzoni, 2010; Braz *et al.*, 2011; Bisbe and Malagueño, 2012; Zanon and Alves Filho, 2012). The terms indicator, metric and Key Performance Indicator (KPI) are often used synonymously. In this research the term performance measure will be used.

Performance Measurement (PM)

Performance measurement (PM) is the process of using a multi-dimensional set of performance measures to capture efficiency and effectiveness of action (cf. Neely *et al.*, 1996b; Bourne *et al.*, 2003; Neely *et al.*, 2005; Taticchi *et al.*, 2010; Braz *et al.*, 2011).

Performance Measurement Systems (PMS)

A performance measurement system (PMS) basically consists of two PM frameworks, one structural and one procedural. These two are interlinked and support each other (Folan and Browne, 2005). The structural perspective defines a PMS as a set of measures, while the procedural perspective defines a PMS as a process (Folan and Browne, 2005). According to the structural perspective, a performance measurement system (PMS) is a set of performance measures used to capture the efficiency and effectiveness of actions (Neely *et al.*, 1996b). Its performance measures should reflect the aspects of strategy and provide a balanced picture of overall performance (cf. Neely *et al.*, 1994, 1996b; Neely *et al.*, 1997; Neely, 1999; Bourne *et al.*, 2000; Neely *et al.*, 2005; Bhasin, 2008; Micheli and Manzoni, 2010; Braz *et al.*, 2011; Bisbe and Malagueño, 2012; Zanon and Alves Filho, 2012). A structural framework focusses on the structure of performance measures by providing a typology for performance measures while a procedural framework describes the procedure of delineating performance measures from strategy (Bourne *et al.*, 2003; Folan and Browne, 2005; Bititci *et al.*, 2012). Performance Measurement Systems can be strategic, looking at the long-term goals, or operational, focussing on day-to-day business performance.

Performance Measurement and Management (PMM)

Folan and Browne (2005) thoroughly discussed the term performance management. While performance measurement is just the collection of data, performance management uses the collected data to make a positive change to an organisation (Amaratunga and Baldry, 2002; 2005; Busi and Bititci, 2006; Karrer, 2006) by setting appropriate performance goals, allocating and prioritising resources, instructing managers of the policies in place and sharing the results (Amaratunga and Baldry, 2002; 2005; Busi and Bititci, 2006; Karrer, 2006; Pekkola, 2013). Neither performance management nor performance measurement are stand-alone solutions. They follow one another in an iterative process. Performance management sets the basis for performance measurement and follows upon performance measurement and creates the context for its existence (Lebas, 1995; 2005; Pekkola, 2013).

Performance Measurement and Management Systems (PMMS)

Taticchi and Balachandran (2008) and Taticchi *et al.* (2012a) expand the view on Performance Measurement and Management by discussing Performance Measurement and Management Systems (PMMS). A PMMS essentially contains a PMS and five milestones which embed a PMS in an organisational context. The perspectives of Folan and Browne (2005) and Taticchi and Balachandran (2008) and Taticchi *et al.* (2012a) can be summarized as depicted in Figure 3.

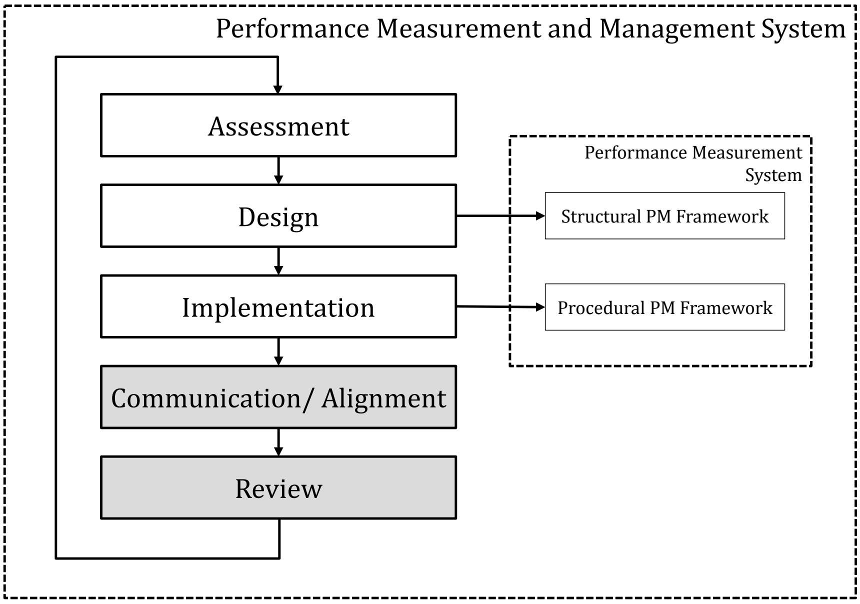

Figure 3 – Milestones of PMMS and their components

At this point it can be concluded that a PMMS is a system which is used to design, implement and communicate a PMS. The PMS will be updated periodically and is used to derive actions to change an organisation positively (Melnyk *et al.*, 2013).

Strategic Performance Measurement and Management Systems (SPMMS)

As noted previously, PMS, and therefore also PMMS, can be strategic, tactical or operational. Neely *et al.* (1994) state that PMS are a means for realising strategy. According to the definitions of SPMS by Gimbert *et al.* (2010) and Bisbe and Malagueño (2012), SPMS contain both strategic and operational measures. However, as Gunasekaran and Kobu (2007) point out, most existing PMS concentrate on operational process measures only. These operational process measures often fail to properly reflect strategy. This is especially problematic for the measurement of strategic manufacturing performance when "*[...] many of the manufacturing strategies are based on structural properties embodied in the system architecture, technology resources and system control policies*" (Gunasekaran and Kobu, 2007, pp. 2829–2830) and not on process outputs. It has to be concluded that a SPMS for manufacturing networks requires special strategic performance measures that reflect the achievement of strategy. Franco-Santos *et al.* (2007) add that from a strategic perspective a PMMS is not just a set of performance measures. Instead it reflects the procedure to cascade down performance targets and measures, and thus implement strategy, and it also provides information that challenges the content of existing strategies and policies. Therefore, the concept of an SPMMS is defined as follows:

An SPMMS is a system which is used to design, implement and communicate a SPMS. The SPMS has the goal to monitor the fulfilment of the defined long-term strategies, is used to derive information to change an organisation positively and adjust strategy. A SPMS needs to be updated periodically. The SPMS further contains (1) performance measures in various perspectives which reflect strategy in a balanced matter, (2) goals and action plans connected to the long-term strategy for each perspective and (3) a causal relationship between goals and performance measures (cf. Gimbert *et al.*, 2010; Bisbe and Malagueño, 2012; Zanon and Alves Filho, 2012; Melnyk *et al.*, 2013).

1.3 Contingency Theory, Manufacturing Networks and Performance Measurement

This section will outline the scientific theory underlying this thesis. Contingency theory was chosen for two reasons. Firstly, contingency theory has been broadly and successfully applied to operations research and performance measurement research. Thus, it has proven its suitability and worth to these research streams. Secondly, this thesis will develop a generic framework that is supposed to be applied to various manufacturing networks from a multitude of backgrounds, industries and organisational structures. Contingency theory allows accommodating to this variety, as will be further illustrated in the following paragraphs.

The roots of contingency theory lie in systems theory (Lawrence *et al.*, 1967; Thompson, 1967; Kretschmer, 2008). Contingency theory has been dominant in the past when discussing organisational theory and performance (Drazin and van de Ven, 1985). In its essence, contingency theory states that an organisation achieves better performance[2] when it is externally aligned to its environment and internally aligned in its processes and structures (Friedli, 2006; Sousa and Voss, 2008). Drazin and van de Ven (1985) distinguish three types of approaches to describing contingency (fit): Selection, Interaction and Systems Approach. These three approaches differ in their underlying views on the initial situation of an organisation and the current-future view. Both views are connected to different underlying definitions and test methods. This perspective is complimented with Venkatraman's (1989) six types of fit in contingency theory. These forms of fit are based on the degree of precision of the functional form of fit and the number of variables incorporated into the fit consideration (Sousa and Voss, 2008). The

[2] The individual definition of performance depends on the context an organisation operates in.

six types defined by Venkatraman are: moderation, mediation, matching, gestalts, profile-deviation and co-variation. Sousa and Voss (2008) noted that these two perspectives are connected and the different types are overlapping; this is illustrated in Figure 4 (cf. Drazin and van de Ven, 1985; Venkatraman, 1989; Sousa and Voss, 2008).

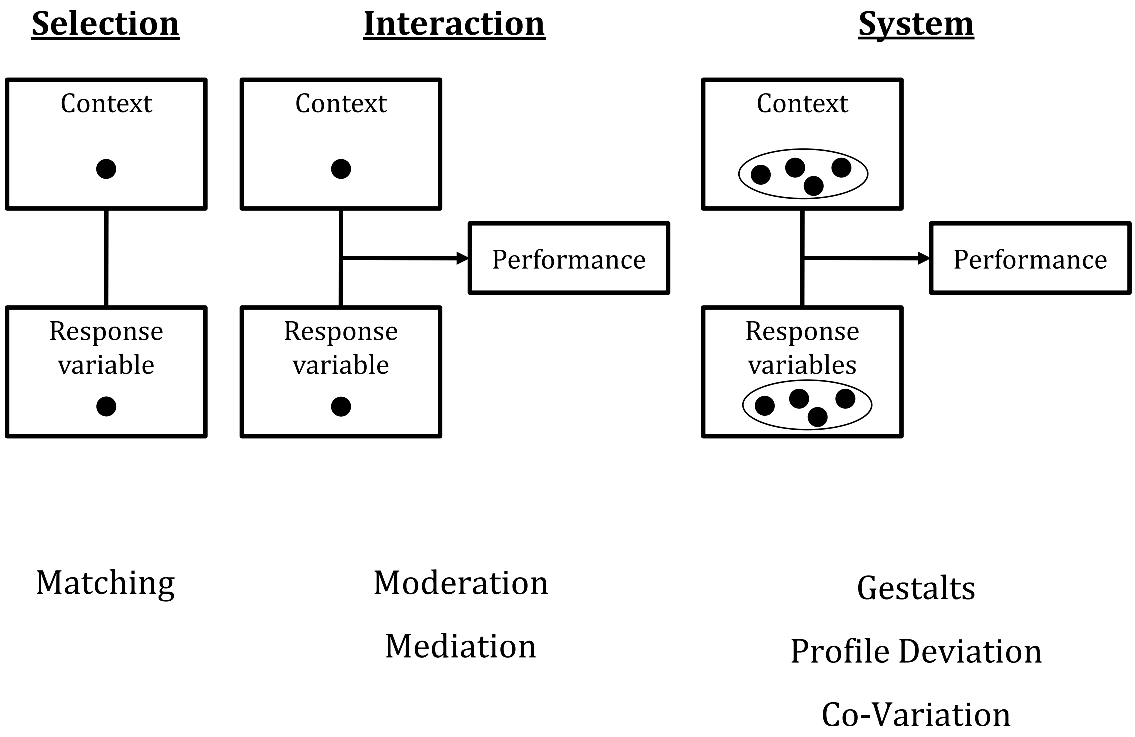

Figure 4 – Different Types of Fit

For the current research, the systems approach will be the underlying concept. Following the system approach, the management of manufacturing networks will be understood as a set of interrelated response variables that must be aligned with each other and with external contextual variables. For this research, several types of fit have to be considered. Firstly, the set-up of the overall manufacturing network (the layers manufacturing strategy, manufacturing network coordination and manufacturing network configuration are distinguished (for further details see Mundt, 2012; Thomas, 2013) needs to fit to its external environment (e.g., markets, customers, legislations etc.). This is called the external fit. The second fit describes the internal alignment of decision dimensions and their variables within each layer and between the different layers. This is called the internal fit. Last but not least, the performance measurement and management system employed in manufacturing network needs to fit to the manufacturing network. And since the overall manufacturing network should be aligned with the external factors, the performance measurement and management system will indirectly be aligned to the external factors as well. This last fit is the relevant one for the work at hand. The developed strategic performance measurement and management system needs to accurately reflect the specifics of the implementing manufacturing network to function successfully. The description of the three different types of fit is consistent with findings in the literature. Neely *et al.* (2005), Franco-Santos and Bourne (2005) and Melnyk *et al.* (2013) state that a SPMMS needs to be in line with the external environment (the one the organisation is facing) and the internal environment.

As pointed out by Drazin and van de Ven (1985), in the current-future view of systems fit there are multiple equally effective internally consistent patterns of organisational context and structure. This concept is called equifinality. Equifinality means that there is no single best way to achieve fit between internal response variables and external contextual variables (Donaldson, 1985; Sousa and Voss, 2008). Transferred to a business environment, this means that the optimal business practice is dependent on the outside environment but there are multiple ways to achieve this optimal business practice (Shetty, 1974; Kretschmer, 2008). This essentially means that what companies have to do in order to perform well in the market depends on the specific market and situation they are in. Therefore, performance is market- and situation-dependent. It can be concluded that:

- Manufacturing networks need to be aligned both externally and internally in order to be successful. There are multiple, equally effective ways of organising a manufacturing network.
- SPMMS need to fit the organisation (manufacturing network). They need to reflect the specific structure of the manufacturing network and the contextual factors.
- The definition of performance is context-dependent and varies between organisations and different environments.

1.4 Research Objectives and Research Questions

Based on the previous findings and discussions, the main research question (MRQ) of this thesis is:

MRQ: What are special requirements of intra-firm manufacturing networks and how do they need to be incorporated into a holistic strategic performance measurement and management system?

In order to answer the main research question, the following three sub-questions (SQ) are investigated:

SQ.1: How can strategic site and network performance in the context of intra-firm manufacturing networks be defined?

The first subquestion asks what strategic performance on a network and a site level actually is. A clear definition of performance is necessary before performance dimensions and measurement of the performance can be discussed.

SQ.2: What are the performance dimensions of a holistic SPMMS for intra-firm manufacturing networks?

To fully understand strategic performance in the context of manufacturing networks, the dimensions in which manufacturing networks can perform need to be established.

SQ3: How can a holistic strategic performance measurement and management system for intra-company manufacturing networks be designed?

Finally, a process is needed that supports the definition and derivation of site- and network-strategic performance targets from strategy and that supports the evaluation of performance and continuously updates site and network strategy.

1.5 Research Methodology and Design

This sections aims at illustrating the research grounding and process and the general research methodology as well as the process of theory building. The discussion in this section will be transferred transparently into the structure of the dissertation in section 1.6.

1.5.1 Research Grounding and Process

In line with St.Gallen tradition, this research sees business studies as an applied social science (Ulrich *et al.*, 1983; Bleicher, 2011). The basis for this type of research are practical management problems of manufacturing companies – business studies then aim at providing practical solutions for identified problems while ensuring scientific validity. Based on Ulrich (1983), it business studies strive for the development of a normative model that influences the social reality. Based on this approach, the goal of this research was not the testing of theory-driven hypotheses (Kubicek, 1977). Instead, the current research strives for the development of new theory and models that aid in the design of realities in today's manufacturing networks (Ulrich *et al.*, 1983).

The core problem with the concepts discussed in this thesis, namely strategic performance, performance measurement and management and manufacturing networks, is their inherent complexity. Therefore, in the context of this thesis the aspiration of full controllability is dismissed. This thesis thus differs from approaches of natural sciences with their irrefutable logic in their search for a general truth (Ulrich, 1983; Giddens, 1984; Friedli, 2006). The current thesis focuses on qualitative research, the analysis of reality and the application of models to reality. It seeks to establish a sound understanding of reality and to derive models and concepts which are beneficial for both academia and practice (Gassmann, 1999). To do so, the research process is designed as an iterative process (Kubicek, 1977) with the researcher playing an active role in the studied phenomena. The iterative process depicted in Figure 5 starts with a basic theoretical understanding of real-life phenomena which is used to raise questions towards practice (cf. Kubicek, 1977). The questions are answered through the collection of empirical data. However, these data raise new questions, leading to a systematic and incremental accumulation of experiences and their transformation into theoretical knowledge.

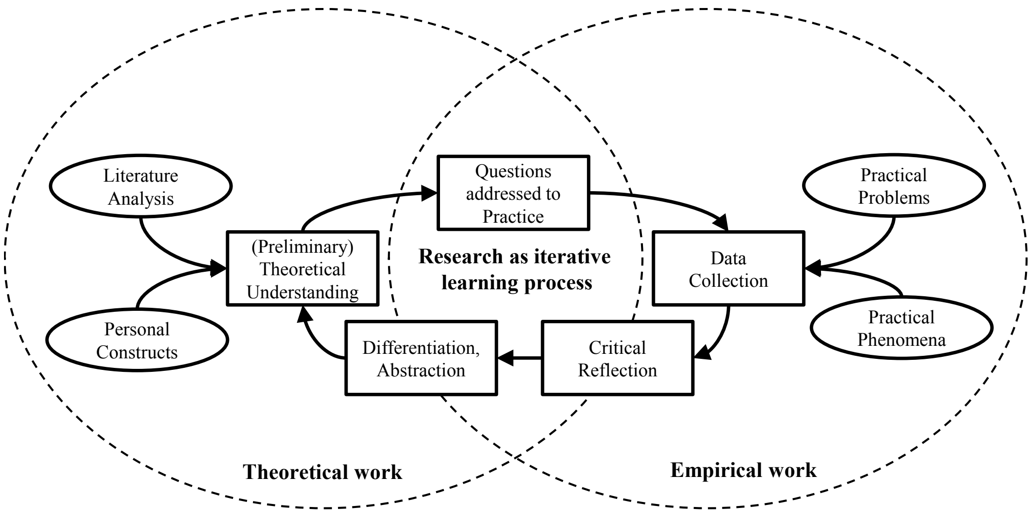

Figure 5 – Iterative Research Process based on Kubicek (1977)

1.5.2 Research Methodology and Theory Building

The research questions and topics addressed in this thesis are motivated by practical problems of manufacturing companies with a multi-national or global spread of manufacturing sites that operate in manufacturing networks. As outlined above, the current research is based on the understanding of Ulrich (1983) and Kubicek (1977).

This thesis mainly utilises qualitative research approaches, more precisely case study research. Qualitative research is most useful when the following applies:

- The research is aiming at answering "how" and exploratory "what" questions rather than "who, where, how many and how much" questions (Yin, 2003)
- The research is aiming at taking over a position that aspires a general and holistic understanding of the research object instead of oversimplification and the testing of simplified hypothesis (Easterby-Smith *et al.*, 2012).

- The research covers new grounds and aims at the establishment of new theories. Furthermore results are assumed and should be looked at from a new perspective (Eisenhardt, 1989; Yin, 2003)

While the research process was highly iterative (see Figure 5), it is presented in a more structured way here to clarify the thought process and the interconnection between the different chapters. In summary, the research process of this thesis is understood as a theory-guided learning process that is based on systematically refined knowledge from practice experiences. The process aims at gaining practical knowledge and creatively translating said knowledge into theoretical conclusions.

Phase I – Understanding Practical Relevance

Based on previous research and experience from interactions with manufacturing companies, the initial research interest was developed. This interest was then further extended by a literature review focussing on the general aspects of performance measurement and manufacturing as well as input from industrial companies.

Phase II – Desk Research

The initial understanding of the problem served as a basis for an in-depth literature review covering literature on manufacturing networks and performance measurement and management. The literature review was conducted using the structured approach by vom Brocke *et al.* (2009). This structured and extensive literature review was necessary to gather and structure existing knowledge regarding strategic performance measurement and management and regarding manufacturing networks and related literature fields. The review allowed identifying research gaps and deriving research questions. Furthermore, the review was used to develop a heuristic research framework. During the literature review it became increasingly evident that key scientific terms were not defined consistently across various publications; this was true for performance measurement and management as well as manufacturing network literature. Therefore, key terms had to be defined in this phase to ensure a consistent research proceeding. During the review, important findings and aspects were supported with anecdotal evidence from practice. The literature review culminated in a summary that provided innovative conclusions and pointers for the SPMMS to be developed and strategic performance measurement and management in practice. They also identify requirements of manufacturing towards SPMMS and shortcomings of existing SPMMS.

Phase III – Model Development

Based on the extensive literature review and findings from practice, a structural and a procedural framework were developed which support the manufacturing network-specific development of SPMMS. As a first step in model development the various scientific and practical requirements on a SPMMS for manufacturing networks were derived. These requirements were then used to evaluate existing SPMMS. This evaluation identified the gaps in current scientific literature and served as the basis for the framework development. Both developed frameworks incorporated the latest scientific knowledge regarding strategic performance measurement and management and manufacturing networks. The developed frameworks were created with a strong focus on scientific validity and practical applicability. While they were based on existing scientific knowledge, they revolutionise the understanding, implementation and measurement of strategic performance in manufacturing networks.

The structural framework broke down the aspects of strategic performance into distinctive dimensions, which are easily graspable by practitioners and researchers alike. To do so, the content of manufacturing strategy was extended by a broad stakeholder perspective in line with most recent observations of SPMM research. It was further acknowledged that strategic performance on manufacturing network and site level is closely interconnected but needs to be adjusted for every entity in the network according to site roles.

The procedural framework incorporated state of the art of procedural approaches in scientific SPMM literature. However, it was amended to suit the specificities and requirements of manufacturing networks towards SPMMS. That is, it incorporated different levels of a manufacturing network and the possibility to include varying performance foci along those levels.

Since the structural and procedural frameworks were based on the latest findings in scientific literature, Phase III closed with a list of new contributions towards SPMMS that needed to be verified in Phase IV.

Phase IV – Validating the Model

The model, which was based on thorough scientific work and an understanding of the practical problem, was validated in Phase IV. Since the procedural and structural framework were based on existing knowledge in the areas of SPMMS and manufacturing networks, the validation focussed on the new contributions identified at the end of phase III. However, each performance dimension of the structural framework and each step of the procedural framework were also validated. Case studies were chosen for the validation. The case studies stem from a variety of industries, and represented companies of different sizes and strategic foci. Furthermore, the case studies varied in their network design, defined site roles and general network management maturity. While the depth and focus of the case studies varied, each displayed specific characteristics of the SPMMS at the case study companies.

Phase V – Critical Reflection

In a final step, the findings and developed frameworks were critically reflected on. This was done by discussing and critically assessing the findings from theory and practice for each strategic performance dimension of the structural framework, for each step of the procedural framework and each new contribution.

Underlying Data

The concepts and ideas in this dissertation have been gathered through extensive project and research work with companies from multiple industries. The involved companies as well as the companies incorporated in the case studies were kept anonymous. The data incorporated into the case studies was taken from various sources such as workshops, interviews, company presentations, strategy papers and company-internal databases as well as studies conducted by the institute of technology management. While the interaction with many companies as well as the findings of studies conducted by the Institute of Technology Management have shaped the author's perspective and understanding of the topic of the thesis at hand, they are not all covered in detail in this thesis. The following table gives an overview of the underlying data and highlight the data that is directly incorporated into this thesis. Further details about the companies discussed in the case studies are provided in section 4.1.

Company	*Industry*	*Involved Functions*	*Data Gathering*		*Used for*
			Interviews	*Workshops*	
Electronic Packaging Company*	Electronic packaging products	CEO, CFO, Head of Sales, Head of Logistics, Product Line Manager, Supply Chain Manager*	Multiple Interviews on Site	10 (4 h per Workshop)	Case Study
Pet Food Company	Pet food	Head of Global Production, Head of Supply Chain Management	1 (ca. 7 h per Interview)		Case Study
Cable Company*	Connectivity Solutions	Head of Global Operations, Project Manager Global Operations, COO of all BUs, Site Heads*	4 (ca. 2 h per Interview)	12 (4 h per Workshop)	Case Study
Materials Technology Company	High Tech Metal Components	Head of MTC Technology, Innovation & Sustainability, Project Manager PMS	2 (ca. 2 h per Interview)		Case Study

Company	Industry	Involved Functions	Data Gathering		Used for
			Interviews	Workshops	
Sanitary Products Company	Sanitary Products and Technology	Head of Manufacturing Network	1 (ca. 4 h per Interview)		Case Study
Pharma Company	Pharmaceutical Industry	Senior Director, Network Performance Lead,	1 (ca. 2 h per Interview)		Case Study
Insulation Company	Building Insulation Materials	CFO, Head of Operations, Markeging		4 (6 h per Workshop)	Case Study
Packaging Company	Manufacturer of packaging machines for	Head of Manufacturing		3 (6 h per Workshop)	Anecdotal Evidence
Chassis Technology Company	Driveline and Chassis Technology	International Location Planning, Various Site Heads		4 (ca 4 h per Workshop)	Anecdotal Evidence
Pharma Packaging Company	Co-Packer for Pharmaceutical Products	CEO, Head of Production, Head of Sales, Head of Controlling	1 (ca. 4h per Interview)	2 (6 h per Workshop)	Anecdotal Evidence
Process Automation Company	Measurement Solutions for Industrial Processes	COO, Product Manager, Production Manager	2 (ca. 2h per Interview)		Anecdotal Evidence
White Ware Company	Household Appliances	Head of Central Technology, Heads of Product Divisions, Head of Manufacturing Site, Head of Central Controlling	1 (ca. 2h per Interview)	7 (7 h per Workshop)	Shaping Understan ding
Dairy Company*	Cheese and other Milk Products	Head of Production Cheese, Head of Production Milk, Head of SCM, Project Manager Business Development, Project Manager Global Support		10 (4 h per Workshop)	Shaping Understan ding
Chocoalate Company*	Producer of Chocolate and Chocolate Products	Head of International Operations, Manager Production, Manager SCM, Manager Controlling		10 (4 h per Workshop)	Shaping Understan ding
Technology Supplier Company	Supplier of Technologies and Services in many fields	Central Manufacturing and Investment Planning, Various BU Manufacturing Heads		6 (4 h per Workshop)	Shaping Understan ding
Steering Company	Steering Columns for Cars and Trucks	Head of Business Development, Project Manager Business Development	1 (ca. 4h per Interview)		Shaping Understan ding
Plastics Company	Plastic-based Products for the Building and Automotive Industry	Division COO	1 (ca. 2h per Interview)		Shaping Understan ding
		Total	>14 (>41 h)	68 (311 h)	

VELA Study 2005 – 48 Participants

Scope Study 2012 - 36 Participants

*** =** The companies also conducted an internal quantitative survey targeting all major manufacturing sites which targeted the sites' understanding of strategy and performance.

Table 1 – Overview of the Underlying Database

All company information has been anonymised so that critical strategic information can serve as a basis for the case studies in this thesis. The data underlying this thesis is mostly of qualitative nature. It was gathered through work at the manufacturing companies in workshops, interviews, strategy material of the companies and additionally with quantitative surveys addressing manufacturing sites of some of the companies (marked with an asterisk in Table 1). The contact persons for workshops and interviews were working in the mid- to top-management level. Furthermore, two quantitative industry studies conducted by the Institute of Technology Management also addressed aspects of strategic performance measurement and management. The findings have been included in this thesis. Overall, the combination of qualitative and quantitative data and the fact that multiple researchers where involved in data gathering allows scientific triangulation.

1.6 Dissertation Structure

The structure of the dissertation is outlined in the following paragraphs. Generally, the topic of manufacturing networks and strategic performance measurement and management is very diverse. Therefore, a large part of this thesis is devoted to a thorough review of the relevant literature. Based on literature review and industry insights, a structural and a procedural framework are developed which support SPMMS development at industrial companies. These frameworks and the new contributions to science developed along the frameworks are tested for their applicability through detailed case studies. This is followed by a detailed examination of the findings in this thesis. The following chapters structure this thesis:

Chapter 1 – Introduction

Chapter 1 sets out the motivation for the current thesis. The relevance of the current work for both research and practice is outlined and a gap in the existing knowledge is illustrated. Relevant terms used throughout the thesis are defined to establish an understanding of the discussed topics. Based on the identified research gap, the research objective is formulated. Finally, the aspired achievement of the research objective is matched with a fitting research methodology and dissertation structure.

Chapter 2 – Literature Overview

Chapter 2 introduces and discusses previous findings and concepts in the scientific literature. The chapter is split into two sections; the first covers the management of manufacturing networks, while the second addresses performance measurement and management. Each section examines historical developments and presents up-to-date definitions and important models. A summary of the findings relevant to this thesis closes Chapter 2.

Chapter 3 – Developing a SPMMS for Manufacturing Networks

Chapter 3 develops the SPMMS for manufacturing networks and answers the research questions stated in Section 1.4. First, the main research question is reviewed and further detailed in Section 3.1. to recap the findings and implications from Chapter 2 and to set the focus for Chapter 3. Section 3.2 identifies the requirements a SPMMS for manufacturing networks has to fulfil. Section 3.3. reviews and evaluates the presented SPMMS based on the requirements discussed in Subsection 3.2. This review aims at identifying valuable aspects that can be used for the definition of the SPMMS for manufacturing networks. Before the SPMMS can be developed, evaluation criteria for the quality of scientific models in general and SPMMS specifically will be reviewed in section 3.4. The SPMMS itself will then be developed in Sections 3.5 and 3.6. The development of the SPMMS is split into developing the structural framework (the identification of the necessary performance dimensions or content of an SPMMS; Section 3.5) and the procedural framework (the process for the use of the SPMMS; Section 3.6). The developed SPMMS will not entirely redefine strategic performance measurement and management. However, it will include some innovative and valuable additions to the understanding of strategic performance and strategic performance measurement and management in manufacturing networks. Section 3.7 summarises these additions.

Chapter 4 – Testing the Applicability of the SPMMS

This chapter demonstrates the applicability and validity of the developed SPMMS in general and the structural and procedural SPMMS specifically. To do so, several case studies were selected. The case studies are practice examples from collaborative projects and interviews with various companies. Not all of the cases are discussed in equal detail. Instead, the most striking aspects from the different cases are highlighted. The chapter closes with a thorough discussion of the applicability of the structural and procedural framework and the new contributions identified in Chapter 3.

Chapter 5 – Summary and Outlook

Chapter 5 reviews findings and matches them with the research objectives initially defined in Chapter 1. The contribution the current thesis makes to theory and practice is laid out, followed by a discussion of research limitations and potential for further research. The last section addresses the topics of general limitations, manufacturing networks and strategic performance measurement and management separately.

2 Literature Overview

The basis for any research project is a thorough and comprehensive literature review (Baker, 2000). Understanding existing knowledge, concepts and research gaps is a necessity in order to prevent the recreation of existing knowledge and to conceptualise new research topics (cf. Baker, 2000; vom Brocke *et al.*, 2009). In this research the unification of two research streams, namely “performance measurement and management” and “manufacturing networks”, is aspired. Thus, this chapter reviews the latest findings and theories in these two areas. Vom Brocke *et al.* (2009) propose a five step process to review scientific literature. These five steps are:

1. Definition of review scope
2. Conceptualisation of topic
3. Literature search
4. Literature analysis and synthesis
5. Research agenda

According to vom Brocke *et al.* (2009), the first step of a literature review should be to define the review scope. One useful tool in this context is Cooper’s (1988) taxonomy, which is summarized in Table 2 (vom Brocke *et al.*, 2009). This taxonomy contains six characteristics, which comprise different categories. Some of these categories are mutually exclusive (the categories of characteristics 4 and 6) while some can be combined (categories of characteristics 1, 2, 3 and 5) (vom Brocke *et al.*, 2009; Herz *et al.*, 2010). Table 2 shows the categories relevant to the current literature review highlighted in bold characters.

As the goal of this literature review is to determine the state of the art in the merging of the fields “performance measurement and management” and “manufacturing networks”, all previous contributions in the literature combining these two research streams are of interest. Thus, following the taxonomy laid out in Table 2, the focus (1) of this research lies on *research outcomes* and *methods*, *theories* and *applications*, with the goal (2) to *integrate* and identify *central issues* in the literature. The organisation (3) of the literature review is supposed to be both *conceptual* and *methodological*, and a *neutral* position (4) will be assumed. The intended audience (5) comprises *specialised* and *general scholars* as well as *practitioners*. As the literature on the discussed topics is rather vast, the review’s coverage (6) will be *representative* of the existing literature.

Characteristics	Categories			
(1) Focus	**Research outcomes**	**Research methods**	**Theories**	**Applications**
(2) Goal	**Integration**	Criticism	**Central issues**	
(3) Organisation	Historical	**Conceptual**	**Methodological**	
(4) Perspective	**Neutral representation**	Espousal of position		
(5) Audience	**Specialised scholars**	**General scholars**	**Practitioners/ politicians**	General public
(6) Coverage	Exhaustive	Exhaustive and selective	**Representative**	Central/ pivotal

Table 2 – Taxonomy of the literature review on "performance measurement" and "manufacturing networks" based on Cooper (1988)

The second review step is to conceptualise the topic. This requires to define core terms and concepts (cf. Zorn, 2006; vom Brocke *et al.*, 2009), which can then serve as search terms when searching journals and databases (vom Brocke *et al.*, 2009). The terms central to the current research were already defined in Section 1.2., i.e. "production networks", "manufacturing network", "intra-organisational network"[3], "performance measurement" and "performance management". These terms are considered as general enough to prevent a too narrow search focus.

The third step in the literature review process is the actual literature search. Vom Brocke *et al.* (2009) propose that a literature search should have four phases. First, relevant journals should be searched for; this is followed by the search for suitable databases. The journals and databases are then searched for the predefined keywords (vom Brocke *et al.*, 2009). The fourth phase, a forward and backward search, can be done in isolation or can be added to the results achieved in the previous search phases.

In the first phase of the literature search, vom Brocke *et al.* (2009) suggest to focus on journals and conference proceedings as published results are typically peer-reviewed and tend to be of high quality. However, experience from earlier discussions and research shows that when researching a topic that has been barely discussed in the scientific literature, a focus on specific journals artificially unnecessarily limits the results from the literature review. Therefore, the current literature search started with phase 2 of vom

[3] Different ways of spelling „intra-organisational network" were also taken into account.

Brocke *et al.* (2009)'s framework, i.e. by a search based on the defined keywords. The following databases were selected based on previous experience and the journals and conferences covered by the databases: EBSCOhost, Emerald, ISI Web of Knowledge, Science Direct and Wiley Online Library. The databases were then queried with a combination of the defined search terms. Table 3 provides an overview of the used search terms, the applied search parameters and the results from the different databases, i.e. the total number of hits for each search. The search was not restricted to any specific publication period in order to identify as many publications as possible.

Keywords			***Databases***				
	"Performance Measurement"	"Performance Management"	EBSCOhost*	Emerald**	ISI Web of Knowledge***	Science Direct****	Wiley Online Library*****
"production network"	AND		1	0	1 (2)	0	(0) 25
		AND	(1) 2	(0) 1	1	0	(1) 24
"manufacturing network"	AND		(1) 2	1	(1) 3	1	(0) 8
		AND	0	0	0	0	(0) 17
"intraorgani-sational network"	AND		0	0	0	0	0
		AND	0	0	0	0	0
"intraorgani-zational network"	AND		0	0	0	0	0
		AND	0	0	0	0	0
"intra-organisational network"	AND		0	0	0	0	0
		AND	0	0	0	0	(0) 1
"intra-organizational network"	AND		0	0	0	0	(0) 1
		AND	0	0	0	0	(0) 1
Sum			6				

*The search was conducted on February 2nd 2013; *Search in title, abstract and keywords; **Search in all fields except full text; *** Search in topic and title; ****Search in title, abstract and keywords; ***** Search in title, abstract and keywords;*

Table 3 – Results of the literature search with combined keywords

The hits were individually examined and checked for relevance by scanning keywords, title and abstract. The number of relevant publications per search term combination is stated in parentheses. As the databases are not mutually exclusive in their entries, the hits were checked for duplications. Overall, only six relevant publications were identified. The results clearly show that performance measurement and management have not been sufficiently discussed in the context of intra-organisational networks.

As the number of relevant publications was found to be very small, despite the search not having been restricted to any specific journal or database, the next step was a closer evaluation of the identified material rather than the forward and backward searches proposed by vom Brocke *et al.* (2009).

All six publications were examined individually, and it was checked whether content and topic of the publications fit the focus of the current research (cf. Subsections 1.2.1 and 1.2.2). Table 4 presents an overview of each publication's central topic as well as the specific aspects it addressed. Table 4 also lists what the publications did not address, and whether or not any valuable insights were gained from each publication - none of the identified publications had focussed on intra-organisational networks.

Publication	***Core Topic***	***Does address***	***Does not address***	***Relevant to this research***
Lau *et al.* (2001)	Evaluation of performance of potential business partners through an online software tool	Supplier Selection, Supplier performance (3 dimensions)	intra-organisational manufacturing networks, manufacturing strategy, site roles	no
Hon (2005)	Evaluation of operational manufacturing technology/systems performance	Multi-dimensional operational performance measures, supply chains and inter-company manufacturing networks	intra- organisational manufacturing networks, manufacturing strategy, site roles	no
Vuorinen (2006)	Discussion of two perspectives on cooperative SME-networks and derivation of a performance measurement framework	inter-company manufacturing networks, SME cooperation	intra- organisational manufacturing networks, manufacturing strategy, site roles	no
Weil (2007)	The concept of industrial dynamics is applied to several settings	company performance from a system dynamics view	intra- organisational manufacturing networks, manufacturing strategy, site roles	no
Cunha *et al.* (2008)	Identifying performance measures and implementing those measures	inter-company manufacturing networks	intra- organisational manufacturing networks, manufacturing strategy, site roles	no
Jähn (2009)	Operational performance analysis of coordination and operation processes	inter-company manufacturing networks, SME	intra- organisational manufacturing networks, manufacturing strategy, site roles	no

Table 4 – Evaluation of the identified publications

Thus, the results of the literature search are unsatisfying at best. The identified literature clearly fails to provide a sound basis for any further scientific discussion. However, the literature search did indicate that there is currently no scientific focus on performance measurement in intra-organisational manufacturing networks. Therefore, the literature streams on manufacturing networks and performance measurement will be discussed separately in the next two sections. The goal of this separate discussion is to establish a thorough understanding of the existing literature and to identify research gaps and implications from the two research streams. However, searching the literature databases separately for the specified terms resulted in a vast number of hits, too extensive to be covered within the scope of this review (cf. Table 5).

Keywords	***Databases***				
	EBSCOhost*	Emerald*	ISI Web of Knowledge**	Science Direct*	Wiley Online Library*
"Production Network"	1'799	169	370	2'588	1'804
"Manufacturing Network"	764	85	150	668	240
"Performance Measurement"	4'528	1'496	5'920	1'583	11'133
"Performance Management"	6'420	2'374	2'572	319	8'060

The search was conducted on March 23rd 2013. *search in all fields, **search in title, topic and publication name

Table 5 – Results of the literature search

Thus, a different approach was chosen in the next two sections. Based on existing literature reviews, an extensive forward and backward search was conducted. This has the advantage that connected literature that would not have been identified by a search based on search terms alone can be found and reviewed. At the beginning of each section, the literature reviews that served as a basis for the discussion will be shortly presented.

2.1 Managing Manufacturing Networks

This section aims at providing a basic scientific understanding of manufacturing strategy, manufacturing networks and manufacturing management. The presentation of theoretical knowledge is accompanied by short case studies illustrating the relevance of the scientific models. As a starting point for the identification of relevant literature previous literature reviews from the Institute of Technology Management were used, i.e. the dissertations of Deflorin (2007), Mundt (2012) and Thomas (2013). These were complemented with insights from the works of Dangayach and Deshmukh (2001), Miltenburg (2005; 2008; 2009), De Toni and Parussini (2010) and Nguyen (2011). This section then is organised as follows: First, a brief history of industrial manufacturing will be provided which illustrates the development of manufacturing towards the global activity it is today and the challenges it faces. Secondly, a review of manufacturing strategy, its content and formulation will be discussed. In that discussion it will become evident just how much manufacturing networks in different markets, industries etc. can differ regarding their structure and infrastructure, and why this needs to be taken into account in a SPMMS. This is especially relevant due to the definition of "strategic performance" as the degree of fulfilment of manufacturing strategy in Section 1.2. Thirdly, the state of the art of performance and performance measurement in manufacturing will be summarised, further outlining the existing research gap. Fourthly, a concluding model incorporating formulation and content approaches to manufacturing strategy for manufacturing networks will be developed based on the observations. Finally, the key findings of this chapter will be summarised and serve as a basis for the discussion of existing SPMMS in Chapter 3.

2.1.1 Latest Challenges in the Management of Global Manufacturing Networks

Historically, manufacturing as it is known today emerged from small family-run manufactures and transformed into industrialised large-scale manufacturing through the industrial revolution (cf. Henning, 1995; Stevenson, 1996). This change in manufacturing was accompanied by several innovations. Firstly, the division of labour enabled a faster manufacturing process. Secondly, standardisation of products and components replaced the time consuming modification of parts for unique products (Stevenson, 1996; Westkämper, 2006). Thirdly, automation fundamentally increased productivity (Duguay *et al.*, 1997). Since the industrial revolution, manufacturing has undergone further development. Bititci *et al.* (2009; 2012) distinguish four eras in the way business and manufacturing was conducted throughout the 20th and the early 21st century. After mass production, Bititci *et al.* (2009) identify the lean era with a performance focus on effectiveness and waste minimisation. This was followed by the agile era in which performance focussed on competitiveness and flexibility in general. The final era, which endures until today, is dubbed the networking era. When discussing manufacturing networks from a network perspective, the network is considered to be a holistic system, in which sites are seen as interacting nodes (Shi and Gregory, 1998; Rudberg and Olhager, 2003). Essentially, this means that optimisation approaches cannot be limited to local optimisation but need to target an optimum on the manufacturing network level. In this networking era the scope of performance is a lot broader than before; focussing on financial, customer and general stakeholder aspects in the context of networks. However, this at least three-dimensional understanding of performance has not been incorporated into existing performance measurement systems (cf. Bititci *et al.*, 2009; Bititci *et al.*, 2012) and has therefore not found its way into the heads of manufacturing managers. Anecdotal evidence from different cases shows that the understanding of performance and the main goal managers in manufacturing strive to achieve mainly consist of financial factors (costs).

It is important to note that during these eras it was not only the focus of performance that changed but to stay competitive companies everywhere also had to implement fundamental changes in processes, products and management (Bititci *et al.*, 2009; Bititci *et al.*, 2012). Additionally, manufacturing has increasingly become global since the 1980s (Hayes *et al.*, 2005). To remain competitive, an increasing number of companies has been maintaining a local presence in their addressed markets. The United Nations Conference on Trade and Development (UNCTAD) expects the foreign direct investments (FDI)[4] of the 100 biggest multinational companies to increase from $1.45 trillion in 2013 to $1.8 trillion in 2015 (United Nations, 2013). But it is not only big companies that go global; SME increasingly globalise their footprint as well (Ruzzier *et al.*, 2006). The main drivers of the global spread of production are the globally inhomogeneous dispersion of resources (cheap and highly skilled labour, natural resources), heterogeneous markets (regarding customer demands, legal specifications etc.) and nationally differing legal conditions (Thomas, 2013; United Nations, 2013).

As the competitive environment of each globalised company differs, it follows that these emerging international manufacturing networks can be configured and managed differently. Shi and Gregory (1998) differentiate eight configurations of manufacturing networks according to the degree of product mobility within the network (from low to high), the geographic dispersion of manufacturing (from national over regional to multi-national and global) and the degree of coordination/integration across the network (from rather autonomous regional networks to well-coordinated global networks). Although there is no single correct way to design manufacturing networks, Shi and Gregory (1998) state that there is a trend of companies aiming at more integrated and better coordinated global manufacturing networks in order to realise global competitive advantages. However, coordinating such a global manufacturing network is far from trivial. In fact, managers face many difficulties. Klassen and Whybark (1994) identified the key challenges in managing international manufacturing as the implementation of a global, rather than a local, view and the definition and implementation of a manufacturing strategy. If managers fail to implement a manufacturing strategy and cannot implement a global view among the different production sites, the realisation of global competitive advantages above site level will prove to be difficult. However, as Bartlett and Ghoshal (1989) and Rudberg and West (2008) point out, this is necessary for companies to remain competitive in the future. This task is additionally aggravated by a dynamism evolving around international manufacturing (Feldmann *et al.*, 2010). Managers of

[4] FDI are the investments of companies into business activities outside their home country with continuing control and influence over the investment. This is in contrast to portfolio investments.

manufacturing networks therefore must optimize the networks in order to realise the desired competitive priorities while being able to rebuild the network to address changes in the global environment (Deflorin *et al.*, 2012).To do so, they need to decide on the strategy of the network, and thus they need to set goals and objectives for each of the plants (Vereecke *et al.*, 2008). These goals need to be in alignment with the specific role[5] a site takes within the network, as the site role has an influence on the level of coordination and supervision a site requires or the contribution a site is able to give to the network (cf. Feldmann *et al.*, 2010).

In conclusion, the manufacturing environment has become increasingly complex and global over the last decades. Managers of manufacturing sites are no longer solely responsible for the supply of goods to local markets but have to supply multiple markets with sometimes contradictory product requirements while interacting with other manufacturing sites in a network. Network managers on the other hand have to orchestrate manufacturing networks by defining a manufacturing (network) strategy and linking this strategy to manufacturing site targets. This strategy should also incorporate the dynamism of global markets and supply development paths for the entire network and the manufacturing sites.

2.1.2 Manufacturing Strategy – An Introduction

Mintzberg (1978) defines strategy in general as *"a pattern in a stream of actions"* (Mintzberg, 1978, p. 935). Thus, strategy is understood as both a statement and realisation of pre-defined actions as well as a-posteriori evolved consistencies in action (Mintzberg, 1978). Mintzberg (1978) further states that an intended strategy needs to be deliberately implemented before it becomes a realised strategy. An intended strategy can be discarded or replaced by an emergent strategy (Mintzberg, 1978; Pun, 2004). This is depicted in Figure 6.

For the current research, the focus is set on intended strategy and its translation into realised strategy through the use of an SPMMS. The discarding and emergence of strategies is therefore not covered in detail. This is in line with Miltenburg's (2009) perspective: *"[...] strategy is implemented in a sequence of actions that begins with strategy formulation and ends at business performance."* (Miltenburg, 2009, p. 6179). In a company context, strategy can be discussed on different levels. Mostly, a hierarchical concept is used where functional strategies (including a manufacturing strategy) are

[5] For an overview of different models for site role see Schmid and Kutschker (2003); Kretschmer (2008) and Table 11 in this thesis.

derived from business strategies which are derived from overall corporate strategies (cf. Wheelwright, 1984; Fine and Hax, 1984, 1985a; Hill, 1986; Leong *et al.*, 1990; Platts and Gregory, 1990; Menda and Dilts, 1997; Christiansen *et al.*, 2003).

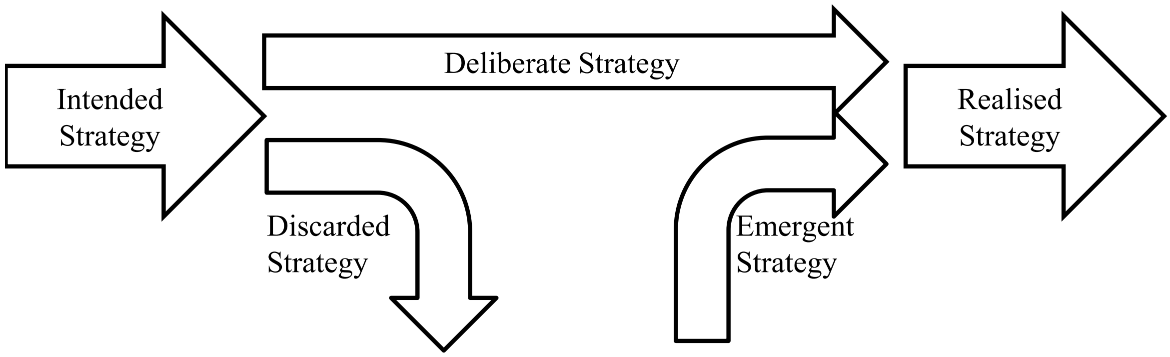

Figure 6 – Types of Strategies based on Mintzberg (1978) and Pun (2004)

In 1969, Wickham Skinner first identified manufacturing as a competitive weapon and laid the basis for manufacturing strategy with his ground breaking article "Manufacturing – Missing link in corporate strategy" (Skinner, 1969). This article established a bridge between the engineering-driven manufacturing and overall business strategy that caused extensive discussions both in the literature as well as in practice (Skinner, 1969; Swamidass and Newell, 1987; Deflorin, 2007; Thomas, 2013). Skinner pointed out that there was no single best way to run manufacturing. Instead, companies have to focus on their distinctive strengths and weaknesses (Hayes and Pisano, 1996). The alignment of manufacturing strategy with business strategy is seen as beneficial for overall business success (Skinner, 1969; Swamidass and Newell, 1987; Dangayach and Deshmukh, 2001; Miltenburg, 2009).[6] However, currently no unified definition of manufacturing strategy exists. Dangayach and Deshmukh (2001) provide an overview of definitions of manufacturing strategy which is extended and depicted in Table 6.

[6] Obviously, the idea that an internal fit between business strategy and production strategy is beneficial for overall business success is rooted in contingency theory. However, this statement assumes that the business strategy is suitable for the markets being served. If the business strategy is faulty, then an alignment of production strategy to business strategy will obviously not result in business success.

Author	***Definition of manufacturing strategy***
Skinner (1969)	*"Manufacturing strategy refers to exploiting certain properties of the manufacturing function as a competitive weapon"*
Fine and Hax (1985b)	*"[Manufacturing strategy] is a critical part of the firm's corporate and business strategies, comprising a set of well-coordinated objectives and action programs aimed at securing a long-term sustainable advantage over competitors"*
Hayes and Wheelwright (1985)	*"[Manufacturing strategy is] A sequence of decisions that over time, enables a business unit to achieve a desired […] [manufacturing] structure, infrastructure and set of specific capabilities"*
Hill (1986)	*"[Manufacturing strategy] represents a coordinated approach which strives to achieve consistency between functional capabilities and policies and the agreed current and future competitive advantage necessary for success in the marketplace"*
Swamidass and Newell (1987)	*"[Manufacturing strategy is] the effective use of manufacturing strengths as a competitive weapon for the achievement of business and corporate goals"*
McGrath and Bequillard (1989)	*"[Manufacturing] strategy [serves] as the overall plan for how the company should manufacture products on a world-wide basis to satisfy customer demand"*
Berry *et al.* (1995)	*"[Manufacturing strategy is] the choice of a firm's investment in processes and infrastructure that enables it to make and supply its products to chosen markets"*
Swink and Way (1995)	*"[Manufacturing] strategy as decisions and plans affecting resources and policies directly related to sourcing, manufacturing and delivery of tangible products"*
Wathen (1995) based on Hayes and Schmenner (1978)	*"[…] Manufacturing strategy is […] an integrated set of facility and infrastructure decisions […] to support the competitive priorities of a business."*
Hayes and Pisano (1996)	*"In today's turbulent competitive environment a company more than ever needs a strategy that specifies the kind of competitive advantage it is seeking in the marketplace and articulates how that advantage is to be achieved"*
Cox and Blackstone (1998)	*"[Manufacturing strategy is] a collective pattern of decisions that acts upon the formulation and deployment of manufacturing resources. To be most effective, the […][manufacturing] strategy should act in support of the overall strategic directions of the business and provide for competitive advantages"*
Platts *et al.* (1998)	*"A manufacturing strategy is defined by a pattern of decision, both structural and infrastructural, which determine the capability of a manufacturing system and specify how it will operate, in order to meet a set of manufacturing objectives which are consistent with the overall business objectives"*
Brown (1999)	*"[Manufacturing] strategy is a driving force for continual improvements in competitive requirements/priorities and enable the firm to satisfy a wide variety of requirements"*
McCarthy (2004)	*"[Manufacturing strategy is]the effective use of manufacturing capabilities to achieve business and corporate goals"*

Author	*Definition of manufacturing strategy*
Deflorin (2007, p. 16) based on Corbett and van Wassehove (1993)	*"Manufacturing strategy aims at making manufacturing decisions based on superior goals. It provides guidelines for the development of internal capabilities in accordance to external demands"**
Miltenburg (2009, p. 6179)	*"[Manufacturing] strategy is one of several functional strategies in a hierarchy of industrial, corporate, business, and functional strategies. […] [Manufacturing] strategy is how a company uses its assets and prioritises its activities to achieve its business. […] [Manufacturing] strategy depends on a company's industry and geographic location and is a pattern of competition that tries to generate competitive advantage."*
Mundt (2012, p. 29)	*"[Manufacturing] strategy sets the overall direction to support business strategy from the […] [manufacturing] perspective. Thereby, competitive […] priorities have to be formulated to facilitate business strategy's competitive advantages. These priorities, in turn, are supported by the capabilities of the […] [manufacturing] function. In order to shape these capabilities, the decision categories of the […] [manufacturing] system have to be defined or adjusted."*
Thomas (2013, p. 53)	*"Manufacturing strategy has to be aligned to corporate strategy. For the formulation of a manufacturing strategy the concept of competitive priorities can be used"**

*Translated by the author

Table 6 – Definitions of manufacturing strategy based on Dangayach and Deshmukh (2001)*, extended by the author*

The definitions presented in Table 6 provide a basic understanding of manufacturing strategy. However, they do not explain how a manufacturing strategy is formed and what its components are. Strategy literature revolving around the manufacturing function, and strategy in general for that matter, can be divided into literature focussing on the formulation of (manufacturing) strategy and literature focussing on its content (cf. Leong *et al.*, 1990; Dangayach and Deshmukh, 2001). The following subsections will give a short overview of literature on both these approaches.

2.1.3 The Formulation of Manufacturing Strategy

According to Platts (1994), the main role of processes for manufacturing strategy formulation is to:

- *Provide a discipline forcing managers to take a careful look ahead periodically*
- *Require rigorous communications about goals, strategic issues and resource allocations*
- *Stimulate longer term analyses than would otherwise be made*
- *Generate a basis for evaluating and integrating short-term plans*
- *Lengthen time horizons*
- *Create an information framework (Platts, 1994, p. 93)*

One of the first researchers to develop a process for the definition of manufacturing strategy was Skinner (1969). As illustrated in Figure 7, Skinner classed manufacturing strategy as a functional strategy that is to be derived from company strategy in a hierarchical process.

According to Skinner, a company-wide manufacturing strategy is defined by incorporating requirements based on the overall company strategy, identifying economic and technological constraints and evaluating the company's current set-up of manufacturing based on its resources. The results of manufacturing in terms of productivity, quality, service and return on investment (ROI) serve as feedback for the manufacturing strategy and analysis of the competitive situation and company in the beginning of the definition process.

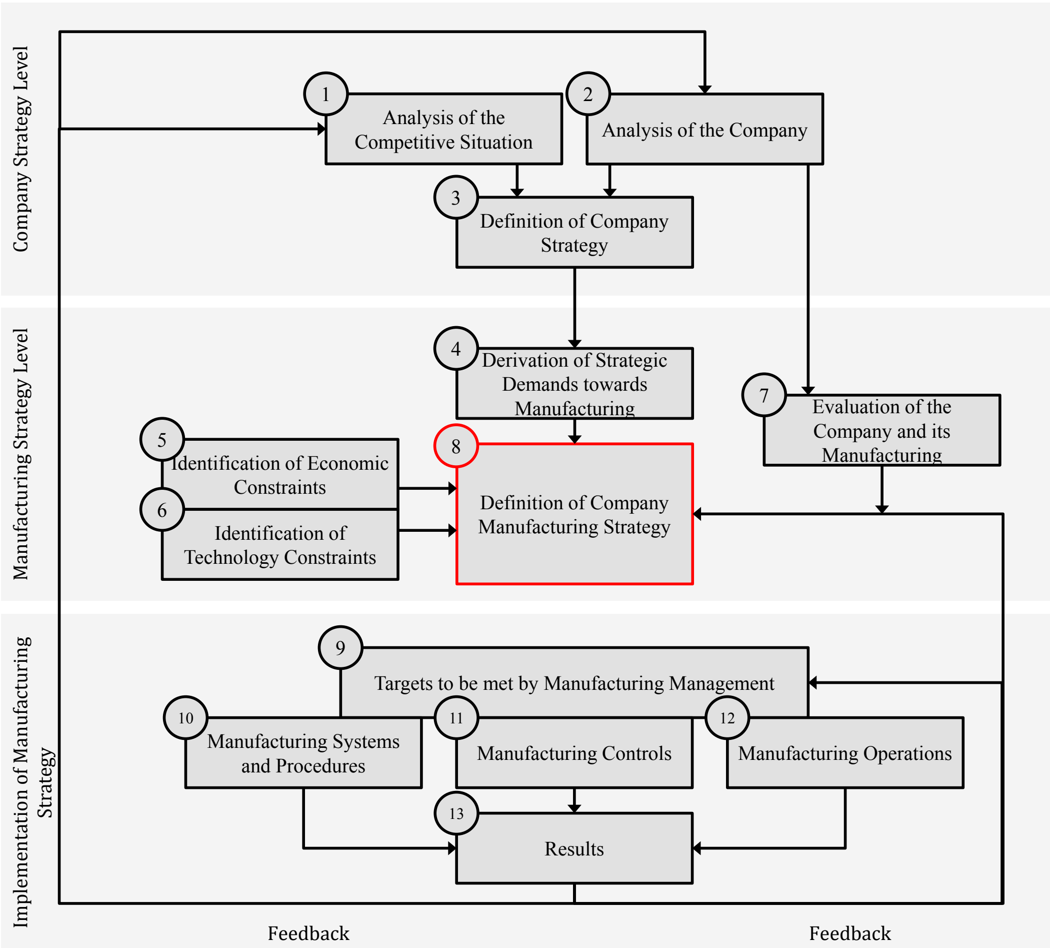

Figure 7 – Manufacturing Strategy Formulation adapted from Skinner (1969)

Charles H. Fine and Arnoldo C. Hax too were deeply concerned with manufacturing strategy, its content and the process of its formulation. Fine and Hax (1984; 1985a; 1985b) propose a six step methodology for the development of a manufacturing strategy. Although the process is hierarchical, deriving manufacturing strategy from corporate or business strategies, like the process proposed by Skinner, it further recognises that a) not all manufacturing organisations are the same and the strategy process and content can differ based on the structure of the organisation and b) that not all products pose the same requirements towards manufacturing and products therefore need to be grouped (Fine and Hax, 1984, 1985a, 1985b). The process is designed as follows:

1. *"Provide a framework for strategic decision-making in manufacturing.*
2. *Assure linkages between business strategies and manufacturing strategy*
3. *Conduct an initial manufacturing strategy audit:*
    a. *to detect strengths and weaknesses in the current manufacturing strategy by each category, and*
    b. *to assess the relative standing of each product line regarding the strategic performance measurements against the most relevant competitors.*
4. *Address the issue of product grouping*
    a. *by positioning the product lines in the product/process life cycle, and*
    b. *by assessing commonality by performance objectives and product family missions.*
5. *Examine the degree of focus existing at each plant or manufacturing unit*
6. *Develop manufacturing strategies and suggest allocation of product lines to plants or manufacturing units."* (Fine and Hax, 1984, p. 432)

Two things are striking about this process. Firstly, it requires a framework that supports the strategic decision-making in manufacturing. According to Fine and Hax (1984; 1985a; 1985b) the framework's task is to organise the thought process of manufacturing managers. It should contain the most important decision dimensions of manufacturing strategy as well as performance outcomes of manufacturing. Secondly, it recognizes that a manufacturing strategy needs to incorporate product groups and the focus of factories. The two case examples in Section 1.1. demonstrate the daily relevance of product groups and factory focus to manufacturing managers.

Another important contribution to the definition of manufacturing strategy came from Terry J. Hill (1986; 1993). Similar to Skinner (1969) and Fine and Hax (1984; 1985a; 1985b), Hill describes a hierarchical process that delineates manufacturing strategy from corporate strategy. To do so, Hill introduces the order winner/order qualifier concept. This concept ranks manufacturing outputs (such as cost, quality, delivery, flexibility etc.) into order qualifiers and order winners. Order winners are manufacturing outputs that when increased can be used to differentiate the products from the competition and thus generate orders. Order qualifiers are manufacturing outputs that need to be met in order to enter a certain market[7] (Hill, 1993). Hill (1986; 1993) proposes a five step process:

1. *Define corporate objectives regarding ROI, growth, profit and other financial objectives*
2. *Define the marketing strategy regarding product markets and segments, product range, product mix, product volumes, standardisation versus customisation, the level of innovation and leader versus follower alternatives*
3. *How do products win orders in the market place? Rank manufacturing outputs into order winners and order qualifiers.*
4. *Define the manufacturing strategy regarding manufacturing processes. This includes the evaluation of alternative processes, trade-offs embodied in the process choice and the role of inventory in the process configuration.*
5. *Define the manufacturing strategy regarding infrastructure. This includes function support, manufacturing systems, controls and procedures, work structuring and the organisational structure.*

This approach is innovative as it directly links manufacturing outputs to a marketing perspective. Manufacturing is thus able to directly realise a customer-oriented production instead of an engineer-driven manufacturing optimisation that does not necessarily add value for the customer. Similar to Fine and Hax's (1984) proposition, Hill (1986) also suggests that products need to be grouped in order to derive product-specific desired order winners/qualifiers and supply forecasts regarding sales volume per product. Hill (1986) points out that strategy definition is not a one way street. The configuration and coordination of a manufacturing network influence manufacturing strategy formulation, and the manufacturing function gives feedback back to marketing and the corporate level of strategy, creating a truly integrated process of manufacturing strategy definition.

Leong *et al.* (1990) synthesise the above discussed process models and add the idea that manufacturing strategy does not only need to be aligned with marketing, but also with other functions and their strategy. They further dissect the manufacturing function internal strategy process into the three steps strategy definition, strategy implementation and development of capabilities. Leong *et al.* (1990) see these three steps in close collaboration with other functions in the company as only the collaborative effort will lead to true service-enhanced products which will differentiate the company from its competitors.

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[7] E.g.: Product quality would be an order qualifier for the pharmaceutical industry as companies have to meet certain quality standards in order to be FDA approved.

Another researcher that greatly contributed to the understanding of manufacturing strategy formulation is Ken W. Platts. The evaluation or audit of the existing manufacturing function has played a key role in the manufacturing strategy formulation processes described above. In his work, Platts operationalizes the audit of a manufacturing function in a strategy process by providing frameworks that support the audits (cf. Platts, 1990; Platts and Gregory, 1990; Mills *et al.*, 2002). Platts and Gregory's process for manufacturing strategy definition and manufacturing system design includes three stages with six steps[8], and is depicted in Figure 8.

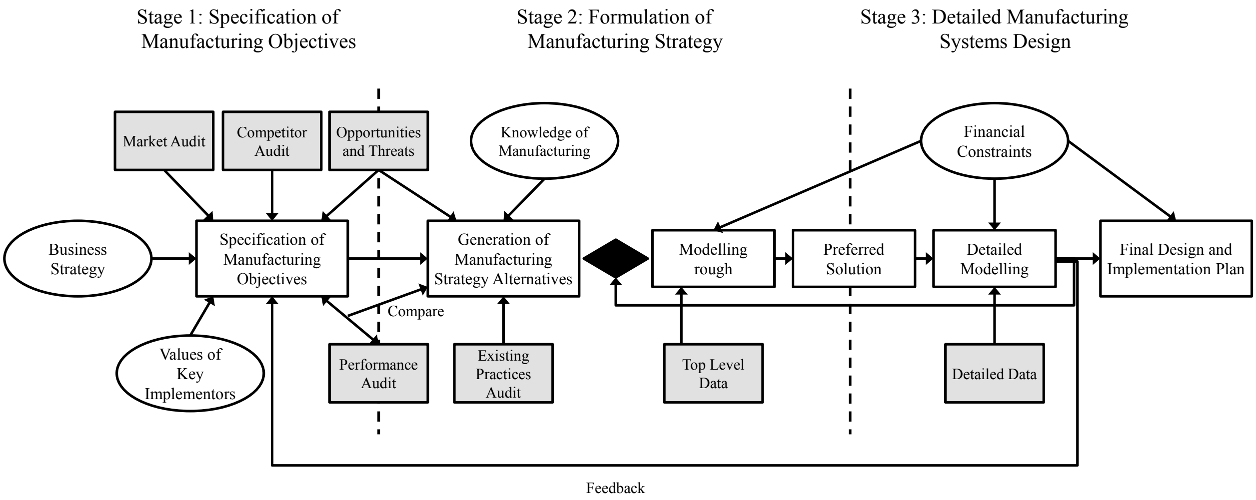

Figure 8 – Process for Manufacturing System Design adapted from Platts and Gregory (1990)

The process steps in Figure 8 are represented as rectangles with a white background, outside knowledge or influences are depicted as ovals and the different audits are depicted as rectangles with a grey background. Manufacturing strategy in this process is derived from business strategy, which provides objectives for the manufacturing function. It should be noted that most business strategy objectives are not suitable for a manufacturing function (Platts and Gregory, 1990)[9]. Similar to the previously described processes, customer demands and requirements are used in combination with the competitive situation to derive the task the manufacturing function has to fulfil. These targets are evaluated against the current manufacturing performance and current practices in manufacturing and alternatives to fulfilling the targets are derived. Defining

[8] This process for manufacturing strategy is loosely based on the seven steps of prescriptive strategy formulation by Hofer and Schendel (1978): 1) Strategy identification/assessment of current strategy, 2) Environmental analysis, 3) Resource analysis, 4) Gap analysis, 5) Identification of strategic alternatives, 6) Evaluation of the strategic options, 7) Strategic choice (Platts, 1994).

[9] E.g. the target of 10 % market growth needs to be translated into a manufacturing target incorporating additional knowledge and understanding about the manufacturing function (Platts and Gregory, 1990).

the manufacturing strategy ends by selecting a preferred solution from different strategic alternatives that were evaluated through modelling. In a later publication, Platts and colleagues simplify this process and add the grouping of products as an initial step (cf. Platts *et al.*, 1998).

While the literature describes further processes for the definition of manufacturing strategy, these will not be discussed in detail here as the insight gained from presenting further processes would be rather slim. Instead, additional key implications are presented in the following list:

- Menda and Dilts (1997) propose to not only use perspectives from marketing, manufacturing and overall business to define order-winning manufacturing outputs, but instead to incorporate perspectives from all corporate functions.
- The process of defining the manufacturing strategy depends on the manufacturing structure (Fine and Hax, 1984) and infrastructure (Marucheck *et al.*, 1990). In manufacturing networks, manufacturing strategies can be defined centralised, integrated and decentralised. The degree of decentralisation seems to be connected to the competences of the different sites (Feldmann and Olhager, 2011)
- Manufacturing strategy might emphasise different aspects on manufacturing network, site and production line level. Miltenburg (2005; 2008; 2009) provides frameworks that support the definition of manufacturing strategy on these different levels.
- Strategy formulation should be embedded into a manufacturing setup and be repeated periodically (cf. Platts *et al.*, 1998; Christodoulou *et al.*, 2007; Pun, 2004)

In later research, Platts and others also supply quality criteria for manufacturing strategy formulation approaches (cf. Platts, 1994; Platts *et al.*, 1996). These criteria address the categories procedure, participation, project management and point of entry, and are listed in Table 7.

This subsection has illustrated the different approaches researchers have taken to manufacturing strategy definition. Understanding and mastering the process of strategy definition and implementation is important for manufacturing companies as it allows them to build up capabilities that can be used as competitive advantages and to dynamically adapt to changes in market requirements (McCarthy, 2004).

Procedure	Participation	Project Management	Point of Entry
The process is well defined	Individuals and group Process achieves: • Enthusiasm • Understanding • Commitment	Adequate resourcing	Clearly defined expectations
It includes stages of: • Gathering information • Analysing information • Identifying improvements • Simple tools and techniques	Workshops are styled to: • Agree on objectives • Identify problems • Develop improvements • Catalyse involvement	Identify: • Managing group • Supporting group • Operating group	Understanding and agreement of managing group
Written record	The process is used as a decision making forum	Agreed timescale	Commitment from managing and operating groups

Table 7 – Quality criteria of processes for manufacturing strategy formulation based on Platts (1994)

In sum, it can be concluded from this chapter that a process for manufacturing strategy definition

- Aims at developing a long-term strategic advantage over competitors through manufacturing
- Should incorporate relevant aspects of overall business strategy and support that strategy
- Should reflect external (market) demands towards manufacturing
- Should consider financial and technological constraints
- Should incorporate perspectives from different functions within the company and other stakeholders
- Is mostly hierarchical and derives the manufacturing strategy of an entity in connection to the manufacturing strategy of a hierarchically higher entity
- Can set a focus that differs on different levels (network, region, product group, site or production line) of the manufacturing function
- Is dependent on the organisational structure and infrastructure
- Evaluates the existing manufacturing focus, manufacturing processes, the manufacturing structure and manufacturing infrastructure
- Develops for the future design of manufacturing focus, manufacturing processes, the manufacturing structure and manufacturing infrastructure and derives an implementation plan
- Is well organised, has a clear target and is supported by adequate resources
- Is ideally transparent and integrative

2.1.4 The Content of Manufacturing Strategy

As pointed out by Miltenburg (2008), manufacturing strategy can be analysed and hence defined on different levels. He distinguishes industry, company, strategic business unit, production network, factory, production line (factory-within-a-factory) and product levels. Although these are separate levels, it is evident that foci set on one level should ideally be connected to and not contradict those of other levels. For the current research, the manufacturing network level and the layers below are of interest. Similarly to literature on the process of manufacturing strategy definition, the content of manufacturing strategy has been extensively discussed in the literature. In general, the elements described as content of manufacturing strategy can be grouped in four categories: manufacturing capabilities, structural levers, infrastructural levers (cf. Leong *et al.*, 1990; Mills *et al.*, 1995; Menda and Dilts, 1997; Boyer and Lewis, 2002; Christiansen *et al.*, 2003; Miltenburg, 2005) and network level capabilities (cf. Shi and Gregory, 1998; Colotla, 2003; Miltenburg, 2009; Thomas, 2013). Table 8 provides an overview of the elements in the different categories as named by various authors (cf. Miltenburg, 2009). Multiple sources by the same author are joined in one row.

Authors	***Components of Manufacturing Strategy***			
	Manufacturing Capabilities	Network Level Capabilities	Structural Levers	Infrastructural Levers
Wheelwright (1978; 1984), Hayes and Wheelwright (1985)	• Price • Quality • Dependability • Flexibility • Efficiency		• Capacity • Facilities • Technology • Vertical integration • Process	• Workforce • Quality Management • Production planning/materials control • Organisation
Fine and Hax (1984; 1985a)	• Cost • Delivery • Quality • Flexibility		• Facilities • Capacity • Vertical Integration • Technologies/Processes • New Products • Inventory	• Human Resources • Quality Management • Organisation • Planning and Scheduling Systems • Control and Information Systems • Standardisation • Centralisation • Vendor Relations
Hill (1986; 1992; 1993)	• Price • Delivery Reliability • Delivery Speed • Quality • Demand Flexibility • Product Range		• Processes • Trade-offs • Inventory levels • Capacity	• Function Support • Manufacturing System • Controls and Procedures • Work Structuring • Organisational Structure • Quality assurance and control • Manufacturing systems engineering

Authors	*Components of Manufacturing Strategy*			
	Manufacturing Capabilities	Network Level Capabilities	Structural Levers	Infrastructural Levers
Leong *et al.* (1990)	• Cost • Quality • Delivery Dependability • Delivery Speed • Volume Flexibility • Product Mix Flexibility • Changeover Flexibility • Modification Flexibility • Rerouting Flexibility • Material Flexibility • Sequencing Flexibility • Innovativeness in Product • Innovativeness in Sequencing		• Facilities • Capacities • Technologies • Vertical Integration	• Production Planning and Control • Quality • Organisation • Workforce • Product Design • Performance Measurement Systems
Vickery (1991)	• Cost • Quality in Design • Quality in Conformance • Delivery Dependability • Delivery Speed • Flexibility in Product Mix • Flexibility in Volume • Innovation • New product introduction		• Equipment • Facilities • Process Technology • Capacity	• Vertical Integration • Quality Management • Human Resource Management • Organisation • Manufacturing Planning • Control Systems
Kim and Arnold (1996)	• Price • Quality • Dependability • Flexibility		• Capacity • Facilities • Technology • Vertical integration	• Quality Management • Production planning/materials control • Organisation • Workforce
Platts *et al.* (1998)	• Cost • Quality • Product Features • Design Flexibility • Delivery Lead Time • Delivery Reliability • Volume Flexibility		• Facilities • Capacity • Vertical Integration • Suppliers • Processes	• Human resources • Quality • Control Policies • New Products
Shi and Gregory (1998)		• Accessibility • Thriftiness • Mobility • Learning	Site Level • Capacity • Facilities • Technology • Vertical Integration Network Level • Site Level Characteristics • Geographic Dispersion • Horizontal Coordination • Vertical Coordination	Site Level • Workforce • Quality • Production Planning/Material control • Organisational Structure Network Level • Dynamic Response Mechanisms • Product life cycle and knowledge transfer • Operational Mechanisms • Dynamic capability building and network evolution
Dangayach and Deshmukh (2001)	• Cost • Quality • Delivery Dependability • Delivery Speed • Flexibility		• Processes • Technology	• Human Resources • Quality Systems • Organisational Culture • Information Technology
Boyer and Lewis (2002)	• Cost • Quality • Flexibility • Delivery		• Capacity • Facilities • Technology • Vertical Integration/Sourcing	• Workforce • Quality • Productions Planning • Organisation

Authors	*Components of Manufacturing Strategy* Manufacturing Capabilities	Network Level Capabilities	Structural Levers	Infrastructural Levers
Christiansen *et al.* (2003)	• Price • Quality Conformance • Quality Performance • Delivery Speed • Delivery Dependability • Design Flexibility • Volume Flexibility • Broad Product Line • Service		• Layout • Production Practices	• Production Planning • Quality Control
Miltenburg (2008; 2009)	• Cost • Quality • Delivery Time • Delivery Reliability • Product Performance • Flexibility • Innovativeness	• Accessibility • Thriftiness • Mobility • Learning	Site Level • Facilities • Process Technology • Layout • Material Flow • Sourcing	Site Level • Human Resources • Organisation Structure & Controls
			Network Level • Facility Characteristics • Geographic Dispersion • Vertical Integration	Network Level • Organisational Structure • Coordination Mechanisms • Knowledge Transfer Mechanisms • Capability Building Mechanisms
Thomas (2013)[10]	• Price • Quality Specification • Quality Conformance • Delivery Speed • Delivery Reliability • Flexibility regarding Design • Flexibility regarding Volumes • Innovation • Service	• Accessibility • Thriftiness • Mobility • Learning	• Design of the internal supply chain • Technologies • Resources • The global distribution of facilities • Capacity • Specialisation of the network • Specialisation of the sites	• Managerial Structure • Cost or Profit Centre Organisation • Centralisation • Standardisation • Knowledge Exchange • Information Exchange • Resource Exchange • Incentive System

Table 8 – Content of manufacturing strategy in scientific literature

It can be concluded that most of the research focussing on the content of manufacturing strategy addresses the categories manufacturing capabilities, structural and infrastructural levers. The network level content has only recently been introduced by Shi and Gregory (1998). Network and site level perspective were then joined by Miltenburg (2009) and Thomas (2013). While the network level capabilities are mostly identical in the different sources, the content of the other categories somewhat differs across the reviewed publications. Structural levers comprise the physical configuration of the operation's resources, whereas infrastructural levers comprise activities that are conducted within the structures (Colotla *et al.*, 2003). In most cases, changes in any

[10] The model for global manufacturing networks developed by Thomas (2013) contains the layers manufacturing strategy, manufacturing configuration and manufacturing coordination. Although the layers manufacturing configuration and manufacturing coordination are not part of what Thomas (2013) considers manufacturing strategy, their content is listed in Table 8. The content has been translated from German by the author and it has also been slightly adapted.

structural lever will also impact infrastructural levers; therefore a clear separation of theses dimensions is difficult (Meijboom and Vos, 1997; Pontrandolfo and Okogbaa, 1999; Rudberg and Olhager, 2003; Cheng *et al.*, 2011). However, the separation presented above has proven to be useful and thus has been broadly accepted (Slack and Lewis, 2011).

In general, set priorities within the manufacturing and network capabilities need to be supported by the structural and infrastructural levers. This means that the structure and infrastructure of a manufacturing network need to be configured to make the realisation of the aspired network and manufacturing priorities possible. However, according to the concept of equifinality, the same set of priorities can be realised in different ways. For example, low costs can be realised by producing in low cost countries with a high share of manual labour, or producing in high cost countries with a high share of automation. Therefore, defining a manufacturing strategy does not end with defining manufacturing and network priorities. Instead, the direction defined by the manufacturing and network priorities has to be addressed through the adjustment of structural and infrastructural levers. The following paragraphs discuss the content of the different categories in manufacturing strategy in more detail. The list of sub-dimensions in the different categories could be almost indefinitely extended. Therefore, only the most relevant sub-dimensions will be addressed. Relevance is based on scientific mentions and the importance of the different sub-dimensions through the case studies and research work with practitioners throughout the creation of this thesis.

Manufacturing Capabilities

As described above, manufacturing strategy contains the definition of a focus for manufacturing activities based on manufacturing capabilities (Deflorin, 2007; Mundt, 2011; Thomas, 2013). For this research, the following manufacturing capabilities are distinguished:

Manufacturing Capabilities		
Cost		Being able to compete with competitors on low costs.
Quality	Superiority*	Providing products whose features fully meet or exceed customers' requirements.
	Conformance	Providing products to their defined specifications reliably and consistently.
Delivery	Speed	Meeting and exceeding the expected delivery speed.
	Reliability	Delivering goods on time in full.
Flexibility	Product Range/ Design Flexibility	Providing a wide product range or developing new designs/products quickly in order to meet customers' specific expectations.
	Order Size/ Delivery Flexibility	Being able to adjust order sizes or delivery times quickly if demanded by the customer.
Innovation		Providing innovative products or products that enable the customer to be innovative.
Service		Providing outstanding services accompanying the core product.

*Denomination changed by the author as the original denomination provided e.g. by Mundt (2012) often led to confusion in discussions with practitioners and scientist alike

Table 9 – Manufacturing Capabilities based on Mundt (2012) *and Thomas* (2013)

Different terms are used in the context of manufacturing capabilities, such as manufacturing outputs, competitive priorities, manufacturing competencies, manufacturing performance etc. Based on Koufteros *et al.* (2002) and Hallgren *et al.* (2011), these terms can be connected as follows:

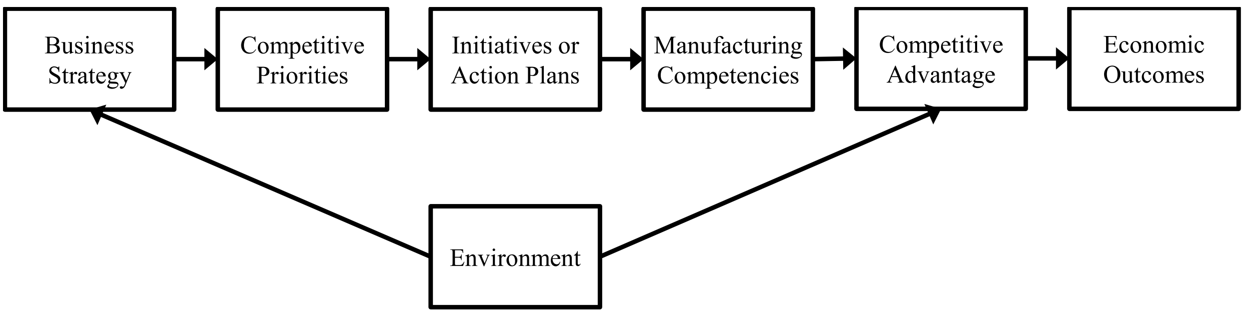

Figure 9 – The Connection between Competitive Priorities and Manufacturing Capabilities

Figure 9 illustrates that the business strategy is used to define competitive priorities. This is in accordance with the manufacturing strategy formulation processes described in Subsection 2.1. Competitive priorities present a ranking of the different manufacturing capabilities in order to answer market demands. If the ranking of the manufacturing capabilities does not represent the current level of competence, initiatives or action plans are deployed to adapt the manufacturing structure and infrastructure. This then leads to new or changed manufacturing competencies in accordance with the previously defined competitive priorities. The manufacturing competencies can then act as a competitive advantage if the manufacturing function addresses market demands better than the competition, which in turn leads to positive economic outcomes.

In setting their manufacturing strategy, companies need to translate market demands into the prioritization of different manufacturing capabilities while taking into account their relative position regarding competitors (Slack and Lewis, 2011). It is not necessary to emphasize all manufacturing capabilities with the same intensity in all markets; nor is it certain if all capabilities can be realised on a high level at the same time. Scientific literature widely discusses trade-offs between the different manufacturing capabilities and the cumulative build-up of a competitive advantage in the manufacturing capabilities (cf. Ferdows and de Meyer, 1990; Skinner, 1992; Corbett and van Wassenhove, 1993; Boyer and Lewis, 2002; Deflorin, 2007; Hallgren *et al.*, 2011). Whether or not certain manufacturing capabilities exclude or cumulatively improve each other depends on the products produced, the manufacturing structure and the manufacturing infrastructure. The concept of order-winners and order-qualifiers provided by Hill (1993) is useful for deciding upon the relevance of the different manufacturing capabilities. Order-qualifiers are manufacturing capabilities which need to be achieved in order to be perceived as a buying option for customers. Excelling in those capabilities will not result in gaining additional sales. Order-winners are manufacturing capabilities which are perceived as highly important by the customers and allow a business to distinguish itself from competitors. Excellence in these capabilities wins orders.

However, practical experience shows that it is often hard if not downright impossible to choose competitive priorities so they are feasible for the entire manufacturing network and the same for all manufacturing sites. The served customer base might be very divergent (e.g., a company might be active within two different regional markets with entirely different customer demands) and, therefore, products for the different markets have to meet different requirements. Another problem in defining competitive priorities (and delineating targets for sites) might arise from a manufacturing network’s structure and the different roles manufacturing sites take over in this network. This is illustrated in the following examples:

The **Packaging Corporation** (**PC**) from Subsection 1.1.2 is an example of how different regional markets require different competitive priorities from the respective sites. While the European sites are more focused on top-level quality and innovation, the Indian sites strongly focus on costs. The sites’ competitive priorities differ accordingly.

The **Process Automation Company (PAC)** is a globally active leading supplier of industrial measurement and automation equipment. The **PAC** offers comprehensive process solutions for flow, level, pressure, analysis, temperature, recording and digital communications across a wide range of industries, optimizing processes in regards to economic efficiency, safety and environmental protection. It is possible for the **PAC** to deliver measurement equipment tailored to customer specification globally within two days after receiving the order. To do so, its value chain is divided in two core blocks: a) critical and technologically complex core components are centrally produced and stored in its headquarters; b) the final products are assembled at regional sites that store a wide array of components but have low inventory levels and are supplied through global JIT activities. Although all sites participate in the production of the same products, their roles and thus their foci fundamentally differ. The **PAC**'s headquarters takes over the role of a lead factory, where core research and development activities and the most complex production steps for critical parts are conducted. This leads to the following characteristics of the production site at the headquarters: a) research and development as well as the function as a global support side require a high headcount of highly qualified individuals in support activities; this in turn leads to high costs in overhead activities that increase the overall production costs at this site. The costs are further increased by the high inventory levels which are necessary to continuously supply the JIT system implemented at the manufacturing sites; b) research and development activities require a setting that allows for innovation through trial and error. In summary, this site clearly focuses on reliability - it has to be a reliable source of replacement parts for the assembly sites. Thus, it would be less than ideal for the headquarters to solely focus on cost optimisation; to ensure the functioning of the entire network and the company's long-term success, the headquarters have to provide the above described inventory levels and research resources. The other sites take over the role of sole assembly sites. Their role is to supply their local market fast and reliably. In order to conduct the assembly steps, only employees with mediocre qualifications are required. Since there are several identical assembly sites, the **PAC** decided to keep inventory levels low to prevent a high tie-up of capital. In conclusion, the focus of the assembly site is set on low costs, speed and quality conformance.

Network Level Capabilities

As manufacturing networks are increasingly perceived as holistic systems in which the sites, seen as nodes, interact, there is increasing awareness of the capabilities the network can achieve as a whole (Shi and Gregory, 1998; Rudberg and Olhager, 2003; Miltenburg, 2009). According to Gulati *et al.* (2000), a network can provide access to certain information, resources, markets and technologies. Building on Ghoshal and

Bartlett (1990), Shi and Gregory (1998) and Miltenburg (2009), Mundt (2012) and Thomas (2013) identify the following network capabilities:

Network Capabilities

Provide access to	Markets and Customers	The network provides access/proximity to markets and customers.
	Competitors	The network provides access/proximity to competitors to fight them in their (home) market
	Socio Political Factors	The network is designed in a way that it profits from social political factors: Trade barriers are overcome, exchange rate fluctuations are hedged, financial subsidies are exploited etc.
	Image	The network benefits from image factors, such as "made in …"
	Suppliers/ Raw Material	The network provides access to suppliers and raw materials that can be used as a competitive advantage: Scarce raw material is bought right from its source, suppliers deliver quickly and at low costs etc.
	Best Cost Labour	The network provides access to cheap work force.
	Skilled Labour	The network provides access to a highly qualified work force.
	External Know-How	The network provides access to external know-how such as Universities, competence clusters, technology hubs etc.
Increase efficiency by	Economies of Scale	By bundling production of identical products in the network, cost savings are realised
	Economies of Scope	By bundling production of products with similar production processes in the network, cost savings are realised
	Reduction of Duplication	By bundling support functions, cost savings are realised
Provide mobility of	Products, Processes and Personnel	The network enables a flexible and fast transfer of products, production processes and personnel between the sites and therefore realises a competitive advantage.
	Production Volume and Orders	Production Volume and incoming orders can be shifted between production sites in order to realise higher production flexibility and faster deliveries.
Explore and exploit know-how and innovation about	External Factors	The network provides the possibility to unlock and share knowledge about external factors, such as local market needs an customer expectations, buying behaviour etc.
	Internal Factors	The network provides the possibility to unlock and share knowledge about internal factors, such as product or technology innovations, best practices etc.

Table 10 – Network Capabilities adapted from Mundt (2012)

It is apparent that the sites support these overall network capabilities. However, it has not been discussed how exactly the sites contribute towards network capabilities, if all sites (should) contribute to all capabilities and how exactly these network capabilities translate to site capabilities or targets (cf. Mundt, 2012). Further, it has not yet been fully evaluated if and what trade-offs between the different network capabilities exist. Shi and

Gregory (1998) state that there probably are trade-offs. Some of those are obvious: for example, by bundling the production of a certain product in a single site to realise maximal economies of scale, the mobility of production volume and orders will be difficult to realise if there is only a single site producing the product.

Similarly to manufacturing capabilities, network capabilities can also be ranked. However, the order winner/order qualifier concept is not useful in this context, as some network capabilities are not visible to the customers but focus on the internal organisation of the manufacturing network. They further elevate the perspective of what can be done in a manufacturing network from the simple outputs of processes in terms of manufacturing capabilities towards the realisation of synergies and strategic targets above singular production lines or manufacturing sites. Therefore, it is easier to first discuss the network's currently realized degree of maturity regarding its different capabilities (e.g., how well is the network currently able to realise the mobility of personnel), and then to discuss what degree of maturity is desired in the future. The resulting gap between as-is and desired future state can inform action plans or projects to change the as-is setup of the manufacturing network.

In practice, discussing and applying the network capabilities is not always easy. Often it is unclear which company-owned plants are actually part of the manufacturing network; or to put it differently, which network the discussion of network capabilities revolves around. The following examples will clarify this challenge a bit further.

The case of the **Chassis Technology Company (CTC)** from Section 1.1 illustrates the above described challenge. The **CTC** is organised in divisions, which focus on different markets (product-based) and technologies (e.g., powertrain technology, chassis technology, commercial vehicle technology, industrial technology). Below the level of divisions, business units are further specialised on certain product types (e.g., the division commercial vehicle technology incorporates the business units powertrain, damper, transmission, chassis modules and driveline). Discussing the current status of network capabilities, different perspectives can be obtained: From a corporate perspective, all manufacturing sites would be included in the so-called network. However, from a market perspective, technologies, processes and manufacturing knowledge are rather diverse; the synergies that can be created on a corporate level are limited. The further one moves down the corporate hierarchy, the smaller the networks in question get. For example, the manufacturing network for the business unit transmission only consists of six manufacturing sites compared to 121 sites on the corporate level. Naturally, the manufacturing processes, required knowledge etc. are more similar within a business unit than across different business units. As a result, sites within a business unit can collaborate more closely than sites across different business units. Thus, on a corporate level it is only possible to set a general focus regarding manufacturing capabilities. This focus then can be detailed when moving down the corporate hierarchy. It has to be noted that the focus on network capabilities can differ between the different business unit networks. For example, the realisation of economies of scope has a high priority for the manufacturing networks of the business units *powertrain* and *transmission*, while it is not important for the business unit *damper*. This is rooted in the different ways the different business units produce. While the business unit *damper* lets its manufacturing sites cover all required manufacturing processes, the business units *powertrain* and *transmission* bundle certain production steps at their main sites as the equipment for those manufacturing steps is particularly expensive.

Structural Levers of Manufacturing Networks

Structural levers of manufacturing networks describe the physical design of manufacturing activities and can be divided into manufacturing network level and manufacturing site level structural levers. The network level structural levers incorporate the geographic dispersion of sites, the general specialisation of the network and its sites and thus the horizontal and vertical integration. On the manufacturing site level the levers facility layout, technology, equipment, processes, capacity/assigned products, vertical integration, inventory level and suppliers can be used. This list of structural levers is not comprehensive but represents the most important structural levers in manufacturing networks.

GEOGRAPHIC DISPERSION OF SITES

In general, manufacturing companies can manufacture their products variably between a highly focused approach, in which only one manufacturing site exists, or a global approach, in which the products are produced directly in all countries where demand for the product exists (Miltenburg, 2005). The decision regarding the global dispersion of manufacturing activities is based on the customer base, industry, product and market. Dispersing manufacturing activities across different countries enables companies to access more sources of competitive advantage (Miltenburg, 2005). Countries differ regarding inflation, wages, productivity, energy costs, taxes and government regulations which can result in profoundly differing manufacturing costs (Porter, 1991, 1989). However, manufacturing costs are not the only decision factor when opening a new manufacturing site. Instead a manufacturing site can benefit from access to local markets, customers, suppliers, resources, image, skilled labour, external know-how (e.g. research institutions and Universities) and socio-political factors (e.g. subsidies or the avoidance of tariffs) (Shi and Gregory, 1998). Not all manufacturing sites in a manufacturing network benefit from all of these factors to the same extent and they do not need to. Instead it is important that the overall network has access to the critical factors of the business and that the sites assigned to the factors exploit those factors sufficiently. When increasingly dispersing manufacturing activities, a certain share of duplication in manufacturing competences, equipment and processes is inevitable. While duplication often increases costs it also decreases the risk sensitivity of the manufacturing network. A manufacturing company then has to decide what level of duplication is coherent with its manufacturing strategy and competitive situation.

THE SPECIALISATION OF THE MANUFACTURING NETWORK

The manufacturing network's specialisation can be described from different perspectives. Schmenner (1982) originated the first, resource-based perspective by comparing the manufacturing structure of 300 plants of Fortune 500 companies and deriving four so-called multi-plant strategies. These multi-plant strategies describe a network structure based on the general focus of its manufacturing sites. Schmenner (1982) distinguishes four different foci for manufacturing plants:

- **Product Focus** – The different manufacturing sites are responsible for the manufacturing of certain products or product groups. This responsibility extends to the complete manufacturing process. The sites are generally responsible for the distribution of products to the entire market. This strategy is suitable for high volume items or products that are tied to resources that are only locally available.
- **Market Area Focus –** Manufacturing sites are focused on a certain market area and manufacture all products sold in this market area. This strategy is suitable for products that are highly sensible to logistics costs.
- **Process Focus** – Manufacturing sites are focused on certain process steps along the production process. This strategy enables the realisation of economies of scale and scope and is most suitable for complex products, industries that are highly vertically integrated with a segment of the production process being locally tied, and industries where part of the production process may be susceptible to significant economies of scale.
- **General Purpose Sites** – To achieve high flexibility, the manufacturing sites are assigned a broad array of competences and responsibilities. Responsibilities for certain product groups, market areas or customers can be variably assigned between the plants. This strategy is suitable for products with short product lives or highly volatile customer demands.

This set of multi plant strategies was adapted by Khurana and Talbot (1999) and Hayes *et al.* (2005). Khurana and Talbot (1999) agree with the different foci identified by Schmenner but rename the "general purpose sites" to "volume sites". The focus of those sites lies on the flexible allocation of product volume and orders. Additionally, Khurana and Talbot (1999) claim that certain sites can be opened based on location advantages or specialised manufacturing abilities present at certain sites.

The second perspective on the manufacturing network specialisation is based on a network's overall geographic dispersion and its internal supply chain. Stremme (2000) identifies four main types of international manufacturing network based on their internal supply chain structure. Stremme (2000) explicitly acknowledges that strong interdependencies exist between the overall structure of the global manufacturing network, based on its internal supply chain, and the horizontal and vertical integration between the different manufacturing sites, which Schmenner (1982) calls the focus of plants. The four types of manufacturing networks identified by Stremme (2000) are:

- **Monocentralistic** – Monocentralistic networks are designed in a way that the main production activities are conducted in a hub site while only certain production steps are outsourced. The main reason for pursuing this structure is ensuring the long-term existence of the hub site. By outsourcing production steps, cost advantages are realised that provide a competitive advantage in the supplied market. Often, the products produced in these structures target national markets only and their specification is not designed to appeal to a global customer base. Companies pursuing this network design often have a local or regional focus (Stremme, 2000).
- **Cross-linked** – In cross-linked networks, no one single production hub exists. Instead, networks of many production sites with partially or completely overlapping production competences form along the production chain of the different products. This allows to systematically exploit the specialisation and location advantages of the different sites. The variety of interlinks between manufacturing sites in cross-linked networks requires a high degree of standardisation, which in turn reduces the ability of the overall manufacturing network to include local content in their production processes. Therefore, cross-linked networks are especially useful for globally or regionally convergent markets. However, limitations regarding the inclusion of local content can partially be overcome by producing standardised modules and standard components centrally, while placing the finishing, assembly and engineering at local manufacturing sites. These networks tend to be organised centrally which means that in a central entity basic guidelines and standards for manufacturing are defined and then implemented across the network (Stremme, 2000).
- **Insular** – Insular manufacturing networks are networks in which the different sites do not mainly depend on one another regarding their specific production

activities. Insular manufacturing networks can be further categorised into concentrated insular networks and deconcentrated insular networks:

  - Concentrated insular networks consist of manufacturing sites that are focused on certain product groups and entirely cover the necessary production steps. The goods are then exported globally. Sites responsible for different product groups can be dispersed globally. This concept can be used in globally convergent markets (Stremme, 2000).
  - Deconcentrated insular networks are organised similar to the concentrated insular networks. However, the different sites do not supply global but regional or national markets. This allows adapting products to local market requirements. Therefore, the same product groups can be produced in multiple plants for their respective local markets (Stremme, 2000).
- **Combinations of the different network types –** In reality, combinations of the different types might exist. This can especially be the case when the overall manufacturing network is divided into different regional networks (Stremme, 2000).

The network types described by Stremme (2000) differ in the realisation of economies of scale and scope and the ability to adapt to local or regional market demands. Meyer and Jacob (2008) create a similar typology of manufacturing networks while ranking the different network types based on the ability to realise of economies of scale and scope on the one hand, and the importance of local content/the sensitivity of transaction costs on the other hand. They distinguish the following five types of manufacturing networks:

- **World factory (high realisation economies of scale and scope/ low importance of local adaptions and logistic costs)** – World factories are manufacturing sites that cover the entire production process of a product group and supply those products globally. Recently, the importance of world factories has decreased, but they remain relevant in industries with significant economies of scale and scope and long enough delivery lead times (Meyer and Jacob, 2008).
- **Sequential or convergent networks (medium realisation economies of scale and scope/ low importance of local adaptions and logistic costs)** – The sequential or convergent network aims at exploiting specific advantages of individual locations. To do so, blocks of manufacturing steps are concentrated at locations that best suit the requirements of the respective production step. While some economies of scale and scope can be realised in this set-up, logistic costs are very high due to the frequent shipping of unfinished parts and components. Therefore, this structure is only suitable for products with a high volume density (Meyer and Jacob, 2008).

- **Web structure networks (low realisation economies of scale and scope/ low importance of local adaptions and logistic costs) –** The web structure includes a web of manufacturing sites with identical or similar manufacturing abilities that allow to allocate orders in a flexible way and to adapt capacity to demand (Meyer and Jacob, 2008).
- **Hub & spoke (high realisation economies of scale and scope/ high importance of local adaptions and logistic costs)** – In a hub & spoke set-up, knowledge-intensive production steps or production steps that allow the realisation of economies of scale and scope are bundled centrally. The rest of the manufacturing is placed in various manufacturing sites close to market. This set-up allows the management of a large number of local variants with a reasonable delivery time (Meyer and Jacob, 2008).
- **Local for local (low realisation economies of scale and scope/ high importance of local adaptions and logistic costs)** – Local for local manufacturing networks localise manufacturing. This means that the products sold in one region are also produced in that region. This can be done by building regional networks or regional "world" factories. While rather low economies of scale and scope are realised in this network type, the network is highly flexible and able to adapt regional market requirements (Meyer and Jacob, 2008).

At this point it can be concluded that the specialisation of the manufacturing network includes the design of the (intra-organisational) supply chain and the location, the competences and roles of the manufacturing sites, and their connection with each other. It has to be noted that the structure and specialisation of a manufacturing network are rarely defined when the network is created but result from historical growth and adjustment processes. Therefore, manufacturing networks are often a mixture of the theoretical types described above. Nonetheless, the manufacturing network manager has to understand the external requirements towards manufacturing and shape the manufacturing network accordingly. The different perspectives on manufacturing network types described above show that within manufacturing networks the vertical and horizontal integration of the manufacturing sites and the network are inseparably intertwined, and cannot be viewed in isolation.

The Specialisation of Sites – Site Roles

The (aspired) structure and specialisation of a manufacturing network has to be supported by the manufacturing sites the network consists of. As pointed out in the previous section, the manufacturing sites can differ in their set-up, competences, strategic advantages and general role. From a scientific perspective, a range of typologies for manufacturing site roles, or more generally subsidiary roles, exist. These typologies distinguish up to 24 types of site roles each (cf. Enright and Subramanian, 2007) based on numerous dimensions. The typologies focus on different aspects of manufacturing, network management or strategy. Table 11 gives an overview of the different dimensions considered when defining site roles. The cited sources describe roles for manufacturing sites, R&D sites and subsidiaries in general. However, the dimensions used to define the type of site roles by the selected sources can be applied to manufacturing sites.

Authors	*Dimensions of Differentiation*				
	Production Perspective	R&D Perspectives	Logistics Perspective	Dependency/Influence on the Network	Strategic Advantage presented by the Site
White and Poynter (1984)	• Product Scope • Value-Added		• Market Scope		
D'Cruz (1986)	• Market Scope	• Market Scope	• Market Scope	• Decision-Making Autonomy	
Bartlett and Ghoshal (1989; 1990)	• Level of competence	• Level of competence	• Level of competence	• Level of competence	• Importance of local market
Marcati (1989)				• Degree of coordination • Dependency on headquarters	
Jarillo and Martíanez (1990)	• Degree of integration • Degree of localisation	• Degree of integration • Degree of localisation	• Degree of integration • Degree of localisation	• Degree of integration • Degree of localisation	
Gupta and Govindarajan (1991)				• Degree of knowledge inflow • Degree of knowledge outflow	
Hoffman (1994)	• Level of capabilities	• Level of capabilities	• Level of capabilities	• Strategy determines site roles • Local environment influences site roles	
Birkinshaw and Morris (1995)	• Product dependency on parent company • Degree of inter-company purchasing • Degree of international focus in manufacturing • Degree of international focus in downstream activities			• Degree of independency in site strategy setting	
Ferdows (1997)	• Basic production responsibility • Maintenance of technical processes • Make process improvement recommendations • Assume responsibility for process development	• Make product improvement recommendations • Assume responsibility for product development	• Responsibility for procurement and local logistics • Assume responsibility for the development of suppliers • Supply global markets	• Become global hub for knowledge	• Access to low-cost • Access to skills and knowledge • Proximity to market
Medcof (1997)		• Level of capabilities • Extent of activities	• Geographic scope	• Functional areas of collaboration in the network	
Taggart (1997a)				• Degree of integration into the network • Degree of local responsiveness necessary	

Authors	*Dimensions of Differentiation*				
	Production Perspective	R&D Perspectives	Logistics Perspective	Dependency/Influence on the Network	Strategic Advantage presented by the Site
Taggart (1997b)				• Degree of autonomy from the network • Degree of procedural justice in the network	
Forsgren and Pedersen (1998)		• Extent of R&D Activities	• Extent of Product Export		
Nobel and Birkinshaw (1998)		• Basic research • Development • Product/process improvement • Product/process adaptation	• Global/local perspective	• Mode of control	
Randoy *et al.* (1998)				• Outflow of resources • Inflow of resources	
Surlemont (1998)				• Number of other sites controlled by a site • Number of activities conducted for other sites	
Kuemmerle (1999)					• Overall objective for the site
Delany (2000)	• Product Scope • Extent of value adding activities	• Product Scope	• Market scope		
Jones and Herbert (2000)		• R&D activity type	• Geographic Orientation		• Focus of motivation
Benito *et al.* (2003)	• Scope of activities • Level of Competence	• Scope of activities • Level of Competence	• Scope of activities • Level of Competence		
Fusco and Spring (2003)	• Production of World or local products	• Incorporation degree of local design aspects			• Access to low-cost • Access to skills and knowledge • Proximity to market
Meijboom and Vos (2004)	• Production • Production Scheduling • Production Planning	• Recommendations on simple product & process development • Simple product development • Simple process development • Recommendations on complex product & process development • Complex product development • Complex process development • Creation of new processes and products for entire company	• Responsibility for purchasing and/or local distribution	• Creation of new processes and products for entire company	• Access to low-cost • Access to skills and knowledge • Proximity to market
Maritan *et al.* (2004)	• Long range production planning • Production scheduling • Quality standards • Maintenance policies and practices	• Responsibility for changes in product design • Responsibility for changes in process design • Responsibility original product design • Responsibility original process design	• Raw materials sourcing • Component sourcing • Equipment sourcing	• Human resource policies for management or labour • choice of accounting systems • Choice of management information system • Choice of production planning and control system	Access to • Low cost labour • Raw materials • Energy • Key suppliers • Local technology • Skilled labour • Advanced Structure Proximity to • Important markets • Key customers

Authors	*Dimensions of Differentiation*				
	Production Perspective	R&D Perspectives	Logistics Perspective	Dependency/Influence on the Network	Strategic Advantage presented by the Site
Johansen and Riis (2005)	• Focus of production activities (Full-scale, benchmarking, ramp-up, prototype and laboratory)				
Hogenbirk and van Kranenburg (2006)	• Value added scope	• Value added scope	• Market scope		
Vereecke *et al.* (2006)				• Outflow/Inflow of information • Outflow/Inflow of people • Intensity of communication with other sites	
Enright and Subramanian (2007)	• Capability creation • Product Scope • Geographic Scope	• Capability utilisation	• Geographic Scope	• Capability creation • Capability utilisation	
Feldmann und Olhager (2013)	• Level of production activities	Level of R&D activities	• Level of supply chain activities		

Table 11 – Dimensions of site roles based on Schmid et al. (1999), Schmid and Kutschker (2003) and Kretschmer (2008) extended by the author

The different dimensions used to describe site roles point the researchers' attention to different aspects of network or corporate management. It is noteworthy that site roles are strategic constructs that describe the tasks of manufacturing sites from different perspectives. In reality, manufacturing sites can take over site roles from multiple site role typologies at the same time. Depending on how a manufacturing network is structured, manufacturing sites even can take over different site roles within the same typology. For example, if a network is structured based on product groups (cf. the model of Schmenner 1982), a manufacturing site might be a lead factory for one product group and an outpost for another product group.

When discussing site roles in the context of holistic manufacturing network management and strategy, it is not advisable to focus on the choice of one single typology of site roles. Instead, it is important to understand the full range of activities manufacturing sites cover, the competencies they have and their linkages to other sites. Thus, a set of typologies should be chosen that best reflect the existing manufacturing network set-up and the manufacturing strategy.

Most site typologies in a manufacturing network context are based on the groundwork of Ferdows (1997), as Ferdows' site roles incorporate competency-based as well as strategic dimensions. Ferdows identifies three strategic reasons for the existence of a manufacturing site: a) the access to low-cost production b) the access to skills and knowledge and c) the proximity to a market. These, in combination with different levels of competences, lead to six types of manufacturing sites or site roles: outpost, offshore, server, source, contributor and lead.

Importantly, Ferdows views the role of a manufacturing site as non-static. According to Ferdows, it is the main task of manufacturing management to continuously question the role of manufacturing sites and develop the sites to higher levels if suitable for the overall manufacturing network (Ferdows, 1997). The idea of dynamically changing site roles has been shared by other researchers (cf. Meijboom and Vos, 2004; Feldmann and Olhager, 2009a; Feldmann *et al.*, 2010; Blomqvist and Turkulainen, 2011; Cheng *et al.*, 2011). A manufacturing network manager therefore should consider possible development paths of the manufacturing sites in the manufacturing network in accordance to the manufacturing strategy. The site roles are developed by adjusting and developing the structural and infrastructural levers on a site level and ensuring the interplay on a network level. Often, site configurations result from reactions to short-term pressure. However, to fully utilise the potential and synergies of a manufacturing network, the site roles of manufacturing sites and their development should be a strategic choice (Hayes and Pisano, 1996; Vokurka and Davis, 2004).

FACILITY LAYOUT, PROCESSES, TECHNOLOGY AND EQUIPMENT

The four levers facility layout, processes, technology and equipment are closely interconnected and need to be discussed in unison. Based on the desired strategic manufacturing priorities, the type of manufacturing process should be chosen (e.g., job shop, batch flow, operator paced line flow, equipment paced line flow, just in time, continuous flow) (Miltenburg, 2008). This then holds implications regarding the facility layout, which technology and concrete equipment needs to be bought. As these levers are directly connected to the strategic manufacturing priorities, they can be used to build up a desired strategic advantage in the market.

CAPACITY AND ASSIGNED PRODUCTS

The capacity lever deals with the level of production capacity that is assigned to a manufacturing site. Generally, this depends on a) the volume of the markets delivered by the manufacturing site, b) the assigned products, c) whether demand is cyclical, and d) if there is an expansion strategy (Fine and Hax, 1985a). It is evident that excess capacity costs money but enables additional flexibility. Thus, excess capacity can be used as a competitive advantage in accordance with the selected strategic manufacturing priorities. The products assigned to a manufacturing site can be produced on similar machinery or they might require additional equipment, production lines personnel etc. The increased complexity at the manufacturing site through the introduction of additional products and a possible decrease in utilisation of available capacity have to be considered, when assigning additional products to a manufacturing site.

VERTICAL INTEGRATION AND SUPPLIERS

Vertical integration describes the extent to which a company owns the process steps along the value chain of products (Rudberg and Olhager, 2003). Generally, companies can extend their activities along the value chain, meaning they acquire additional competencies and broaden their process portfolio, they can continue with the assortment of process steps they originally had or they can focus on core competencies and outsource non-critical process to outside suppliers (Rudberg and Olhager, 2003). In doing so, the availability, selection and development of key suppliers becomes an important task that manufacturing managers have to consider before focussing on core competences.

HORIZONTAL INTEGRATION

The horizontal integration describes how manufacturing sites that conduct similar process steps are aligned within an organisation. The question of horizontal integration is closely connected to infrastructural levers of manufacturing networks such as standardisation, centralisation, the choice of IT-systems and the site autonomy in general. Both high and low levels of horizontal integration have their advantages and disadvantages. A high level of integration allows the flexible assignment of product orders and thus lowers overall lead times and higher flexibility. However, the products need to be highly standardised across plants, or the induced complexity can be hard to handle. In contrast, a low level of integration allows manufacturing sites to flexibly adjust to customer requirements in their specific markets. The resulting differences in product specifications lead to difficulties when trying to work flexibly as a network.

INVENTORY LEVEL

The inventory level kept at manufacturing site can also be a strategic lever. Having a high inventory of spare parts and finished products can be advantageous as fluctuations in demand can be flexibly addressed. However, inventory binds capital and continuously costs money. If a manufacturing site holds high levels of inventory of a product that is suddenly outdated, a significant depreciation might damage the company’s overall annual result. Thus, it is important to consider potential consequences of building up high inventory levels.

Infrastructural Levers of Manufacturing Networks

Infrastructural levers of manufacturing networks address aspects of how manufacturing is managed rather than how it is physically designed. As all levers discussed in this subsection can apply to single sites and networks alike, the differentiation between the network and site level is not as necessary as for the structural levers. Once again, the levers discussed here do not represent an exhaustive list but are examples of the most important infrastructural levers.

ORGANISATIONAL STRUCTURE

The organisational set-up of a manufacturing network is a powerful lever. There are certain advantages and disadvantages to specific organisational set-ups. Manufacturing network managers can run their sites as cost or profit centres, implement flat or hierarchical organisational structures, value line and staff functions differently, change the responsibility and authority of different organisational levels etc. (Miltenburg, 2005). Decisions regarding the organisational structure are strongly related to questions of centralisation and standardisation. Organisational complexity increases if different manufacturing sites have different organisational structures. Many global companies try to duplicate the structures of their manufacturing sites to ensure that fast and clear communication between headquarters and manufacturing sites is ensured.

STANDARDISATION

Decisions regarding the centralisation and standardisation within a manufacturing network are closely related to the degree of autonomy manufacturing sites are granted (cf. Maritan *et al.*, 2004; Feldmann and Olhager, 2009b; Mundt, 2012). Standardisation can focus on systems, decisions and processes within a manufacturing network (Maritan *et al.*, 2004; Hayes *et al.*, 2005; Vereecke *et al.*, 2006; Christodoulou *et al.*, 2007; Feldmann and Olhager, 2011; Mundt, 2012). Generally, standardisation can be used to allow manufacturing sites to act within predefined borders.

CENTRALISATION AND FUNCTIONAL SUPPORT

Another way of limiting autonomy of a manufacturing site is to centralise decisions, processes, systems and activities. By limiting local sites' competency to make certain decisions, corporate headquarters gain maximal control over manufacturing activities. However, centralising tends to slow the reaction time to external changes. If competencies and processes are centralised, many manufacturing companies implement central departments that deliver functional support to the manufacturing sites. This ensures a central build-up of knowledge and competences but might be a costly solution as the staff at the headquarters is often more expensive. Nonetheless, these costs might be less significant than costs due to competence multiplication throughout the network.

Quality Management

Manufacturing management knows the challenges associated with product and process quality well. Yet, the complexity and difficulty of this task has increased in the context of global manufacturing networks (Seghezzi *et al.*, 2013). As manufacturing sites differ according to their layout, employee training level, competence and process scope, different quality management mechanisms have to be employed. Deciding which quality management mechanisms should be employed where is further complicated by the fact that the different global markets a single manufacturing site may serve are likely to vary in terms of the expected product quality (Seghezzi *et al.*, 2013).Therefore, implementing quality management in manufacturing networks is closely connected to centralisation and standardisation decisions. The question always is how much autonomy and responsibility should manufacturing sites receive and which aspects of manufacturing should be tightly controlled by a central entity.

Production Planning and Control

Production planning and control includes aspects such as order entry, master production scheduling, materials planning scheduling of machines and employees, controlling of production on the factory floor, coordination production support, the required IT-systems and so on (Miltenburg, 2005). Decisions of manufacturing managers then include whether systems are centralised/standardised, whether a push or pull control system is used, how maintenance is done, how orders, product changes and new products are implemented into production etc. (Miltenburg, 2005).

Workforce and Human Resources

Managing the workforce is also an important lever in the design of manufacturing networks. Aspects that can be addressed include the education and training of employees, the provision of development opportunities within the organisation, participation of employees in problem-solving and improvement activities etc. (Miltenburg, 2005). To remain competitive, it is critical for manufacturing organisations to attract competent employees, train them and keep them in the company. This requires that employees identify with the company, and manufacturing managers can implement a variety of initiatives to increase this identification. Additionally, employee flexibility is an important aspect in a manufacturing network as frequent travels between manufacturing sites might be necessary.

EXCHANGE OF KNOWLEDGE AND INFORMATION

The success of multinational corporations often depends on their ability to identify and utilise critical knowledge within their network (Doz *et al.*, 2001). Access to knowledge can increase innovation at a manufacturing site and has a positive impact on financial site performance (Tsai and Ghoshal, 1998; Tsai, 2001). However, it is important to filter existing knowledge and information and to supply them to the sites and stakeholders that can benefit from them. Therefore, the network managements has to make critical decisions on what, where and how to share (Cheng *et al.*, 2008). “What to share” addresses the question of which pieces of information and knowledge are to be collected and to whom the collected knowledge is disseminated. Generally, the “where to share” is addressed by the design of the exchange structure and transparency regarding knowledge and information. The structure can range from centrally organised to decentralised, and the transparency can range anywhere between high and low (Chew *et al.*, 1990; Mundt, 2012). Finally, the question of “how to share” addresses the choice of mechanism used to disseminate and transfer knowledge and information (cf. Ferdows, 2006). All three dimensions have to be aligned with each other and the strategy regarding the flow of information and knowledge within the network.

PERFORMANCE MEASUREMENT AND INCENTIVE SYSTEM

Performance measurement is a powerful management tool to control and develop the activities of a business in general. By choosing performance dimension which will be assessed, setting goals and adding an incentive, employees are additionally motivated to improve in those dimensions. The decision of performance dimensions and measures hast to be aligned to overall strategy. Thus, managers can use performance measurement as a supporting tool in their striving to implement an overall vision or strategy, thereby improving overall performance (Ukko *et al.*, 2007). Generally, the dimensions used to evaluate employees have to be influenceable by the respective employees. To further employees’ motivation in reaching certain performance goals, an incentive can be added. In a manufacturing network context, targets can be set for individual manufacturing sites, clusters of sites or entities within a company. Accordingly, the incentives can be awarded based on the achievement of single manufacturing sites or based on the common achievement of a cluster of sites. Generally, defining performance dimensions, setting targets, measuring and evaluating performance is not a trivial task. This is why this dissertation is discussing strategic performance measurement and management in manufacturing networks in detail.

Summary of Manufacturing Strategy Content

It can be concluded that:

- Manufacturing strategy contains four dimensions: manufacturing capabilities, network capabilities, structural levers and infrastructural levers
- Manufacturing capabilities can be ranked based on their current and future importance for
    - Winning orders
    - Qualifying for a market
- Network capabilities can be evaluated based on the current realisation degree and the desired future realisation degree
- The gap between the current and aspired level in manufacturing and network capabilities can be used to derive action plans
- These action plans address changes in the structural and infrastructural levels which are supposed to close the gap between the current and aspired level of manufacturing and network capabilities
- The weighting of manufacturing and network capabilities might differ for different regional markets, product groups, customer groups, manufacturing sites and sub-clusters of manufacturing networks
- The derivation of action plans differs accordingly
- The activities of a manufacturing site and its contribution to the fulfilment of a manufacturing network strategy is described in so-called site roles
- Site roles are dynamic and can be adjusted through the modification of structural and infrastructural levers

2.1.5 Performance Measurement and Management in Manufacturing Networks

As companies increasingly compete in international markets, so increases the difficulty of setting a strategy that adequately addresses all markets and accordingly it becomes more difficult to derive appropriate manufacturing goals and performance dimensions (Shi and Gregory, 1998). Further to these strategic dilemmas, implementing a performance measurement system is complicated by the practical problems that come along with a global spread of manufacturing activities. According to Lohman *et al.* (2004, p. 269), these problems are:

- a decentralized, operational reporting history
- deficient insight in the cohesion between metrics
- poor communication between users and producers of performance measures
- a dispersed IT infrastructure

Additionally, companies increasingly manufacture in networked structures such as supply chains, interorganisational networks and intraorganisational networks, but implications of those networks on performance and performance measurement have not yet been fully understood (Bititci *et al.*, 2012).

According to De Toni and Parussini (2010), performance measurement in manufacturing networks has not been discussed sufficiently in the scientific literature. In particular, the literature lacks a comprehensive discussion of the implications of different types of network coordination and configuration on performance and performance measurement (De Toni and Parussini, 2010, p. 9). De Toni and Parussini (2010) only see three sources that have addressed this gap - Colotla, Shi and Gregory (2003), Colotla (2003) and Mauri (2009), but content and scope of these works vary greatly.

Colotla, Shi and Gregory (2003) and Colotla (2003) present a framework that illustrates the interdependencies between capabilities on site and on network level, and the overall competitive advantage generated by a manufacturing network. This overall competitive advantage is considered as the performance of the manufacturing network (Colotla *et al.*, 2003). According to Colotla, Shi and Gregory (2003), performance on site level refers to operational performance on site level as described by the competitive priorities which result in a competitive advantage. Performance on network level refers to the quality of coordination and configuration of the manufacturing network which results in a competitive advantage. Capabilities on network and site level can offset one another. However, Colotla, Shi and Gregory (2003) fail to clearly define and quantify what overall site or network performance actually is. Their case study-based approach is purely qualitative, and so is their assessment of performance/capability on site and network level.

Mauri (2009) focusses on the interdependencies between network configuration and the volatility of firm performance. Firm performance is described as the quotient of earnings before interest and taxes (EBIT) and total assets[11]. Although Mauri (2009) considers the impact of different types of network configuration on performance, the types of considered configurations are only defined superficially, without incorporating detailed trends and definitions from recent literature on manufacturing networks. Furthermore, Mauri (2009) does not discuss what constitutes performance on a manufacturing network level.

[11] The use of financial performance indicators only is not in line with recent publications on performance and performance measurement (cf. section 2.2.4 and Medori and Steeple (2000)).

The two approaches to performance in the context of manufacturing networks point out another dilemma in the scientific literature: There is no unified definition of manufacturing site performance and hence manufacturing network performance (Colotla, 2003; Nguyen, 2011). In essence, performance and performance measurement in networks has to be redefined: *"A network […] has more goals to achieve than a traditional organisational structure. A network should certainly exhibit a high level of business performance, but it would be a mistake to focus solely on this performance dimension. […] Equity should be assessed in order to be consistent with the strategic objectives behind the creation of a network.*" (Leseure *et al.*, 2001, pp. 33–34). Addressing the aspect of collaboration and reaching goals defined above site level is especially important in an intra-organisational environment, as collaboration within intra-organisational relationships is generally lower than in inter-organisational relationships (Mena *et al.*, 2009). Cheng *et al.* (2011) point out that the definition of network and site performance and the task of network development should not be left to sites alone, but should be steered from a central entity in a top-down process. Additionally, the definition of site and network level performance and the embedding into a network level performance measurement system allow the realisation of network level goals and help align strategies throughout a network (Pekkola and Ukko, 2012; Pekkola, 2013; Zanon and Alves Filho, 2012). A strategic performance measurement system can therefore be used to put strategy into action (Neely *et al.*, 1994). The internal alignment of strategy is important as it positively correlates with external market and business performance (Gregory, 1993).

Perspectives on performance differ depending on the different domains or responsibility areas that are assessed (Lebas and Euske, 2008). It is therefore impossible to transfer concepts regarding, e.g., R&D performance straight to a manufacturing environment. Similarly, supply chain performance does not automatically incorporate all aspects of manufacturing network performance as discussed in this dissertation. In a supply chain context, performance has traditionally focused on logistics performance (Folan and Browne, 2005; Karrer, 2006; Lehtinen and Ahola, 2010). However, as highlighted in this section, performance aspects extend beyond logistical matters in the context of manufacturing networks. Performance Measurement Systems that are suitable for supply chains and logistics networks can therefore not be used in the context of manufacturing networks (Pekkola and Ukko, 2011). Another problem with existing PMS lies in their general focus on financial performance measures which is not suitable for a manufacturing environment (Medori and Steeple, 2000) since manufacturing site and network performance are a complex construct which should incorporate multi-dimensional performance dimensions and measures (Dangayach and Deshmukh, 2001).

In addition, the content and dimensions of manufacturing site and network performance greatly depend on what a company is trying to achieve (Birkinshaw and Morrison, 1995). Furthermore, the definition of performance measures and therefore performance differs depending on whether a strategic, tactical or operational perspective is taken (Gunasekaran *et al.*, 2001; Gunasekaran and Kobu, 2007). Traditionally, the definition of strategic performance in manufacturing revolves around the manufacturing capabilities (Leong *et al.*, 1990; Corbett and van Wassenhove, 1993; Ward *et al.*, 1998; Neely *et al.*, 2005). However, as Subsection 2.1 shows, manufacturing strategy incorporates more aspects than just manufacturing capabilities. Since network capabilities and global manufacturing in general have only emerged recently, they need to be anchored in a strategic performance measurement system for manufacturing networks. This is in line with the observations of Gomes *et al.* (2006), who note that PMS in a manufacturing context are focused on efficiency instead of effectiveness. This means that performance measurement in a manufacturing context often focuses too much on process-based performance measures that assess if things are done rightly. This focus should shift to softer performance measures that address whether it is the right things that are done (Gomes *et al.*, 2006). In general, it can be stated that a sole focus on efficiency in performance measurement systems will not ensure manufacturing success (Vokurka and Davis, 2004). It can be concluded that existing PMS do not focus on all aspects of strategy (Epstein and Manzoni, 1998), and especially not all aspects of manufacturing strategy.

Not only performance measurement in manufacturing networks, but also performance management has been widely neglected in the scientific literature. Manufacturing managers face several problems when defining manufacturing network performance and targets, and deriving site strategy and targets: Different designs of manufacturing networks have different strengths and weaknesses, and the same is true for sites and their roles (cf. Birkinshaw and Morrison, 1995; Dossi and Patelli, 2010). Thus, different manufacturing networks and sites with different roles require different performance measures that are in accordance with their strategic foci (Bendoly *et al.*, 2007; Chenhall and Langfield-Smith, 2007). Strategic performance management, that is the downward translation of manufacturing strategy and the matching of site strategy and goals with network strategy and goals and the derivation of changes, has, however, not gained any attention (Meijboom and Vos, 1997). Important factors that influence the day-to-day outcomes of activities in manufacturing networks, such as different environments, machinery, level of competence etc. (Wathen, 1995), have not been incorporated in today's PMMS. Furthermore, not only does the environment of manufacturing networks change, as pointed out above manufacturing networks with their manufacturing sites and site roles are dynamic constructs that evolve over time. This means that performance management in a manufacturing network context needs to be updated periodically. As manufacturing networks develop, the definition of performance needs to adapt (Gomes *et al.*, 2006). To ensure this, the process of manufacturing strategy formulation and performance definition in manufacturing networks need to be interwoven (Pun and White, 2005). This statement is supported by Melnyk *et al.* (2013) who identified *"the need for a co-evolutionary approach between organisational setting, business strategy and the PMM system."* (Melnyk *et al.*, 2013, p. 2).

It is generally accepted that research should focus on the development of updated PMMS for manufacturing in general (Dangayach and Deshmukh, 2001), and manufacturing networks in particular (Mundt, 2012; Thomas, 2013). It can be summarised that:

- There is no unified scientific definition of manufacturing performance on site or network level
- Performance can be seen from a strategic, tactical and operational perspective.
- Concepts of strategic performance and strategic performance measurement and management from other areas, such as supply chain performance, cannot readily be applied to manufacturing networks
- The specific content of strategic performance in a manufacturing network depends on the manufacturing strategy
- The concept of strategic performance in a manufacturing network needs to extend beyond financial aspects or a sole focus on manufacturing capabilities
- Strategic performance measurement should focus on effectiveness and not solely on (process) efficiency
- Strategic performance measurement in manufacturing networks should be able to address all aspects of manufacturing strategy
- As the strategic focus and purpose of different manufacturing sites and networks differs, so should the specific definitions of performance
- The definition process of strategic performance targets and measures should be linked with the formulation process of manufacturing strategy
- The definition of performance targets and measures should be updated periodically
- The definition of network and site targets and performance dimensions should be conducted by a central entity in a top-down process

2.1.6 Summary

This section provided a broad overview of the latest challenges and developments in manufacturing and manufacturing networks (Subsection 2.1.1), presented an overview of the definition, content and process of formulation for manufacturing strategy (Subsections 2.1.3 and 2.1.4) and discussed the state of the art in performance measurement and management specifically for manufacturing networks (Subsection 2.1.5). The following subsection will summarise findings and provide concluding definitions and models.

Based on the definitions of manufacturing strategy in Subsection 2.1.2, the following definition of manufacturing strategy will be adopted:

Manufacturing strategy is the strategy revolving around the manufacturing function of a company and is connected to the overall corporate strategy. It therefore needs to be aligned with other aspects of corporate strategy, and other functional strategies within a company. Manufacturing strategy describes how structural and infrastructural levers are utilised to realise the strategic focus regarding manufacturing and network capabilities in the manufacturing of goods. The goal is to develop a competitive advantage based on the manufacturing function and support corporate goals and objectives.

Subsection 2.1.3 provided an overview of various formulation processes. Based on those processes and findings on the changing and diverse environment of manufacturing networks, the process depicted in Figure 10 was created. This process contains the core elements from the processes of Skinner (1969), Fine and Hax (1984; 1985a; 1985b), Hill (1986; 1993), Leong *et al.* (1990), Platts and Gregory (1990) and Hallgren and Olhager (2006). Similarly to the reviewed processes, the consolidated process has three main phases. In the first phase, requirements of the manufacturing function are collected and evaluated. It has to be noted at this point that the process is directed at a business unit of a company. This is obvious in phase one, as the business strategy is derived from the corporate strategy. The process then only focuses on the manufacturing activities within that business. The goal of the second phase is to define an overall manufacturing strategy for the manufacturing function of the business in question. To this end, the requirements of manufacturing are used to evaluate the as-is set-up of the manufacturing activities. In the evaluation, a grouping of the manufacturing activities is necessary. The grouping should be based on the variance in the customer base of the manufacturing function. This can be along regional markets, product groups, customer segments etc. The reason for this grouping step is the heterogeneity in customer requirements that today's global manufacturing companies deal with. This heterogeneity makes it difficult to define a homogeneous and unified manufacturing strategy. Based on the grouping and the requirements an overall vision of the future manufacturing set-up can be created.[12] The overall vision addresses the aspired state of the manufacturing networks. By stating the aspired state, gaps towards the future state can be identified and addressed through action plans. This vision is then grounded into a realistic version based on financial and technical constraints of the company. The realistic vision is then used to define an overall manufacturing strategy. This overall manufacturing strategy contains targets for the different entities within the network, principles which describe how operations are conducted and action plans that address changes in the manufacturing set-up.

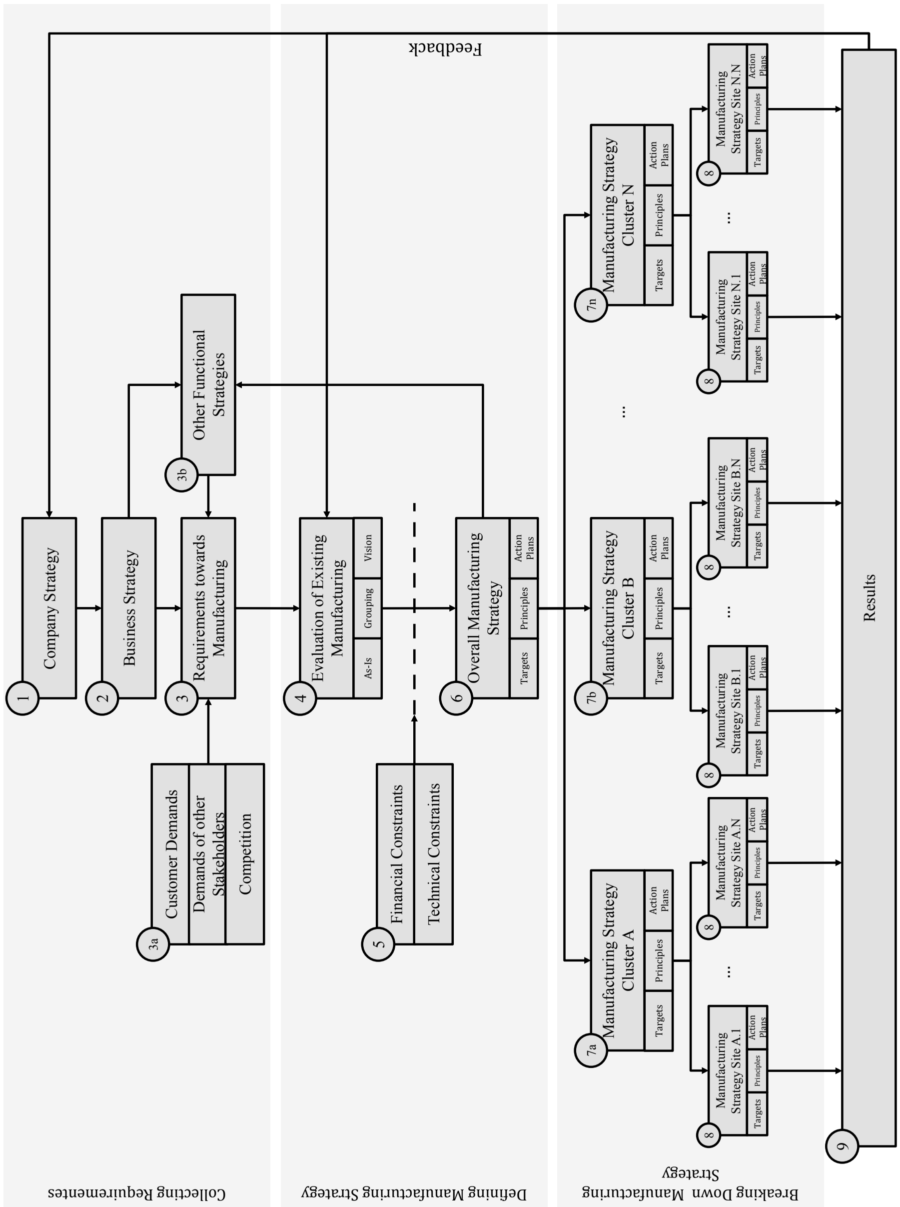

Figure 10 – Extended Strategy Formulation Process

[12] This vision can be created using the scenario approach described by Friedli *et al.* (2014)

The overall manufacturing strategy then needs to be broken down into more concrete manufacturing strategies for the different manufacturing clusters within a manufacturing function. The clusters should be based on the grouping originally conducted in step 4 of the formulation process. The cluster manufacturing strategy is then further broken down into targets, principles and action plans on site level. The implementation of the manufacturing strategy through the site then impacts the overall corporate results, which provides feedback on the validity of the overall corporate strategy. As this process should be repeated regularly, the results can also be used in the re-evaluation of the manufacturing function.

As described in Subsection 2.1.4, there are four dimensions in a manufacturing strategy that can be addressed by the targets, principles and action plans described above:

- Network Capabilities
- Manufacturing Capabilities
- Structural Manufacturing Levers
- Infrastructural Manufacturing Levers

The network and manufacturing capabilities can be used to define capability profiles, that is define the level of capability needed to be successful in the market, and identify gaps or improvement areas. The gaps and improvement areas can then be addressed through action plans changing the structural and infrastructural manufacturing levers.

2.2 Performance Measurement and Management

This section aims at providing a basic scientific understanding of PMM. The described scientific concepts are accompanied by short case studies to illustrate important aspects or findings from the literature. The scientific literature base on performance measurement and connected topics is very diverse, as performance measurement has been extensively and controversially discussed within the scientific community (Marr and Schiuma, 2003). According to Marr and Schiuma (2003), the literature on performance measurement is in fact so diverse that 95 % of all authors are referenced only once or twice. Fortunately, numerous literature reviews are available, and there are only a few authors who make up the core of references[13]. These authors are in order of descending quotations: Robert Kaplan, David Norton, Andy Neely, Mike Gregory, Ken Platts and Robert Eccles.

[13] Marr and Schiuma (2003) only focused on the years 1998-2002.

Marr and Schiuma (2003) point out that the literature base regarding performance measurement has been increasing by multiple hundred publications per year since the late nineties. This annual increase in publications makes it very difficult to conduct a comprehensive literature screening. Instead, relevant literature reviews in existing publications are used to identify important scientific theories regarding performance measurement and management. The following sources and literature reviews were used as a basis for this literature review: Eccles (1991), Gregory (1993), Neely *et al.* (1995), Neely (1999), Bourne *et al.* (2000), Neely *et al.* (2000), Kennerley and Neely (2002), Bourne *et al.* (2003), Marr and Schiuma (2003), Yeniyurt (2003), Gomes *et al.* (2004), Folan and Browne (2005), Franco-Santos and Bourne (2005), Neely (2005), Neely *et al.* (2005), Franco-Santos *et al.* (2007), Gunasekaran and Kobu (2007), Bourne (2008), Akyuz and Erkan (2010), Micheli and Manzoni (2010), Taticchi *et al.* (2010), Braz *et al.* (2011), Nudurupati *et al.* (2011), Simões *et al.* (2011), Bititci *et al.* (2012), Gopal and Thakkar (2012), Taticchi *et al.* (2012a) and Pidun and Felden (2013). These literature reviews were chosen on the basis of a) relevance, b) coverage of a broad area of time and c) coverage of a wide array of perspectives. Additionally, a focus was set on more recent literature reviews to provide an up-to-date perspective on performance measurement. This literature review was then completed by a forward and backward search based on the above named sources.

This section is then organised as follows: First, a brief overview of the historic development on performance measurement theory is given which will illustrate the development of different perspectives on performance measurement. Secondly, an overview of guidelines of existing performance measures will be given. Thirdly, the concept of strategic performance measurement and management systems will be explained in more detail. Fourthly, general guidelines for the development, implementation and use of SPMMS will be provided. Fifthly, exemplary performance measurement and management systems will be presented, before the section closes with a summary.

2.2.1 Historic Development of Performance Measurement and Management

Performance measurement originated in the double entry bookkeeping that emerged in the 13th century (Johnson, 1981; Bititci *et al.*, 2012), and remained mainly unchanged until the industrial revolution (Bititci *et al.*, 2012). Ever since the industrial revolution, changes in the business environment have impacted on the way performance was measured:

- The emergence of the wage system resulted in the measurement of employee productivity (Johnson, 1981; Bititci *et al.*, 2012)

- The emergence of multiple plants resulted in the emergence of divisional and departmental budgets (Chandler, 1977; Bititci *et al.*, 2012)
- With the beginning of globalisation more sophisticated productivity management approaches evolved. The focus was mainly on financial indicators, neglecting customers, employees and other stakeholders (Schonberger, 1982; Suzaki, 1987; Keegan *et al.*, 1989; Johnson and Kaplan, 1991; Neely *et al.*, 1995; Ramaa *et al.*, 2009; Bititci *et al.*, 2012)
- The understanding of this lopsided focus led to the establishment of performance measurement as a multidimensional domain and balanced approaches to PM, incorporating financial and non-financial performance measures as well as qualitative and quantitative and subjective and objective ones (Hayes and Abernathy, 1980; Goldratt and Cox, 1986; Keegan *et al.*, 1989; Dixon *et al.*, 1990; Kaplan and Norton, 1992; Neely *et al.*, 1995; Gunasekaran *et al.*, 2001; Gunasekaran and Kobu, 2007; Taticchi *et al.*, 2010; Nudurupati *et al.*, 2011; Bititci *et al.*, 2012; Gopal and Thakkar, 2012)
- As the complexity of PM increased, the question arose if PM should be aligned to strategy and how this alignment could be achieved (Neely, 1999; Folan and Browne, 2005; Taticchi *et al.*, 2010; Bititci *et al.*, 2012)

The last development led to a massive amount of publications on performance measurement literature and models between the late eighties and the late nineties, focussing on all sectors of industry and commerce (Neely, 1999; Ramaa *et al.*, 2009; Bititci *et al.*, 2012). Neely (1999) dubbed this trend the performance measurement revolution. However, this focus on PM continued into the 21st century. Taticchi *et al.* (2012b) illustrated that the amount of publications peaked in 2007 with 900 PM-related publications in that year alone.

Current Status of Performance Measurement Literature

The development of performance measurement has been described in the previous subsection. The overall development is summed up in Figure 11. This illustration incorporates the diverse perspectives of Folan and Browne (2005), Gomes *et al.* (2004), Hilgers (2008) and Bititci *et al.* (2012). It is apparent that performance measurement with its various sub-streams and aspects has grown to be increasingly complex and will continue to grow in complexity as the scope of performance becomes increasingly diverse.

Today, there are two main trends that can be identified in PM literature: Firstly, PM literature is shifting from an inward focus, i.e. just looking at the own organisation, to an outward focus (Folan and Browne, 2005). This outward focus extends the perspective of performance measurement to external stakeholders (Folan and Browne, 2005; Bititci *et al.*, 2012). According to Bititci *et al.* (2012), this trend is backed by overall business trends such as globalisation, emerging global issues like global warming and sustainability etc. Secondly, performance measurement is increasingly seen as a learning tool, meaning that implementing a PMS will lead to greater gains than just collecting and interpreting data.

Davenport *et al.* (2006; 2010) point out that performance measurement should be focused on learning and understanding rather than sole control (Bititci *et al.*, 2012). This does not only include learning about markets and customers but also a deepened understanding of the own organisation and its stakeholders. Bititci *et al.* (2006; 2012) and Seddon (2008) point out that a unidirectional definition and implementation of PM may lead to the sub-optimization of an organisation. Therefore, a need for a broader understanding of PM incorporating the social aspects of organisations has been identified (Bourne *et al.*, 2002; Franco and Bourne, 2003; Nudurupati and Bititci, 2005; Bititci *et al.*, 2006; Micheli and Manzoni, 2010; Bititci *et al.*, 2012; Taticchi *et al.*, 2012a). Bititci *et al.* (2012) state that there are three main challenges to performance measurement research today:

- Understanding PM as a social system
- Understanding PM as a learning system
- Understanding PM in (external and internal) networks

Generally, Performance Measurement always lags behind developments in business (Bititci *et al.*, 2012). The globalisation of companies and the implications value creation in networks has on performance measurement are therefore not fully integrated into today's PMS. As Leseure *et al.* (2001) point out, performance in networks needs to be viewed from a broader perspective as a network has more goals to fulfil than those of single network players.

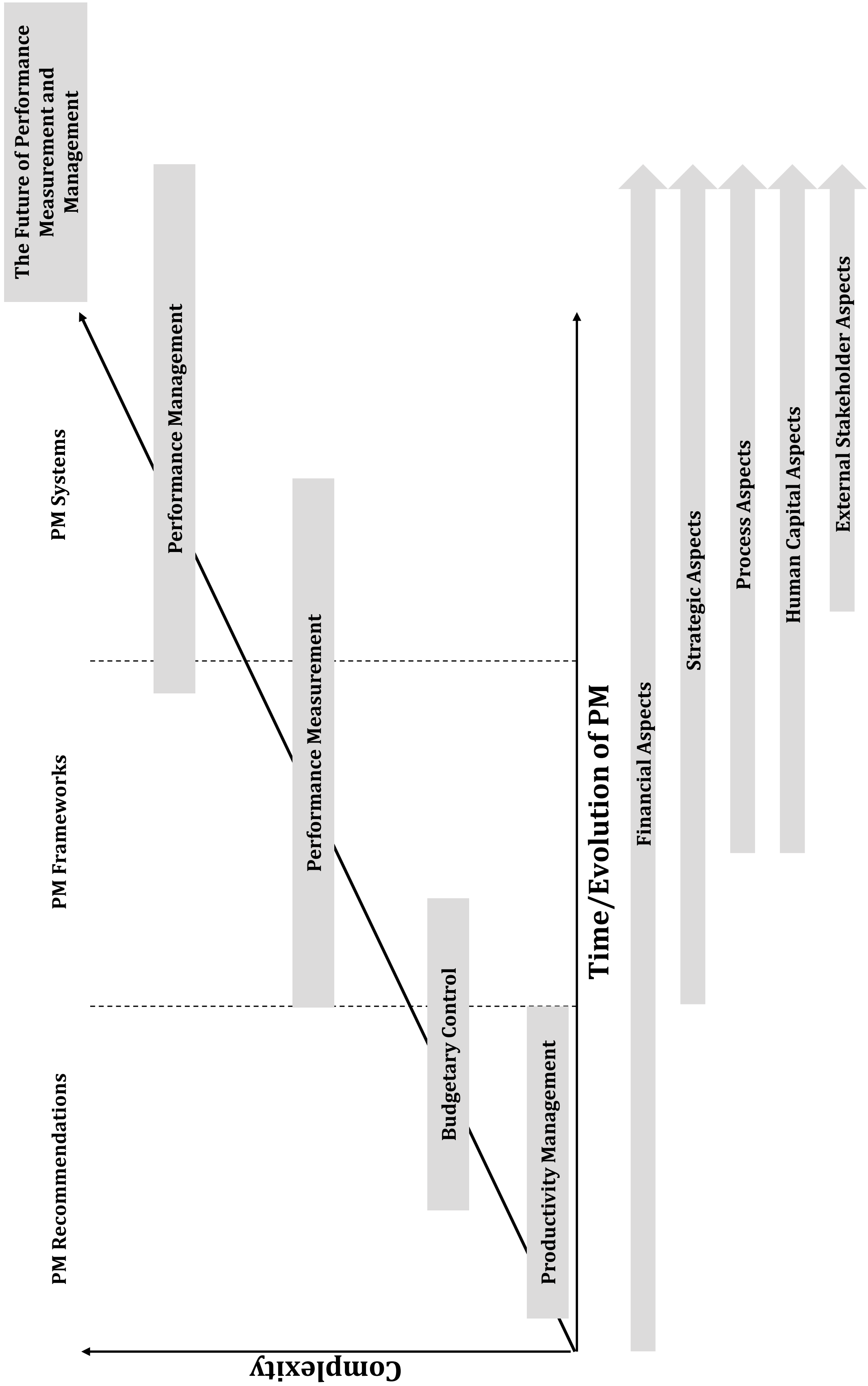

Figure 11 – Development of performance measurement based on Folan and Browne (2005)*, Gomes et al.* (2004)*, Hilgers* (2008) *and Bititci et al.* (2012)

From Performance Measurement to Performance Management

Folan and Browne (2005) classify published models in the performance measurement literature in three historical groups: performance measurement recommendations, performance measurement frameworks and performance measurement systems. Literature in these three groups is increasingly complex and covers an increasingly wide performance scope (Folan and Browne, 2005).

PM recommendations are the building blocks for PM frameworks and systems. They can be split up into recommendations for performance measures and recommendations for PM framework and systems design (Folan and Browne, 2005). However, Folan and Browne (2005) and Neely *et al.* (2000) find that the amount of recommendations in literature has become too vast to incorporate all recommendations into one single framework or system.

Various disciplines concerned with performance measurement have been developing PM frameworks since the late eighties. A PM framework refers to the active employment of a set of recommendations and can be structural or procedural (Folan and Browne, 2005; Bititci *et al.*, 2012). A structural framework focuses on the structure of performance measures by providing a typology for performance measure, while a procedural framework describes the procedure of delineating performance measures from strategy (Bourne *et al.*, 2003; Folan and Browne, 2005; Bititci *et al.*, 2012).

A PM system basically consists of two PM frameworks, one structural and one procedural. These two are interlinked and support each other (Folan and Browne, 2005). Acting upon a performance measurement system is then defined as performance management (Folan and Browne, 2005). Performance management is considered an important aspect as it stimulates managerial changes and promotes organisational learning by acquiring, storing, analysing, interpreting and distributing data and knowledge about performance (Braz *et al.*, 2011).

Taticchi and Balachandran (2008) and Taticchi *et al.* (2012a) expand the view on Performance Measurement and Management by discussing Performance Measurement and Management Systems (PMMS). A PMMS essentially contains a PMS and five milestones which embed a PMS in an organisational context. The perspectives of Folan and Browne (2005) and Taticchi and Balachandran (2008) and Taticchi *et al.* (2012a) can be merged into the model depicted in Figure 12.

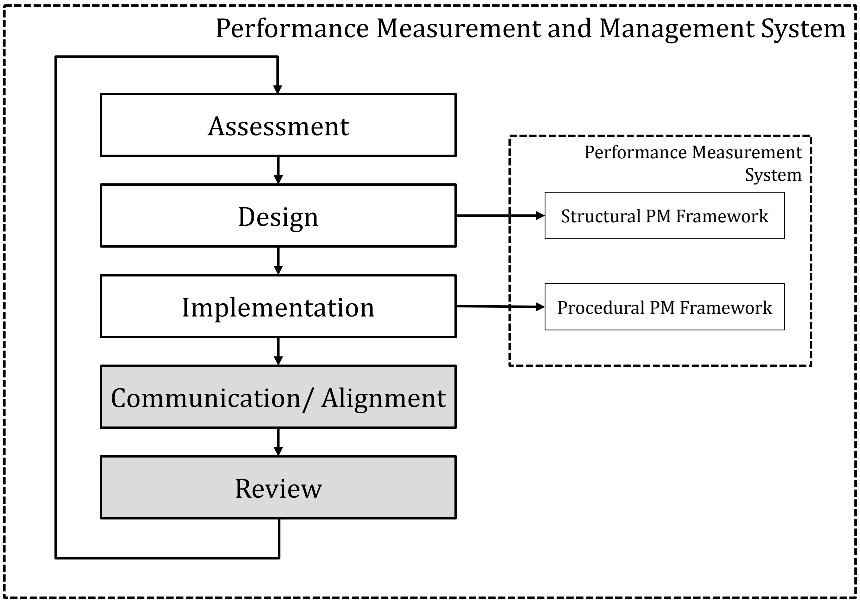

Figure 12 – Milestones of PMMS and its components adapted from Taticchi and Balachandran (2008) *and Taticchi et al.* (2012a)

In the assessment stage, the existing PMS is evaluated. This stages examines whether the existing PMS fulfils the intended purpose and if there are any gaps in the PMS (Bourne *et al.*, 2000; Bourne *et al.*, 2003; Neely *et al.*, 2005; Taticchi and Balachandran, 2008; Farris *et al.*, 2011; Taticchi *et al.*, 2012a). A PMS should be evaluated regularly (Bourne *et al.*, 2000; Bourne *et al.*, 2003; Neely *et al.*, 2005; Taticchi and Balachandran, 2008; Farris *et al.*, 2011; Taticchi *et al.*, 2012a). In the assessment stage, it is important to question existing measures and, if necessary, exclude them from the PMS. Often, this aspect is ignored by corporations, leading to increasingly complex PMS that obscure the focus on the important aspects of business (Neely, 1999; Neely *et al.*, 2000; Kennerley and Neely, 2002; Gunasekaran and Kobu, 2007; Braz *et al.*, 2011). As PMS should reflect a company's business, the design stage serves the purpose of defining a structural PM framework that contains the company-specific aspects of performance measurement. This is the stage were strategy is translated into goals and performance dimensions for the different organisational entities (Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a). Bourne *et al.* (2003) offer a comprehensive overview of different design processes described in the scientific literature. The implementation phase defines and implements the procedural framework of the PMS. Many authors identify this stage as critical for the success of a PMS (Franco-Santos and Bourne, 2005; Taticchi and Balachandran, 2008; Braz *et al.*, 2011; Nudurupati *et al.*, 2011; Taticchi *et al.*, 2012a). After the PMS is implemented, the performance should be communicated in the company based on clear guidelines. This step, connected to an incentive system, is the important driver for aligning the company operations to strategy (Bititci *et al.*, 2000; Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a). The final stage is the review stage. In this stage, the overall alignment of the PMS with the company business is checked (Bourne *et al.*, 2000; Braz *et al.*, 2011). Additionally, it is verified how the PMS contributes to an overall improvement in performance. Failing to review a PMS may lead to overall organisational inertia and failure, since the performance dimensions and goals are not aligned to the demands of the external environment (Micheli and Manzoni, 2010). The review stage serves as the basis for the assessment stage (Bititci *et al.*, 2000; Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a). Overall, a PMMS will change over multiple iterations of this cycle. How a PMMS changes is determined by a multitude of internal and external factors (Kennerley and Neely, 2002). Melnyk *et al.* provide an overall definition of PMMS:

"PMM systems consist of two components: the performance measurement system and the performance management system. The performance measurement system encompasses the process (or processes) for setting goals (developing the metric set) and collecting, analysing and interpreting performance data. The objective of the process is to convert data into information and to assess the effectiveness and efficiency of action. Although performance measurement is important, it is not sufficient to manage an enterprise. There is a complementary need for a performance management system. The performance management system encompasses the process (or processes) of assessing the differences between actual and desired outcomes, identifying and flagging those differences that are critical (thereby war-ranting management intervention), understanding if and why the deficiencies have taken place, and, when necessary, introducing (and monitoring) corrective actions aimed at closing the significant performance gaps. In taking such an approach we need to recognise this must encompass both single and double loop learning. The system should be able to be operated as a simple thermostat, but also to allow higher-level functions, such as the questioning of the standards, assumptions and strategies of the organisation." (Melnyk *et al.*, 2013, p. 3)

Embedding PMMS into an Organisation

A PMMS has to be embedded in other company systems (Robson, 2004; Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a) to function adequately. Taticchi and Balachandran (2008) and Taticchi *et al.* (2012a) identify the following five systems:

- The performance system
- The capability evaluation system
- The cost system
- The benchmarking system
- The planning system

Integration in this context means that the implications and knowledge derived from any of the five systems have an impact on and need to be evaluated against the other four systems. The information coming from the performance system has to be evaluated against the capabilities of the assessed entity, as the capabilities limit the way this entity performs (Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a). For example, the output of two production sites producing the same products greatly depends on the technology implemented at the sites. A capability identified as a limitation can be changed through investments (e.g., in new technologies). To evaluate if this investment is feasible, information taken from the cost system is used (Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a). Information derived from performance system, capability evaluation system and cost system is used to benchmark processes and entities. Implications from the benchmarking are then used to plan changes of the entire value chain (Taticchi and Balachandran, 2008; Taticchi *et al.*, 2012a).

So far, the approaches on PMMS integration just looked at the different systems employed in an organisation. Another aspect that needs to be taken into account is an organisation's structure. A PMMS needs to consider the hierarchy and structure of an organisation such as the tactical structure on operational levels (Maskell, 1991; Lambert and Pohlen, 2001; Gunasekaran *et al.*, 2004; Packová and Karácsóny, 2010; Braz *et al.*, 2011). Furthermore, an orientation along the value-chain is possible (Stewart, 2010). The evaluation of different entities within an organisation needs to fit to the specifications of that entity (Maskell, 1991). An exemplary framework incorporating different levels and specifications of entities in the network is General Motors' integrated PMS described by Neely *et al.* (2005). There, performance measures were identified that can be applied consistently across the entire organisation. However, the specific set of PM applied to a specific organisational level is tailored to the level's specifications. Yeniyurt (2003) states that aligning a multinational company's total actions with the global corporate strategy is a complex task, as the local requirements and specifications of the different sites may annul aspects of the global strategy.

Additionally, social aspects are highly important when implementing a PMMS. Often, evaluating personal performance in a company is met with resistance, fear, politics, emotions and subversions (Kennerley and Neely, 2002; Gunasekaran and Kobu, 2007; Braz *et al.*, 2011; Gopal and Thakkar, 2012). Therefore, it is important to integrate staff at all levels throughout the implementation and development process of a PMMS (Wouters, 2009; Akyuz and Erkan, 2010). In general, it is also pointed out that a PMMS needs to fit to an organisation in the sense of consistency theory (Buttermann *et al.*, 2008; Akyuz and Erkan, 2010).

The Roles of a Performance Measurement and Management Systems

So far, the role of PM(M)S has been mainly described as diagnostic. This means that the system is used to understand what is "wrong" with the organisation and derive solutions to "fix" it. However, based on Simons (1995), Micheli and Manzoni (2010) identify four different roles a performance measurement and management system can play in an organisation. Franco-Santos *et al.* (2007) identify another five roles. The different perspectives on roles are somewhat interlinked. This is illustrated in Table 12.

		Franco-Santos *et al.* (2007)				
		Measure Performance	Manage Strategy	Communi-cation	Influence Behaviour	Learning and Improvement
Micheli and Manzoni (2010)	The Diagnostic Role	X				X
	The Interactive Role		X	X		X
	Belief System			X	X	
	Boundary System			X	X	

Table 12 – Roles of Performance Measurement

As pointed out above, the diagnostic role aims at identifying the shortcomings of the current organisational set-up and identifying solutions to improve the organisation (Micheli and Manzoni, 2010). The interactive role describes a PMMS as a communication tool within an organisation, and between an organisation and its external stakeholders. In this role, the PMMS is used as a tool to support the emergence of new strategies and the evaluation of existing strategies (Micheli and Manzoni, 2010). This role is especially useful for organisational learning (Franco-Santos *et al.*, 2007; Gunasekaran and Kobu, 2007). Furthermore, a PMMS can be used as a tool to communicate an organisation's belief system. This is done by deriving performance measures according to the organisation's goals (Neely and Bourne, 2000; Micheli and Manzoni, 2010). Finally, a PMMS can be used as a boundary system by incorporating limits of freedom within the organisational context (Micheli and Manzoni, 2010). An example of this would be the setting of a performance goal for transparent business, limiting the use of bribes etc. These roles are not exclusive and overlap[14]. A PMMS can

[14] By communicating the belief system certain boundaries are communicated implicitly and explicitly.

take multiple of these roles at the same time. However, it is important an organisation's management is clear about what roles are sought to be able to define a PMMS accordingly. There is no one size fits all solution for performance measurement and management systems (Micheli and Manzoni, 2010). As a result, the thoughts underlying the definition of every performance measure and the entire PMMS should be explicitly documented and communicated during the implementation of a PMMS (Micheli and Manzoni, 2010).

Benefits of Performance Measurement

The development and implementation of performance measurement and management systems requires companies to make an effort, and companies make this effort because they expect significant benefits from the implementation of a performance measurement system. Besides the inherent benefits of the PMMS as described by their roles, the implementation and use of performance measurement systems has a positive impact on business performance (Franco-Santos, 2007). This positive impact is further increased when both financial and non-financial measures are incorporated (Micheli and Manzoni, 2010). However, the primary reason for implementing a (strategic) PMMS is to create transparency regarding the success of the implementation of strategy (Kaplan and Norton, 1996a; Bourne *et al.*, 2000; Kald and Nilsson, 2000; Neely *et al.*, 2008). Additionally, a PMMS can be used to collect information and feedback to challenge the assumptions of a strategy and test its validity (Feurer and Chaharbaghi, 1995; Kaplan and Norton, 1996a; Bourne *et al.*, 2000; Franco-Santos *et al.*, 2007; Neely *et al.*, 2008). Thus, PMMS are tools that can be used to better accommodate adaptive and interpretive characteristics of strategy formulation and implementation (Zanon and Alves Filho, 2012).

Focussing on collaborative aspects within a company, it can be stated that PMMS support cross-functional collaboration in achieving overall goals (Kald and Nilsson, 2000). This aspect can be transferred to the collaboration across the network (Pekkola, 2013). Furthermore, PMM in networks allows the construction of an overall and comprehensive picture of the network; it allows to monitor latest developments in the network and data-driven decisions (Pekkola, 2013).

Conclusion

From this section it can be concluded that:

- Performance measurement systems are sets of performance measures
- PMS consist of a structural framework which contains performance dimensions and a procedural framework which describes a process to derive the measures used in the PMS
- PMS can incorporate objective and subjective measures
- PMS can incorporate qualitative and quantitative measures
- The content and scope of PMS depends on their assumed role
- PMS can take over different roles in an organisation
- Performance Measurement is a learning tool rather than solely a measurement tool
- A performance management system is the meta-system above the PMS. It is used to develop, communicate, implement and re-evaluate a PMS
- PMS should be aligned to strategy
- PMS should incorporate financial and non-financial measures
- Performance should be understood as a multi-dimensional domain
- A PMS should incorporate the perspective of multiple (external) stakeholders
- A PMMS needs to be linked to the different corporate systems and functions
- A PMMS needs to fit to the organisational structure of an organisation
- Social aspects play an important role in the implementation of PMMS
- PMMS should be integrative and people from multiple organisational levels should be incorporated in the development and implementation of PMS

2.2.2 Performance Measures

As performance measures (or metrics, indicators and KPI) are core elements of PMS (cf. Neely *et al.*, 1996b; Packová and Karácsóny, 2010), a wide array of literature has been discussing different performance measures, their applicability and drawbacks. As pointed out previously, performance measures can be financial and non-financial, quantitative or qualitative, subjective or objective and need to be connected to strategy (Neely, 1999; Bourne *et al.*, 2000; Hudson *et al.*, 2001; Bhasin, 2008; Micheli and Manzoni, 2010). It is counterproductive to focus on single measures when evaluating performance; instead various measures reflecting different aspects of performance should be used. These can include subjective measures such as a self-assessment (Nudurupati *et al.*, 2011). More generally, a strategy is translated into key goals. The achievement of these goals is then measured by corresponding performance measures (Bourne *et al.*, 2000).

In practice it is very difficult to define performance measures that are generally applicable to all companies and organisations. Firstly, as pointed out previously, the role of a performance measurement system and the underlying assumptions and targets for implementing a PMS vary throughout organisations. This has implications for the performance measures. Secondly, and also pointed out earlier, performance measurement can have a strategic, tactical or operational focus (Gunasekaran *et al.*, 2001; Gunasekaran and Kobu, 2007). This has implications for the developed performance measures. When only discussing strategic level performance measures, different strategies require different performance measures (Bendoly *et al.*, 2007). Thirdly, as the environment and specific situation and organisational structure of corporations differ, the applied performance measures need to reflect those differences (Townley *et al.*, 2003; Wouters, 2009). Performance measures cannot easily be passed on from one company to another (Soltani *et al.*, 2005; Wouters, 2009). Multiple publications review different performance measures (e.g., Neely *et al.*, 2005; Gomes *et al.*, 2006; Krause and Arora, 2008) and a list of publications including further performance measures focused on manufacturing can be found in Appendix A – Lists of Strategic Performance Measures. Given the limitations of pre-defined performance measures, it is not the target of this dissertation to define concrete measures. Instead, this thesis will leave the definition of company-specific performance measures to the companies applying the developed model. Table 13 provides an overview of guidelines and quality requirements to support companies in defining performance measures.

Requirements and Guidelines for Performance Measures	***Authors***
• Performance measures should be simple to understand	**Globerson (1985), Fortuin (1988), Goold and Quinn (1990), Azzone *et al.* (1991), Eccles (1991), Goold (1991), Maskell (1991) , Wisner and Fawcett (1991), Lynch and Cross (1995) Kaplan and Norton (1996b), Neely *et al.* (1997), Neely *et al.* (2000), Kennerley and Neely (2003) and Braz *et al.* (2011)**
• Performance measures should be derived from strategy	**Globerson (1985), Fortuin (1988), Dixon *et al.* (1990), Azzone *et al.* (1991), Goold (1991), Maskell (1991), Kaplan and Norton (1992), Lynch and Cross (1995), Neely *et al.* (2005), Micheli and Manzoni (2010)**
• Performance measures should support each other and form and integrated entity	**Wisner and Fawcett (1991), Gregory (1993), Neely *et al.* (1995), Bititci *et al.* (1997), Gahlayini *et al.* (1997), Kanji (1998), Beamon (1999), Otley (1999), Neely *et al.* (2000) and Kennerley and Neely (2003)**
• Performance measures should focus on/enable improvement	**Lea and Parker (1989), Wisner and Fawcett (1991), Kaplan (1992), Lynch and Cross (1995), Neely *et al.* (1995), Ghalayini and Noble (1996), Ghalayini *et al.* (1997), Neely *et al.* (2000) and Kennerley and Neely (2003)**
• Performance measures should be re-evaluated and eliminated if not needed.	**Wisner and Fawcett (1991), Gregory (1993), Ghalayini and Noble (1996), Ghalayini *et al.* (1997), Bititci *et al.* (2000), Bourne *et al.* (2000), Neely *et al.* (2000), Kennerley and Neely (2003) and Braz *et al.* (2011)**
• Performance measures should be relevant	**Globerson (1985), Fortuin (1988), Azzone *et al.* (1991), Lynch and Cross (1995), Neely *et al.* (1995), Neely *et al.* (1997), Bourne *et al.* (2000), Neely *et al.* (2000) and Kennerley and Neely (2003)**

Requirements and Guidelines for Performance Measures	*Authors*
• Performance measures should be relevant for employee remuneration	**Eccles (1991), Neely *et al.* (1995), Ghalayini and Noble (1996), Kaplan and Norton (1996b), Ittner and Larcker (1998) and Meyer (2008)**
• Performance measures should provide timely and accurate feedback	**Globerson (1985), Fortuin (1988)and Dixon *et al.* (1990)**
• Performance measures should be based on quantities that can be influenced, or controlled, by the entity evaluated.	**Globerson (1985), Fortuin (1988) and Lynch and Cross (1995),**
• Performance measures should reflect the business process - i.e. both the supplier and customer should be involved in the definition of the measure	**Globerson (1985), Fortuin (1988), Lynch and Cross (1995) and Ghalayini and Noble (1996)**
• Performance measures should relate to specific goals (targets)	**Globerson (1985), Fortuin (1988) and Goold and Quinn (1990)**
• Performance measures should fit to a company's culture	**Neely *et al.* (1995), Neely *et al.* (1997), Neely *et al.* (2000) and Kennerley and Neely (2003)**
• Performance measures should employ ratios rather than absolute numbers	**Globerson (1985), Neely *et al.* (2000) and Kennerley and Neely (2003)**
• Performance measures should be part of a closed management loop	**Kaplan and Norton (1992) and Globerson (1985)**
• Performance measures should be clearly defined	**Globerson (1985) and Fortuin (1988)**
• Performance measures should have a visual impact	**Fortuin (1988) and Lea and Parker (1989)**
• Performance measures should be consistent	**Fortuin (1988) and Lynch and Cross (1995)**
• Performance measures should provide fast feedback	**Fortuin (1988) and Maskell (1991)**
• Performance measures should be objective – not based on opinion	**Fortuin (1988) and Braz *et al.* (2011)**
• Performance measures should be based on explicitly defined formulas and data sources	**Globerson (1985) and Braz *et al.* (2011)**
• Single measures should be compiled into one index	**Kanji (1998) and Beamon (1999)**
• Performance measures should have an explicit purpose	**Globerson (1985)**
• Performance measures should use data which are automatically collected as part of a process whenever possible	**Globerson (1985)**
• Performance measures should be reported in a simple and consistent format	**Lynch and Cross (1995)**
• Performance measures should be based on trends rather than snapshots	**Lynch and Cross (1995)**
• Performance measures should provide information	**Fortuin (1988)**
• Performance measures should be precise – exact about what is being measured	**Fortuin (1988)**
• Performance measures should be applicable throughout an organisation	**Meyer (2008)**
• Performance measures should evolve and change slowly so that people's focus will stay on long-term goals	**Meyer (2008)**
• Performance measures should be designed so that they encourage adequate behaviour	**Braz *et al.* (2011)**
• Performance measures should be visible to everyone involved	**Braz *et al.* (2011)**

Table 13 – Requirements and Guidelines for Performance Measures based on Neely et al. (1997) and Lehtinen and Ahola (2010) extended by the author

The requirements and guidelines for performance measurement presented in Table 13 are extensive, and their general applicability remains untested. In fact, the list is so extensive that it might prove difficult to comply with all guidelines at all times. Some guidelines might seem reasonable and desirable at first, but might prove to be disadvantageous at a second glance. For example, the statement that measures should be compiled into one index seems at first plausible. The aggregation of different measures into a high level index slims down the number of measures to a simple KPI that can easily be interpreted. However, through the aggregation important sources of variation within a firm are concealed. And the measure is no longer easy to understand as demanded by the first requirement in Table 13. When comparing the performance of different manufacturing sites, for example, the things the sites do well are lumped together with the things they do poorly (Meyer, 2008). This makes it almost impossible to identify discrete areas of improvement and action plans. In discussions with practitioners it becomes obvious that practitioners seem to be focussed on finding a perfect, indubitable measure of performance. While quantified performance measures support an objective and transparent evaluation of performance, the explanatory power of performance measures alone is questionable. Instead, performance measures should be evaluated taking into account diverse contextual impact factors.

Focussing solely on quantitative performance measures is also problematic because not all strategies and solutions to occurring problems can be formulated specific enough or broken down to all entities throughout an organisation, thus rendering the definition of a quantitative performance measure impossible (Melnyk *et al.*, 2013). Additionally, contextual factors and a volatile environment make it difficult to follow the traditional process of strategy definition, derivation and implementation of quantitative performance measures and evaluation of performance. By the time performance can be evaluated based on the pre-defined measures, contextual factors and the environment might have changed, making a new strategy and different performance measures necessary. This external volatility can be accommodated for by defining strategies that are not too detailed and specific and thus will work in changing environments. These more general strategies, however, cannot easily be evaluated based on quantitative performance measures (Melnyk *et al.*, 2013). Current PMMS do not address this problem sufficiently, as they largely rely on quantitative performance measures only. Melnyk *et al.* (2013) therefore propose a matrix that matches the specificity of aspired outcomes and proposed solutions to different methods of performance measurement and management. This matrix is depicted in Figure 13, and provides

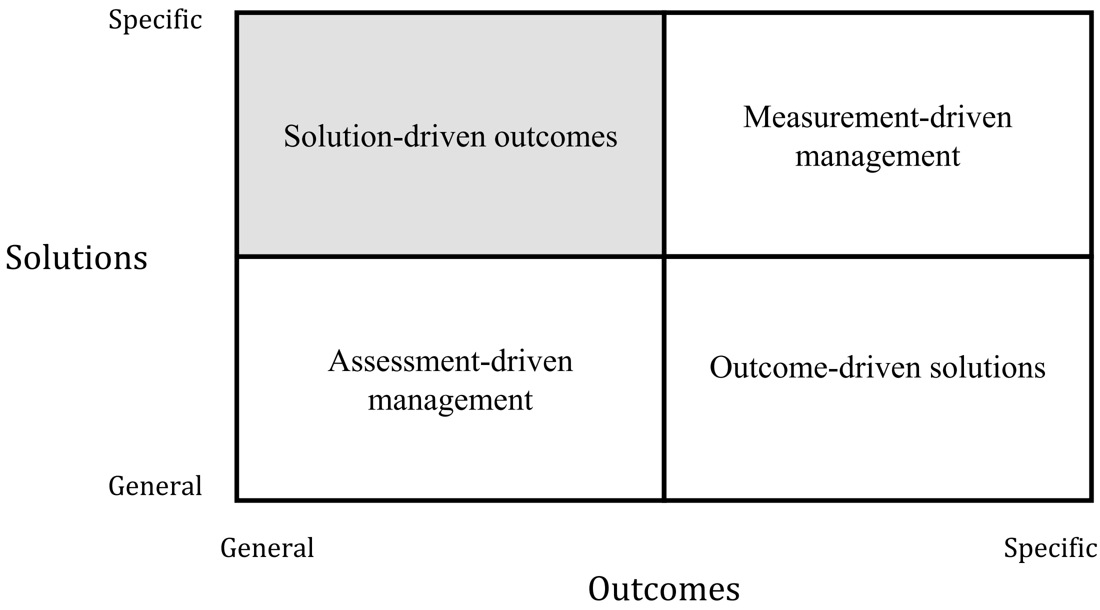

Figure 13- The Performance Alignment Matrix adapted from Melnyk et al. (2013)

a "solution" and an "outcomes" axis. Outcomes refer to the conceptualisation of an organisation's vision or goal. Solutions are the specific approaches a company can adopt to realise the aspired outcome (Melnyk *et al.*, 2013). In the context of Section 2.1, "outcomes" are the vision and aspired state that manufacturing should be conducted in, and the solutions are the action plans and targets that should be fulfilled to reach this future state of manufacturing. Both solutions and outcomes can be general and specific. The following examples will illustrate what is meant by this:

- Outcomes:
  - General: Manufacturing should be radically flexible.
  - Specific: Capacity utilization should be above 90 % for the current year; the new ERP-software should be rolled out company-wide by the end of the year.
- Solutions:
  - General: Manufacturing should achieve operational excellence
  - Specific: A company-wide KANBAN system should be implemented by the end of the year.

A pure measurement-driven PMM system requires both specifically defined outcomes and solutions. Most PMMS in the literature reflect this approach, and it is the most attractive approach when dealing with a stable environment that actually allows the definition of specific outcomes and solutions. Outcome-driven solutions are characterised by specified and quantifiable aspired outcomes, while the method to get there is unspecified. This approach allows the measurement of overall outcomes by lagging performance measures (i.e. measuring a performance in retrospective, e.g., last year's revenue) while it leaves the decision of how to get there up to a company's different entities (Melnyk *et al.*, 2013).

When neither outcome nor solutions are specified, traditional quantitative-based performance measurement is not sensible. Instead, an assessment-based approach should be chosen. The assessment should focus on whether the organisation has the right capabilities in place to implement the solutions. To assess the outcomes, it has to be determined whether the action plans and projects aimed at realizing the broad outcomes are carried out adequately (Melnyk *et al.*, 2013). This quadrant of the matrix is suitable for companies facing very complex conditions, either because the external context changes rapidly or because the internal complexity is very high. This complexity does not allow the definition of specific outcomes and solutions that are applicable throughout the company. Instead, general outcomes and solutions are provided and the different entities (e.g., manufacturing sites, regions or business units) are assessed based on their approaches and outcomes (Melnyk *et al.*, 2013).

The final quadrant of the matrix describes a situation in which the solutions are specific but the outcomes are more general. This captures what happens when a solution and connected measurement drive the outcome (Melnyk *et al.*, 2013). A practical example would be a company that decides to implement a Kanban system without thinking about the overall aspired outcome. By implementing the Kanban system, the basic measures for evaluating performance are pre-defined (e.g., lower inventory and throughput time). This limits the scope of the pre-defined performance dimensions and hinders exploring alternative solutions and developing higher strategic goals (Melnyk *et al.*, 2013). Melnyk *et al.* (2013) therefore consider this quadrant to be somewhat dangerous (hence the grey underlying colour) - management may be letting operational aspects[15] (what the company is doing) instead of strategic aspects (what the company should be doing) shape the corporate strategy. Or, as Melnyk *et al.* put it: *"That is, the strategy over time formalizes what the firm is doing and what it is measuring. Consequently, we could encounter situations where strategy focuses on what the firm does well and what it measures rather than what the market wants. In other words, structure may determine strategy."* (Melnyk *et al.*, 2013, pp. 182–183)

[15] Operational aspects in this case are process-based performance measures that are not necessarily strategic. Based on the classification provided by Gunasekaran *et al.* (2001); (2007) these measures are operational performance measures. Further details about this classification are discussed in subsection 2.2.2.

In conclusion, a wide-array of requirements and guidelines for the definition of performance measures exist. Not all requirements and guidelines need to be followed at all times, but they provide a good overview of aspects that are crucial in defining performance measures. However, defining valid and goal-oriented performance measures requires the definition of specific aspired outcomes or solutions. Under complex conditions this is not possible, and performance measurement and management needs to adapt a more assessment-based approach. This in turn means that a more qualitative assessment without quantitative performance measures needs to be conducted. Last but not least, the evaluation of performance should be grounded in strategic instead of operational considerations.

2.2.3 Strategic Performance Measurement and Management Systems

The previous subsection has discussed the historic development of performance measurement and management system in general. Reviewing the scientific literature on PMMS, it seems most authors like to think of their performance measurement and management systems as strategic. Furthermore, most authors fail to specify the intended role of their PMMS and they fail to define the strategic level their PMMS aims at (for an overview of different perspectives and definitions of (S)PMMS see Franco-Santos *et al.* 2007). This leads to a lacking distinction between strategic and operational levels of performance measurement and measures. While there is a general consensus that performance measures should be connected to corporate strategy (cf. Maskell, 1991; Neely, 1999; Folan and Browne, 2005; Hon, 2005; Taticchi *et al.*, 2010; Braz *et al.*, 2011; Bititci *et al.*, 2012; Gopal and Thakkar, 2012), performance measures are often discussed on a day-to-day operational basis while strategy is discussed on a different level (both hierarchically and perspectively). This is problematic because even though performance measures can be defined for all kinds of processes, a defined strategy does not necessarily include explicit statements or implications for all processes and related performance measures. Vice versa, a certain strategy does not necessarily translate down to actual processes or performance measures. Thus, the question arises if a clear distinction between strategic and operational performance measurement is necessary.

An example for a classic operational performance measure is the overall equipment effectiveness (OEE) (cf. Hübl *et al.*, 2009). This performance measure quantifies how well a given production unit is operated given its planned operating time. Downtime and unscheduled maintenance lead to a lower OEE, which means that a production unit is not operated at optimal capacity. It is a no-brainer that operating a production unit at optimal capacity leads to overall better business performance as ineffectiveness is reduced. Therefore, it is sensible to measure the OEE and discuss methods to improve an OEE on an operational level. However, the OEE is not directly connected to the type of business strategy or production strategy that is in place. In any case the OEE needs to improve. As Nakajima (1989) points out, an OEE over 75% is world class, and importantly independently so of the specific business or production strategy.

An example for a strategy that does not necessarily translate into a certain performance measure is described in Subsection 2.1.3. Strategically, it can make sense to set up a production network in a way that suppresses potential competitors. The importance of this aspect is clear. And, if done correctly, business success will be ensured since no strong competitor will emerge that might take over market share[16]. The success of the efforts supporting this strategy can therefore be indirectly measured by looking at performance measures describing the overall business success of an organisation; however, these measures are of retrospective nature. This means that by the time a negative impact is identified, the critical incidents already lie in the past and it might be too late to correct them. This is just one example of a problem that often occurs in performance measurement: The correct translation of strategy into (operational) performance measures.

While there are linkages between strategy and quantitative performance measures, not every aspect of strategy can be measured with a quantitative performance measure. By classifying goals (e.g., improving the OEE or supressing competitors) as strategic or operational, the level of discussion is set. This then allows the review of performance measures and performance at the level where it is most relevant; that is, the evaluation of operational performance measures on operational levels, and the evaluation of strategic performance on strategic levels. This prevents performance measurement systems from an excess of performance measures that are not relevant at all levels of an organisation. It has to be noted at this point that all operational process measures can be assigned to a strategic level as well. This is the case when a strategic initiative specifically addresses an operational measure. For example, a company might identify that their OEE is substantially lower than the OEE of their competitors. The company then launches a strategic initiative to increase its OEE. Once the initiative is completed, the OEE should increase. Therefore, the OEE can be used as a measure to check if the strategic initiative was successful.

[16] Nokia is an example of a company that was surprised by an emerging competitor. Nokia has dominated the mobile phone market throughout the 1990s and the early 21st century. However, Apple entered the mobile phone market with its IPhone, quickly took over a large share of the market and pushed Nokia into severe economic problems.

This problem has also been discussed by Gunasekaran *et al.* (2001; 2007). They identify the need to classify performance measures, clearly assigning them to a strategic, tactical or operational level. By doing so, the discussion and evaluation will be focussed on the most appropriate level (Gunasekaran *et al.*, 2001; Gunasekaran and Kobu, 2007). In their publications, Gunasekaran *et al.* assign different supply-chain (SC) performance measures to a strategic, tactical or operational level. While they fail to deliver a clear definition of those levels, it can be stated that the measures on the different levels overlap. And, depending on the strategic focus of a company, a formerly operational measure might become strategic.

Currently, most PM(M)S in a manufacturing context focus mainly on operational measures of the system; however, many aspects of manufacturing strategy are based on structural properties embodied in the system architecture, technology resources, and system control policies (Gunasekaran and Kobu, 2007). This leads to the realisation that although the attempt is made to connect performance measure to strategy, existing PMMS lack important aspects of manufacturing strategy. This is also discussed by Bititci *et al.* (2012). They identify a general focus on short-term operational performance measures instead of long-term strategic performance measures. As it becomes increasingly important not only to do things right, but also to do the right things, PMMS should be linked to long-term strategic goals instead of operational performance measures (Drucker, 1994; Bititci *et al.*, 2012). The implementation of a SPMMS is further important since there is a general need to better accommodate adaptive and interpretive characteristics of strategy formation and implementation (Zanon and Alves Filho, 2012).

Besides being a difference in terminology, the “strategic” aspect of certain “S”PMMS has a fundamental implication for their practical use within an organisation (Taticchi *et al.*, 2012a). Furthermore, Taticchi *et al.* (2012a) argue that to make findings on PMS comparable and generalizable, authors will have to be more explicit about the type of PMS they are considering, rather than examining ‘generic’ performance measurement systems (Taticchi *et al.*, 2012a). Therefore, this subsection will end on a definition of strategic performance measurement and management systems (SPMMS). Based on Gimbert *et al.* (2010), the following characteristics of SPMMS are defined:

- A SPMMS is a system which is used to design, implement and communicate a SPMS
- The SPMS integrates long-term strategy
- The SPMS monitors the fulfilment of defined long-term strategies
- Multiple dimensions of performance measures are included
- A sequence of goals/measures/actions is provided in the different performance dimensions
- There is a causal relationship between goals and performance measures

This definition does not mean that an organisation should have two separate PMMS in place, one operational and one strategic. Instead, the PMMS needs to incorporate both perspectives, link them across the organisation and make them visible to the people concerned with operative or strategic decisions.

2.2.4 Guidelines for SPMMS

While the previous subsections have discussed the historic development of performance measurement and management, guidelines for performance measures and strategic performance measurement and management systems in general, this chapter aims at giving an overview of guidelines and requirements of SPMMS. Thus, this subsection is organised as follows: First, criticism of existing SPMMS will be reviewed. This is followed by general guidelines for SPMMS. Subsequently, guidelines for the definition and implementation process of SPMMS and, finally, requirements of the content of SPMMS will be discussed. Partly, these guidelines and requirements have been touched in the previous subsections. However, this section will summarize and recap these requirements to create a holistic collection of requirements.

Since the terms “SPMMS”, “PMMS”, “PMS” etc. are often used interchangeably in the literature, requirements and guidelines found for each of these concepts will be presented here. The general assumption is that the requirements and guidelines presented for any one of those systems are also valid for the other systems, as a PMS is a part of a PMMS, and a SPMMS is a special type of PMMS. This assumption is supported by the incoherent definitions in performance measurement literature. The definition of a PMS of one author might describe a PMMS as seen by other authors.

Criticism of Existing SPMMS

To understand the requirements and guidelines of SPMMS, it is important to understand the points of criticisms of previous SPMMS first. As highlighted in Subsection 2.2.1, performance measurement has undergone an extensive evolution based on identified shortcomings. Firstly, it was identified that traditional, accounting-based and therefore solely financial PMS are not suited for strategic decisions (Neely *et al.*, 2005; Kaplan and Norton, 2005; Bhasin, 2008).This originates from the fact that they are often focused on the past (Kald and Nilsson, 2000; Gomes *et al.*, 2006). Furthermore, most performance measures in existing company SPMMS are based on historically-grown measures that are hard to link to performance (Lawson *et al.*, 2003; Bhasin, 2008) and provide little information on the underlying problems (Bhasin, 2008). If non-financial performance measures are used, they are often based on an operational perspective and often only have a fragile connection to the used financial measures (Bhasin, 2008). One problem resulting from the use of operational performance measures is that they rarely can be aggregated to strategic levels (Maltz *et al.*, 2003; Yeniyurt, 2003; Bhasin, 2008).

Looking at existing SPMMS from a manufacturing perspective, it can be concluded that the way current SPMMS are set up is also not beneficial for an overall company-wide optimisation, as the breaking down of targets can induce local optimisation (Fry and Cox, 1989; Goldratt and Cox, 1993; Neely *et al.*, 2005; Gomes *et al.*, 2006). In a manufacturing context, SPMMS have been an impediment to the implementation of just-in-time manufacturing or lean manufacturing initiatives (Green *et al.*, 1991; Upton, 1998; Gomes *et al.*, 2006). This also leads to the problem that existing SPMMS do not contain sufficient information for productivity improvement measurement (Banker *et al.*, 1989; Gomes *et al.*, 2006). Therefore, it can be concluded that existing SPMMS do not cover all the critical success factors (Eccles, 1991; Epstein and Manzoni, 1998; Gomes *et al.*, 2006; Gopal and Thakkar, 2012). This stems from the fact that performance measures are often the result of management actions and performance above the manufacturing level (Eccles and Pyburn, 1992; Hazell and Morrow, 1992; Hon, 2005; Gomes *et al.*, 2006), and thus are not focused on the performance of a specific organisational level or function (Pekkola, 2013). Hence, it can be concluded that existing SPMMS are inappropriate in modern manufacturing settings (Drucker, 1990; Gomes *et al.*, 2006) and do not support manufacturing organisations in achieving manufacturing excellence (Wisner and Fawcett, 1991; Gomes *et al.*, 2006).

General Guidelines

Within the literature focussing on performance measurement and management, many authors have discussed guidelines for "good" performance measurement and management systems as well as reasons for successful and unsuccessful performance measurement and management initiatives. Folan and Browne (2005) conducted an extensive literature review and identified 32 recommendations for PMMS and hence SPMMS.

General Requirements and Guidelines for PMMS	*Authors*
• PMMS should be based upon the strategic role of the company and company strategy and objectives	**Dixon *et al.* (1990), Azzone *et al.* (1991), Eccles (1991), Grady (1991), Kaplan and Norton (1992), Bititci *et al.* (2000), Medori and Steeple (2000), Kennerley and Neely (2003), and Akyuz and Erkan (2010)**
• PMMS should be based upon multiple criteria	**Crawford (1988), Azzone *et al.* (1991), Neely *et al.* (1995) and Wettstein and Kueng (2002)**
• PMMS should be implemented as means of articulating strategy and monitoring organisation results	**Grady (1991) and Gomes *et al.* (2011)**
• PMMS should reflect the structure of an organisation	**Möller *et al.* (2011)[17] and Demartini (2014)**
• Differentiate between strategic, tactic and operational levels of an organisation	**Gunasekaran and Kobu (2007) and Akyuz and Erkan (2010)**
• Criteria should evaluate group not individual work	**Crawford (1988)**
• Specific goals must be established and revised when met	**Globerson (1985), Crawford (1988) and Ghalayini and Noble (1996)**
• Measurements should be easy to understand by those being evaluated	**Crawford (1988), Fortuin (1988), Lea and Parker (1989), Goold and Quinn (1990), Azzone *et al.* (1991), Goold (1991), Lynch and Cross (1991), Maskell (1991) and Gomes *et al.* (2011)**
• Data should be collected, where possible, by those whose performance is being evaluated	**Crawford (1988)**
• Graphs should be the primary method of reporting performance data	**Crawford (1988)**
• Data should be available for constant review	**Crawford (1988)**
• Performance should be reported daily or weekly	**Crawford (1988)**
• Suppliers should be evaluated upon quality and delivery performance	**Crawford (1988)**
• Emphasis is upon evolving, dynamic, continuous improvement and learning in PM system design	**Crawford (1988), Fortuin (1988), Dixon *et al.* (1990), Lynch and Cross (1991), Eccles and Pyburn (1992), Bititci *et al.* (2000), Medori and Steeple (2000), Kennerley and Neely (2003) and Gomes *et al.* (2011)**
• The connection between accounting and performance measurement should be cut	**Dixon *et al.* (1990) and Kennerley and Neely (2002)**
• PMMS should be mutually supportive and consistent with the business's goals, objectives, critical success factors and programmes	**Dixon *et al.* (1990)**
• Should convey information through as few and as simple a set measures as possible	**Dixon *et al.* (1990)**

[17] Translated by the author

General Requirements and Guidelines for PMMS	*Authors*
• PMMS should reveal how effectively customers' needs and expectations are satisfied	**Dixon *et al.* (1990)**
• PMMS should focus upon measures that customers can see	**Dixon *et al.* (1990)**
• PMMS should provide measures that allow all members of the organisation to understand how they affect the entire business	**Dixon *et al.* (1990),**
• PMMS should consist of well-defined and measurable criteria for the organisation	**Globerson (1985)**
• Routines must be established so that measures can be measures	**Globerson (1985)**
• Feedback from PMMS should report at numerous levels of the organisation	**Grady (1991) and Sieger (1992)**
• Feedback from PMMS must be linked cross-functionally to ensure it supports and not inhibits strategy implementation	**Grady (1991)**
• PM should enable managers to view performance in several areas simultaneously	**Kaplan and Norton (1992)**
• Should provide complementary non-financial performance measures alongside financial measures	**Kaplan and Norton (1996b) and Gomes *et al.* (2011)**
• Should measure the entire product delivery system from the supplier to the customer	**Lockamy (1991), Gomes *et al.* (2011)**
• PMMS is designed, so that at divisional level, the evaluation of PM standards is consistent with the manufacturing environment	**Lockamy (1991) and Kennerley and Neely (2002)**
• PMMS is designed, so that at plant and divisional level, the evaluation of PM standards is consistent with the manufacturing environment	**Lockamy (1991) and Kennerley and Neely (2002)**
• PMMS is designed, so that information on the strategic objectives of the firm are shared at plant and division level to provide organisational focus between them/ The PMMS is used for strategy deployment	**Lockamy (1991), Bititci (1995) and Kennerley and Neely (2002)**
• PMMS information on the strategic objectives of the division must be shared across functional areas to provide organisational focus within plants and divisions	**Lockamy (1991) and Kennerley and Neely (2002)**
• PMMS should be used to challenge strategic assumptions	**Bourne *et al.* (2000), Bititci *et al.* (2001) and Bititci *et al.* (2005)**
• PMMS should be implemented in such a way that it does not induce fear, politics and subversion	**Neely *et al.* (2000)**
• PMMS should be designed so that they facilitate auditing	**Medori and Steeple (2000) and Farris *et al.* (2011)**
• PMMS should be specific to business units	**Bititci *et al.* (1997), Kaplan and Norton (2000a; 2000b) and Bititci *et al.* (2005)**
• PMMS should include competencies – i.e. capabilities and competencies that determine how value is created	**Kaplan and Norton (2000a; 2000b) and Bititci *et al.* (2005)**
• PMMS should include stakeholder contributions	**Neely *et al.* (2001), Bititci *et al.* (2005)**
• PMMS should be integrated (i.e. the relationships between different measures are understood)	**Dixon *et al.* (1990), Suwignjo *et al.* (2000) and Bititci *et al.* (2005)**
• PMMS should be balanced (e.g. using financial and non-financial, internal and external, result and process focussed, lagging and leading performance measures)	**Grady (1991), Bititci *et al.* (2005), Hon (2005), Krause (2006), Meyer (2008) and Akyuz and Erkan (2010)**
• PMMS in a network-context should include non-financial measures because they support the dialogue between headquarters and subsidiaries and allow a more balanced perspective on performance	**Dossi and Patelli (2010)**
• PMMS should incorporate performance measures that are linked to performance improvements projects	**Kaplan and Norton (2000b), Bititci *et al.* (2000) and Krause (2006)**

General Requirements and Guidelines for PMMS	*Authors*
• PMMS should be viewed as a means of continuous organisational improvement.	**Gomes *et al.* (2004)**
• PMMS should take account of strategic and environmental factors	**Feurer and Chaharbaghi (1995) and Bititci *et al.* (1997)**
• PMMS design should be viewed as a coordination effort to understand current metrics in detail, to identify shortcomings and to include ongoing initiatives that affect pm	**Lohman *et al.* (2004)**

Table 14 – List of general requirements and guidelines for PMMS taken from Folan and Browne (2005) extended by the author

The list of general guidelines provided in Table 14 is very extensive. It is in fact so extensive that incorporating all aspects into the creation of a new SPMMS will prove to be difficult. Some of the requirements and guidelines might seem obvious; some might even be contradictory. And the list could be further extended. Table 14 should therefore be seen as a list of suggestions to be carefully considered when creating and implementing a SPMMS. Only selected implications will be addressed in Chapter 3.

Content

Following the division of PMMS approaches into process- and content-based approaches (Folan and Browne, 2005), this sub-subsection covers suggestions regarding the content of PMMS models. As the content of PMMS models varies according to strategies and organisational entities, literature holds numerous content suggestions. To condense these suggestions into a list relevant for this dissertation, the review focuses on content suggestions for PMMS that are suited for general and manufacturing (network) application. Other specialised content suggestions (e.g., for hospitals, HR, agriculture, government institutions etc.) will not be covered in this section. The list will not include concrete performance measures or KPI; instead, it will give an overview of performance dimensions that are most frequently mentioned in the context of manufacturing and networks.

Content Dimensions for PMMS	*Authors*
• Financial Performance	**Cagnazzo, Tiacci and Saetta (2010)**
• Cost	**Gregory (1993), Cagnazzo, Tiacci and Saetta (2010)**
• Competitiveness	**Cagnazzo, Tiacci and Saetta (2010)**
• Learning	**Cagnazzo, Tiacci and Saetta (2010)**

Content Dimensions for PMMS	*Authors*
• Innovation	**Kaplan and Norton (1992), Kaplan (1992), Kanji (1998), Cagnazzo, Tiacci and Saetta (2010) and Lehtinen and Ahola (2010)**
• Environment	**Cagnazzo, Tiacci and Saetta (2010)**
• Quality	**Banker *et al.* (1984), Azzone *et al.* (1991), Wisner and Fawcet (1991), Kaplan (1992), Gregory (1993), Neely *et al.* (1995), Ghalayini *et al.* (1997), Beamon (1999), Hudson, Smart and Bourne (2001) and Lehtinen and Ahola (2010)**
• Flexibility	**Banker *et al.* (1984), Eccles (1991), Kaplan (1992), Neely *et al.* (1995), Beamon (1999), Hudson, Smart and Bourne (2001) and Lehtinen and Ahola (2010)**
• Time	**Wisner and Fawcet (1991), Gregory (1993), Ghalayini *et al.* (1997), Beamon (1999), Otley (1999), Neely *et al.* (1995; 2000), Hudson, Smart and Bourne (2001), Kennerley and Neely (2003) and Lehtinen and Ahola (2010)**
• Productivity	**Kaplan and Norton (1992), Kaplan (1992), Gregory (1993), Neely *et al.* (1995), Kanji (1998), Beamon (1999) and Lehtinen and Ahola (2010)**
• Customer Satisfaction	**Hudson, Smart and Bourne (2001)**
• Inventories	**Wisner and Fawcet (1991), Kaplan (1992), Beamon (1999) and Lehtinen and Ahola (2010)**
• Human Resources	**Hudson, Smart and Bourne (2001)**
• Capabilities	**Neely, Kennerley and Adams (2008)**
• Responsiveness	**Gregory (1993)**
• Process Measures reflecting strategy implementation	**Gregory (1993)**
• Leadership	**Kanji (1998)**
• Network level objective (in manufacturing networks)	**Cunha *et al.* (2008)**

Table 15 – List of Content Dimensions for PMMS based on Lehtinen and Ahola (2010) extended by the author

Such a list can never be exhaustive regarding all possible content dimensions - anything that can be measured and was derived from strategy potentially could be a content dimension for a PMMS. Thus, the most important rule when defining the content of a PMMS for a specific company is: Performance dimensions should be derived from strategy.

Process

Similar to the strategy processes described in Subsection 2.1.3, there is a wide range of process-based approaches to the definition of SPMMS and performance measures (e.g. Neely *et al.*, 1996a; Bititci *et al.*, 1997; Bourne *et al.*, 2000; Medori and Steeple, 2000; Neely *et al.*, 2000; Lohman *et al.*, 2004; Taticchi and Balachandran, 2008; Ferreira *et al.*, 2012; Taticchi *et al.*, 2012a). Instead of reviewing them one by one, Figure 14 summarises core process steps of the different processes. This consolidated process will be described in detail in the following.

The process is conducted on two lanes, Performance Management and Performance measurement. As previously described, these two lanes are strongly intertwined and cannot be discussed in isolation. The first two steps in the process are the translation of company strategy into business strategy. This is based on the integrated performance measurement system by Bititci *et al.* (1997) and is incorporated here to illustrate that companies with different business units might require differing strategies which in turn impacts on business unit-specific performance. In Figure 14, company strategy and business strategy formulation are located outside the performance measurement and management phases. This is based on the understanding that strategy formulation is a process separate from PMM. Nonetheless, these formulation processes should be closely connected to the PMMS, which is illustrated by the links between the performance management lane and the business strategy icon.

The PMM process begins with the business strategy input and the grouping of products (e.g., Neely *et al.*, 2000; Bourne *et al.*, 2003). The product grouping is based on the idea that even within a business unit, groups of products with similar customer bases, similar strategic demands and thus similar demands towards the organisation exist. Based on the grouping and the requirements of customers and other stakeholders, two types of objectives can be distinguished (Medori and Steeple, 2000; Neely *et al.*, 2000): a) business objectives and b) objectives regarding the key performance drivers. Business objectives deal with the overall profitability and business development of the respective unit. They describe which overall business targets have to be met. Objectives regarding the key performance drivers address how the business objectives are to be met in more detail. These objectives can also address changes in the value creation process or the overall organisational set-up. Once the objectives are defined, the actual definition of performance measures and performance measurement itself can begin (cf. Medori and Steeple, 2000; Neely *et al.*, 2000; Lohman *et al.*, 2004).

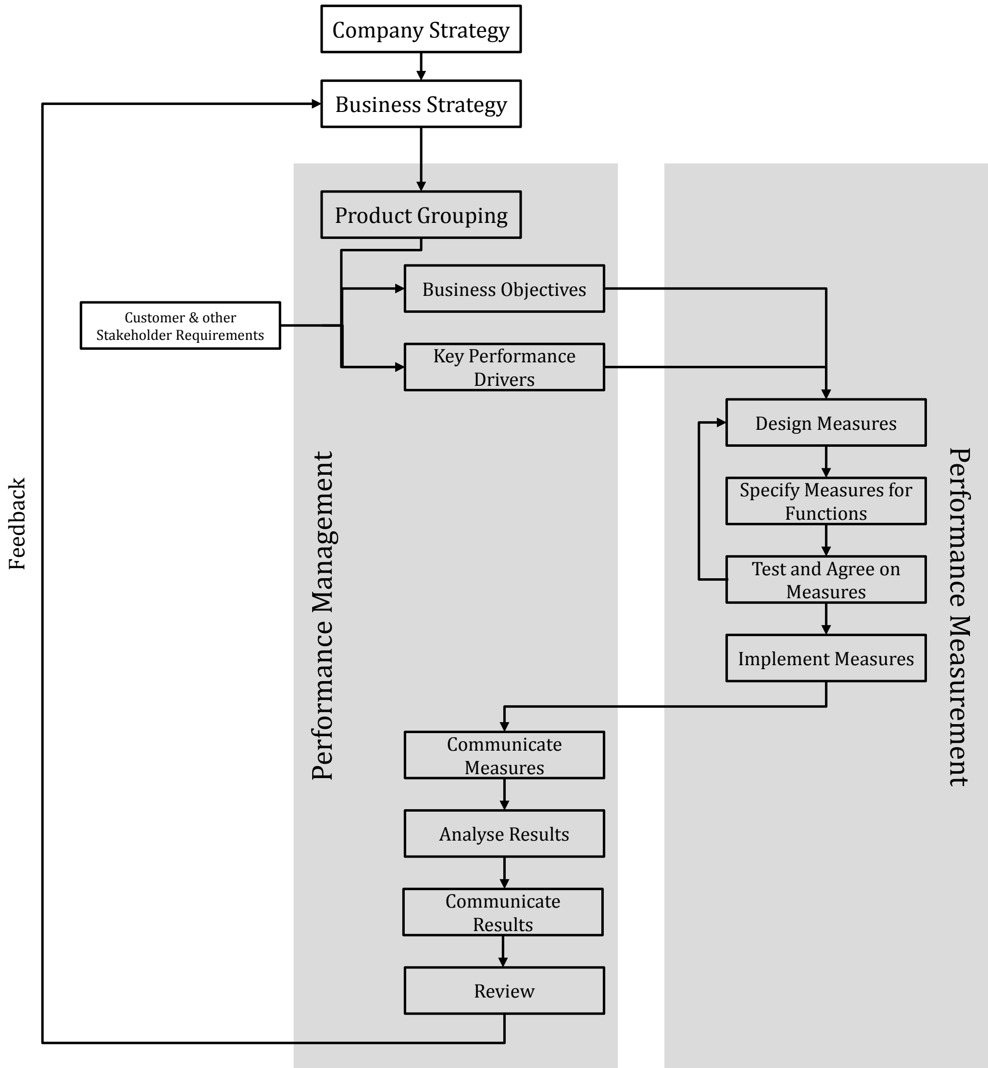

Figure 14 – Consolidated PMM process

The overall objectives are usually defined top-down while incorporating the input of operative organisational levels (cf. strategy and goal formulation processes described in subsection 2.1.3). Similarly, first suggestions of objective and connected performance measures should be made top-down (Bourne *et al.*, 2003; Gomes *et al.*, 2004). However, performance measures for a business unit or a product group might not be specific enough to evaluate the performance of different functions. They might need to be further detailed. This works best if they are developed and agreed upon in cooperation with the entities that they are supposed to be applied to. This ensures the overall support of the PMMS throughout the organisation (cf. Kald and Nilsson, 2000; Bisbe and Malagueño, 2012).

Once the measures have been agreed upon, they need to be implemented. This can be done by implementing them into existing enterprise resource planning (ERP) tools or incorporating them into other standard processes in the organisation. Once the measures have been implemented and are in use, the focus switches back on aspects of performance management (cf. Taticchi and Balachandran, 2008; Ferreira *et al.*, 2012). The measures need to be transparently communicated to increase acceptance throughout the organisation. Measurement results need to be analysed to understand problems and organisational shortcomings. Additionally, results should be communicated to increase awareness throughout the organisation. Finally, performance and performance measures are reviewed. This includes feedback on the strategy definition process as well as the evaluation of the usefulness of different performance measures. In this step, the overall strategy can be audited. Many authors stress the importance of dynamic PMMS development (e.g. Bititci *et al.*, 2000; Kennerley and Neely, 2002; Gomes *et al.*, 2011; Braz *et al.*, 2011; Melnyk *et al.*, 2013; Demartini, 2014 and further authors listed in Table 14). A dynamic PMMS is a system that is periodically updated to accommodate changes in the external and internal environment of an organisation.

So far, this sub-subsection has described a PMMS process that incorporates various authors' perspectives on how to develop and use performance measures. However, the literature provides additional requirements on what a PMMS process needs to incorporate as well as other aspects of the organisational environment that need to be considered. Table 16 gives an overview of these requirements and guidelines.

Requirements and Guidelines for PMMS processes	***Authors***
• A PMMS process should evaluate the existing performance measurement practice in an organisation.	**Hudson *et al.* (2001), Pun and White (2005) and Braz *et al.* (2011)**
• A PMMS process should involve key users.	**Kald an Nilsson (2000), Hudson *et al.* (2001) and Pun and White (2005)**
• A PMMS process should identify vision and mission of an organisation and communicate them	**Möller *et al.* (2011)[18]**
• A PMMS process should identify success factors and communicate them	**Möller *et al.* (2011)**
• A PMMS process should represent the structure of an organisation and point out it influences use and development of the PMMS	**Bititci *et al.* (1997) and Möller *et al.* (2011)**
• A PMMS process should identify other existing processes for performance evaluation	**Möller *et al.* (2011)**
• A PMMS process should link strategy to department, team and individual goals	**Bourne *et al.* (2003)**
• A PMMS process needs a clear owner	**Neely *et al.* (2008)**
• A PMMS process should be linked to the strategy development process in a way that performance measures and objectives are co-created with strategy	**Pun and White (2005) and Melnyk *et al.* (2013)**
• A PMMS process should set the incentives for the fulfilment of objectives	**Eccles (1991), Bourne *et al.* (2003), Franco-Santos and Bourne (2005) and Möller *et al.* (2011)**

[18] This and all further quotes by Möller *et al.* (2011) are translated by the author

Requirements and Guidelines for PMMS processes	*Authors*
• A PMMS process illustrate the flow of knowledge that is necessary to support the activity of performance management/ develop an information architecture	**Eccles (1991), Bourne *et al.* (2003) and Möller *et al.* (2011)**
• A PMMS process should identify strategic objectives.	**Hudson *et al.* (2001), Pun and White (2005) and Möller *et al.* (2011)**
• A PMMS process should include the development of performance measures.	**Hudson *et al.* (2001) and Pun and White (2005)**
• A PMMS process should include a periodic maintenance/update structure	**Hudson *et al.* (2001), Franco-Santos and Bourne (2005), Pun and White (2005) and Neely *et al.* (2008)**
• A PMMS process should be supported from top management	**Eccles (1991), Hudson *et al.* (2001), Bourne *et al.* (2003), Franco-Santos and Bourne (2005) and Pun and White (2005)**
• A PMMS process should be supported from employees	**Hudson *et al.* (2001) and Pun and White (2005)**
• A PMMS process should develop clear and explicit objectives	**Hudson *et al.* (2001) and Pun and White (2005)**
• The objectives developed through a PMMS process should be adequate	**Möller *et al.* (2011)**
• A PMMS process should follow set timescales	**Hudson *et al.* (2001) and Pun and White (2005)**
• A PMMS process should consider external and internal factors	**Franco-Santos and Bourne (2005)**
• Results throughout a PMMS process should be communicated openly	**Franco-Santos and Bourne (2005)**

Table 16 – List of Requirements and Guidelines for PMMS Processes

Similar to the other requirements presented in this subsection, the requirements and guidelines for PMMS processes serve as a stepping stone when developing a company-specific or general PMMS process. The guidelines are also applicable to SPMMS as they are a subset of PMMS

2.2.5 Exemplary SPMMS

As performance measurement and management has been widely discussed, numerous SPMMS have evolved over time. These SPMMS vary in their depth (i.e. not all of them encompass aspects of performance management and performance measurement), their focus (i.e. some focus on companies in general, some on the public sector etc.) and, as the time since their first publication progressed, their timelines. Several publications review the most important performance measurement systems and also provide an evaluation (e.g. Neely *et al.*, 1995; Bititci *et al.*, 2000; Bourne *et al.*, 2000; Medori and Steeple, 2000; Grüning, 2002; Bourne *et al.*, 2003; Garengo *et al.*, 2005; Pun and White, 2005; Gomes *et al.*, 2006; Franco-Santos *et al.*, 2007; Neely *et al.*, 2008; Taticchi and Balachandran, 2008; Taticchi *et al.*, 2010; Biazzo and Garengo, 2012; Pekkola, 2013; Demartini, 2014). Thus, this subsection does not aim at giving a comprehensive overview of existing SPMMS. Instead, selected SPMMS will be reviewed to give an insight into important concepts and approaches to performance measurement and management. The reviewed SPMMS were selected based on their overall impact on performance measurement, their novelty and their fit to the topic of networks or manufacturing. Based on the definitions in Section 1.2, not all of them might fulfil the requirements of a full-scaled SPMMS. Nonetheless, the systems described here represent important additions to the topic of performance measurement and management.

Tableau de Bord

In France, balanced and multi-dimensional PMS have been known under the name "Tableau de Bord" since the early 20th century (Epstein and Manzoni, 1998). A Tableau de Bord refers to a set of performance measures that allow the monitoring of the business, comparing performance to set goals and initiating supportive actions if goals are not met (Epstein and Manzoni, 1998). Importantly, a Tableau de Bord is not intended to be a single document that applies to every entity in a company; instead each sub-unit has a different Tableau de Bord according to its specific responsibilities (Epstein and Manzoni, 1998).

Thus, the Tableau de Bord is described as "nested" (Lebas, 1994). Different Tableaus de Bord are connected hierarchically throughout a company (Lebas, 1994). A suitable comparison would be an Ishikawa diagram of performance where different performance dimensions are connected to related sub-dimensions. On each level, a Tableau de Bord contains performance measures that a) help the manager evaluate how well he is doing in terms of assigned performance targets based on own or subordinate activities, b) provide performance information to the superior and c) inform stakeholders connected to the level how it is doing. This is illustrated in Figure 15.

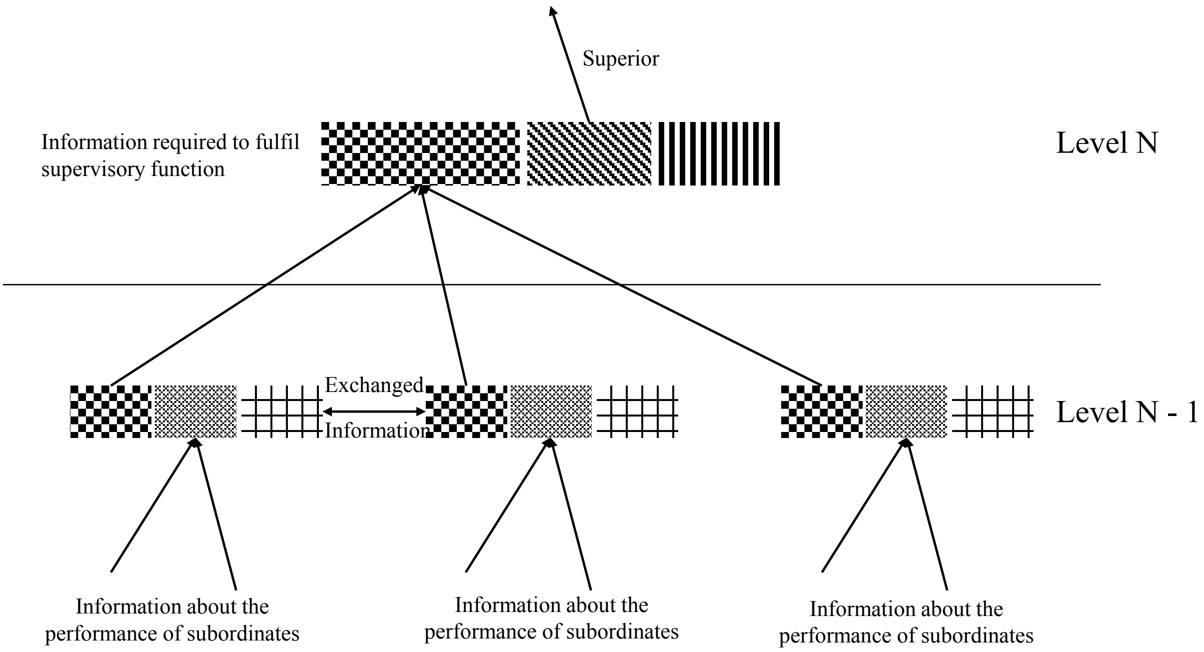

Figure 15 – Nested structure in a Tableau de Bord based on Lebas (1994)

In essence, the Tableau de Bord is a hierarchical PMS that connects results to determinants across an organisation's hierarchy (Neely *et al.*, 2008). Since it is not a scientifically derived model but evolved from industrial practice, it does not contain pre-formed performance dimensions to guide practitioners in their task of developing performance measures. This might have hindered its dispersion and popularity outside of France. It is also more an accounting tool than a means to deploy a strategy holistically.

The Balanced Scorecard

The Balanced Scorecard (BSC) developed by Robert S. Kaplan and David P. Norton (1992) is probably the most renowned performance measurement framework. The reason for this is that Kaplan and Norton most notably broadened the understanding of performance by multiple dimensions. Based on a one-year research project and numerous interviews, Kaplan and Norton developed the balanced scorecard as a tool for top management which provides a multi-dimensional overview of company performance (Kaplan and Norton, 1992). Despite being one of the first SPMMS, the BSC incorporates important aspects of performance measurement (a structural framework that supports the definition of measures) and performance management (a procedural framework that defines, communicates and updates the BSC). The BSC has been updated and amended to various applications. This description only focuses on the original definition of the BSC. In the original BSC, the four dimensions were the financial perspective, the customer perspective, the internal perspective and the innovation and learning perspective.

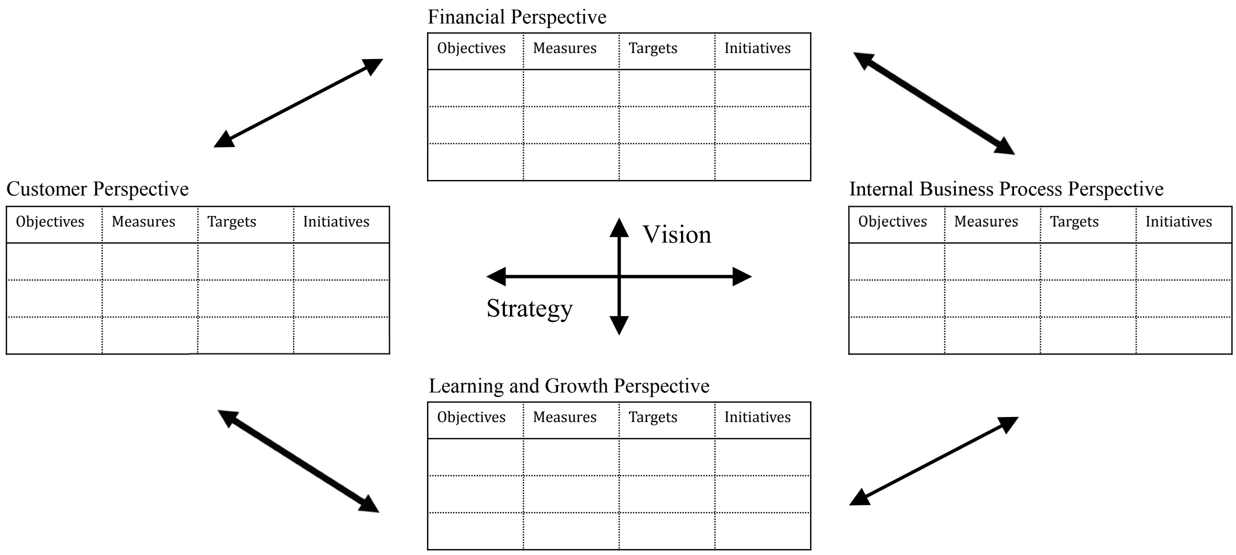

Figure 16 – The four perspectives of the BSC taken from Kaplan and Norton (1996b)

The financial perspective focuses on an organisation's financial result measures. It reflects if a company's strategy, implementation and execution are contributing to overall financial success (Kaplan and Norton, 1992). The targets and measures in this dimension therefore are a) lagging indicators for the results achieved in the other three perspectives and b) define the company's future goals (Schulze im Hove and Stüllenberg, 2003). Per definition, financial indicators are retrospective in nature. That is, they capture the results of a past time period and provide little indication of future company performance. By supplementing the financial performance with the other perspectives that can be directly influenced by a company, this disadvantage is somewhat counteracted.

The customer perspective focuses on measurable and visible aspects of performance that can be observed by customers. This dimension demands managers to translate their general mission statements on customer services into specific measures reflecting customer demands (Kaplan and Norton, 1992). Kaplan and Norton propose measures in this category that focus on time, quality, service and cost. These can be complemented with measures of overall customer satisfaction. A high performance in these categories should predict future financial performance, as satisfied customers will likely buy again and recommend both company and product.

The internal process perspective focuses on measures describing internal processes. These measures are a translation of customer demands into what the company must do internally (Kaplan and Norton, 1992). Measures in this category should focus on business processes that have the highest impact on customer demands as described in the customer perspective. Exemplary measures are operational excellence measures, throughput time, quality, productivity, product defects etc. The better the company performs in these dimensions, the higher customer satisfaction will be (Kaplan and Norton, 1992).

Lastly, the learning and development perspective comprises aspects of organisational and employee learning (Kaplan and Norton, 1992). While the customer and internal process perspective monitor the execution of existing processes and the provision of existing products, a company needs to innovate its products and processes to remain competitive in the future (Kaplan and Norton, 1992). Exemplary measures can be the share of sales of new products, time-to-market, improvement of existing process measures etc.

It is important to note that the performance measures in the different categories are linked through cause-and-effect diagrams that allow a detailed analysis of company performance. To fill the performance categories described above and implement the BSC within an organisation, Kaplan and Norton (1996b) propose a four-step process:

- **Translating the Vision:** The company vision is clarified and a consensus in top-management is reached. Based on the clarification, the vision is translated into concrete performance measures and critical objectives (Kaplan and Norton, 1996b).
- **Communicating and Linking:** Implementing a strategy begins with educating the executioners of the strategy (Kaplan and Norton, 1996b). Therefore, an internal communication program should share the strategy and critical objectives with all employees. The critical objectives of the company as a whole must be translated into objectives and performance measures for operating units and individuals. And these objectives and performance measures are linked to rewards (Kaplan and Norton, 1996b).
- **Business Planning:** In this step, the business objectives are used to set concrete targets and align strategic initiatives. Corporate resources are assigned to the different initiatives and milestones are set to further develop the company (Kaplan and Norton, 1996b).
- **Feedback and Learning:** By communicating and implementing the strategy, feedback from different stakeholders in the organisation is gathered and used to further develop and update the strategy. The BSC can thus also be seen as organisational learning (Kaplan and Norton, 1996b).

It has to be noted that these four process steps are repeated periodically; they may have to be repeated multiple times before a valid and sufficient BSC can be defined. Due to its popularity, the BSC has been adapted and amended various times. In most cases, a fifth dimension has been added, in response to criticism that the BSC sports no competitive dimension (Neely *et al.*, 1995; Neely *et al.*, 2008) nor human resources, supplier, or a corporate social responsibility (CSR) perspective (e.g., Keegan *et al.*, 1989). Furthermore, the BSC is designed for top management application on company or BU level, which makes it difficult to use on site level (Ghalayini and Noble, 1996).

Integrated Performance Measurement System

Based on industry insights and research projects, Umit Bititci and his colleagues (Bititci *et al.*, 1997) identified the need for an integrated performance measurement system. In this context, "integrated" describes the development of an integrated set of performance measures which support rather than contradict business objectives. Specifically, Bititci *et al.* (1997) pointed out that in many companies controlling-based financial measures contradict operations-based measures (e.g., quality measures). Bititci *et al.* (1997) therefore concluded that performance management should be seen as a key business process which includes the coordination of operational and business objectives throughout an organisation. The integrated performance measurement system is a part of the overall performance management process and its content and structure are considered to be critical for the efficiency and effectiveness of the performance management process. Bititci *et al.* also observed that there are two critical considerations with respect to structure and configuration of PMS: integrity of the system and deployment. Integrity refers to the ability of the PMS to promote integration between various areas of the business (Bititci *et al.*, 1997). Deployment describes the ability to deploy business objectives and policies throughout the hierarchical structure an organisation by using consistent performance measures (Bititci *et al.*, 1997).

Based on these two considerations, Bititci *et al.* (1997) developed a reference model for performance measurement systems. This hierarchical model incorporates five key factors on each level: Stakeholders, control criteria, external measures, improvement objectives and internal measures. The levels considered in this model are: Corporate level, business unit level, business process level and activity level. The overall reference model as depicted in Figure 17 is accompanied by an audit method to ensure the integrity and deployment of the PMS.

Although this publication has been frequently cited, its proposed model has been less popular than the balanced scorecard. The reason for this might be that the various sub-systems of the model confuse potential implementers. An interesting aspect of the integrated performance measurement system is the hierarchical approach to the definition of performance measures and targets. However, it remains unclear whether there should not be further hierarchical levels below the business unit level (e.g., regions, factories, product groups etc.). Furthermore, the IPMS is designed in a way that it can be used for auditing existing company-internal SPMS (Bititci *et al.*, 2002). In conclusion, the integrated performance measurement system by Bititci *et al.* (1997; 2002) advocates the cross-company alignment of performance measures and strategy; however it lacks easy applicability.

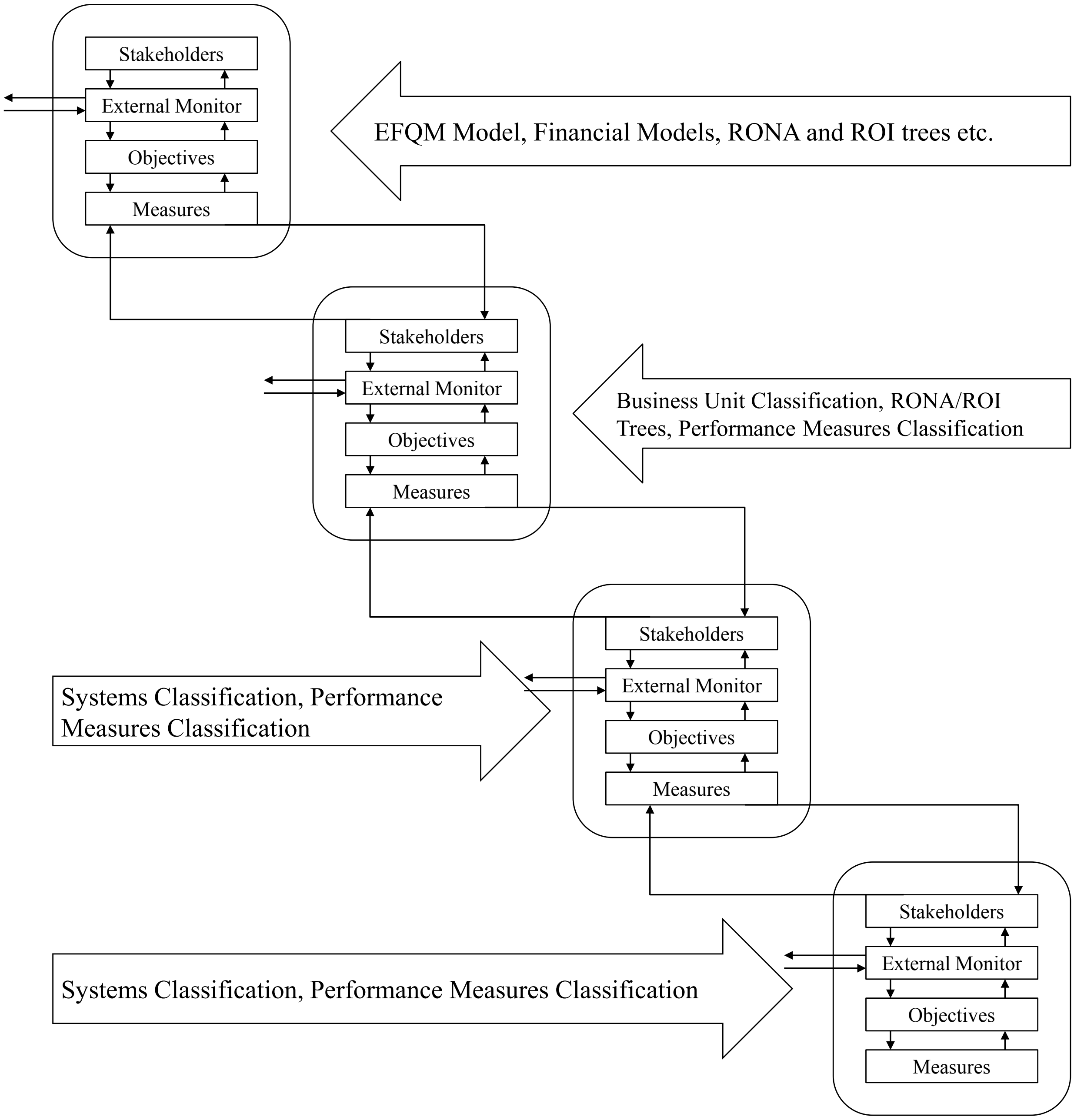

Figure 17 – A model for integrated performance measurement systems (Bititci et al., 1997; Bititci et al., 2002)

The SMART Pyramid

The Strategic Management and Report Technique (SMART) Pyramid developed by Richard L. Lynch and Kelvin F. Cross (e.g., Cross and Lynch, 1988, 1989; Lynch and Cross, 1991, 1995) also is a hierarchical PMS. It distinguishes four organisational levels of performance and aims at effectively linking strategies and operations (Cross and Lynch, 1988). To do so, strategic objectives are translated top-down, while performance measures are created bottom-up. The starting point for defining performance targets is the corporate vision. The targets and objectives are then translated downwards across business units, business operating systems and departments and work centres (Carr and Nanni, 2009). The two halves of the pyramid reflect external effectiveness (visible to the customer) and internal efficiency (in the focus of the owner/shareholders) (Lynch and Cross, 1995). On a business unit level, financial- and market-oriented objectives and measures are developed. This is supported by measures addressing customer satisfaction, flexibility and productivity on the level of business operation systems. This level has also been called "core business process" in later publications (c.f. Lynch and Cross, 1995). These three dimensions are closely linked to the performance dimensions on department and group level, where the core performance dimension are quality, delivery, cycle time and waste.

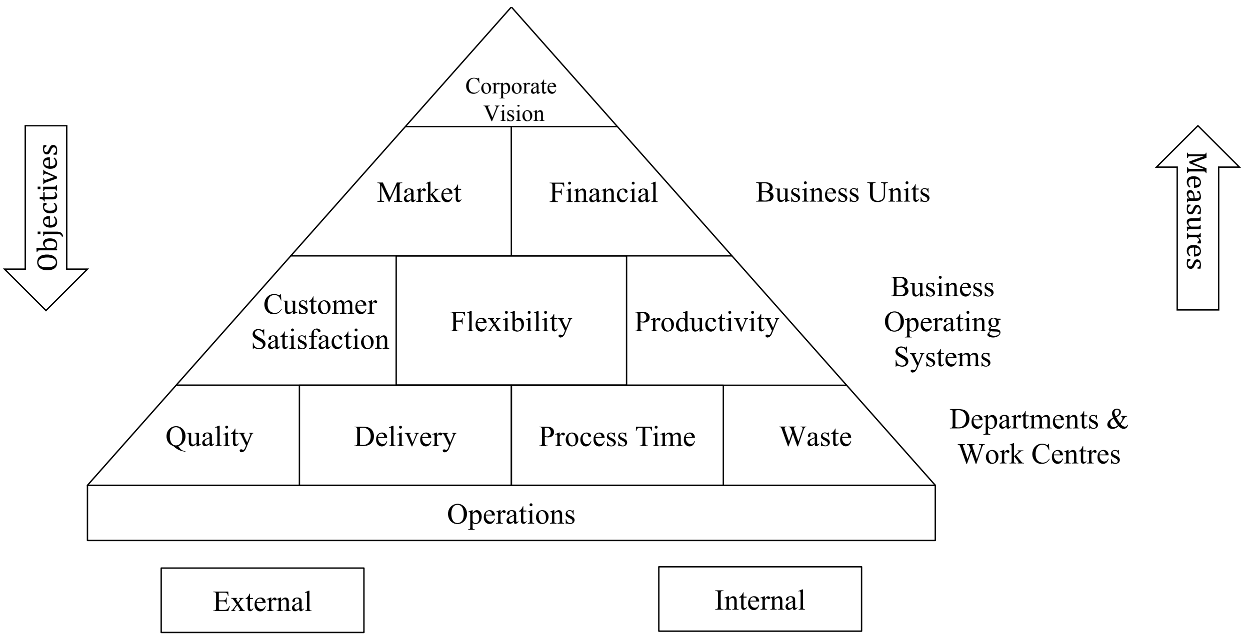

Figure 18 – The SMART Pyramid taken from Cross and Lynch (1989)

Overall, the performance pyramid is a valuable tool to connect a corporate vision to operations. Performance dimensions on the different levels are closely linked to the performance levels above and below.

Performance Measurement Matrix

Another early framework is the Performance Measurement Matrix developed by Daniel P. Keegan, Robert G. Eiler and Charles R. Jones (1989). They believed that performance measures need to be derived from strategy and need to be translated downwards through an organisation (Keegan *et al.*, 1989). These downwardly derived measures need to be accompanied by function-specific performance measures that can be developed along the process chain (Keegan *et al.*, 1989).

The Performance Measurement Matrix then incorporates the developed measures. In doing so, the matrix takes a balanced approach to performance measurement. This means that internal and external, as well as financial and non-financial measures are selected, presumably presenting a balanced picture of performance (Neely *et al.*, 1995). As the Performance Measurement Matrix only addresses the type of measures that need to be found but not the actual dimensions a company or organisation has to perform in, the matrix is very flexible and can be adapted to almost any entity (Neely *et al.*, 2008). At the same time this is a weakness of this framework, as it does not guide companies in their endeavour to define performance and performance measures accordingly.

The Results-Determinant Framework

In 1991, Fitzgerald *et al.* developed a normative model for performance measurement in the service industry (cf. Fitzgerald *et al.*, 1991; Brignall and Ballantine, 1996). This model consists of three main elements (Brignall and Ballantine, 1996):

- A control model for PM
- A level of organisational analysis for PM
- A range of dimensions for PM

In later publications, Fitzgerald *et al.*'s (1991) model has often been discussed as the so-called "Results-Determinant Framework" (cf. Neely *et al.*, 2008). This view only focuses on the range of dimensions for PM while ignoring the other elements of the original model. Often, the focus on service business is also ignored. What is most notable about the range of dimensions for PM as proposed by Fitzgerald *et al.* (1991) is the fact that they separate the dimensions into results and determinants. The content of those categories is described as follows (Brignall and Ballantine, 1996):

- Results
    - Financial Performance (e.g., Profitability, Liquidity, Capital Structure)
    - Competitiveness (e.g., Market Share, Sales Growth)
- Determinants
    - Resource Utilization (e.g., Productivity, Efficiency)
    - Quality of Service (e.g., Reliability, Responsiveness, Comfort)
    - Innovation (e.g., Performance of the innovation process)
    - Flexibility (e.g., Flexibility regarding Specifications or Volume)

The strength of this division is that it reflects the causality in the relationship of process and product performance and company performance. In other words: The performance measures in the determinants category are leading measures for those in the results category. Performing well in their service is therefore a driver for overall company success (Neely *et al.*, 2008).

The EFQM Excellence Model

The European Foundation for Quality Management (EFQM) developed an excellence framework which was originally not designed as a performance measurement framework (Neely *et al.*, 2008). It shares a similar perspective on performance with its American (the Baldridge Award) and Japanese (the Deming Prize) counterparts (cf. Neely *et al.*, 2008). What is striking about the EFQM Excellence Model is that it adopts a broad view of performance which not only incorporates results but also so-called enablers. The EFQM Excellence Model and its performance dimensions based on an illustration by Seghezzi *et al.* (2013) are depicted in Figure 19. It can be seen that not only key financial results and process-based measures are incorporated, but also the satisfaction of multiple stakeholders and the fulfilment of several soft factors.

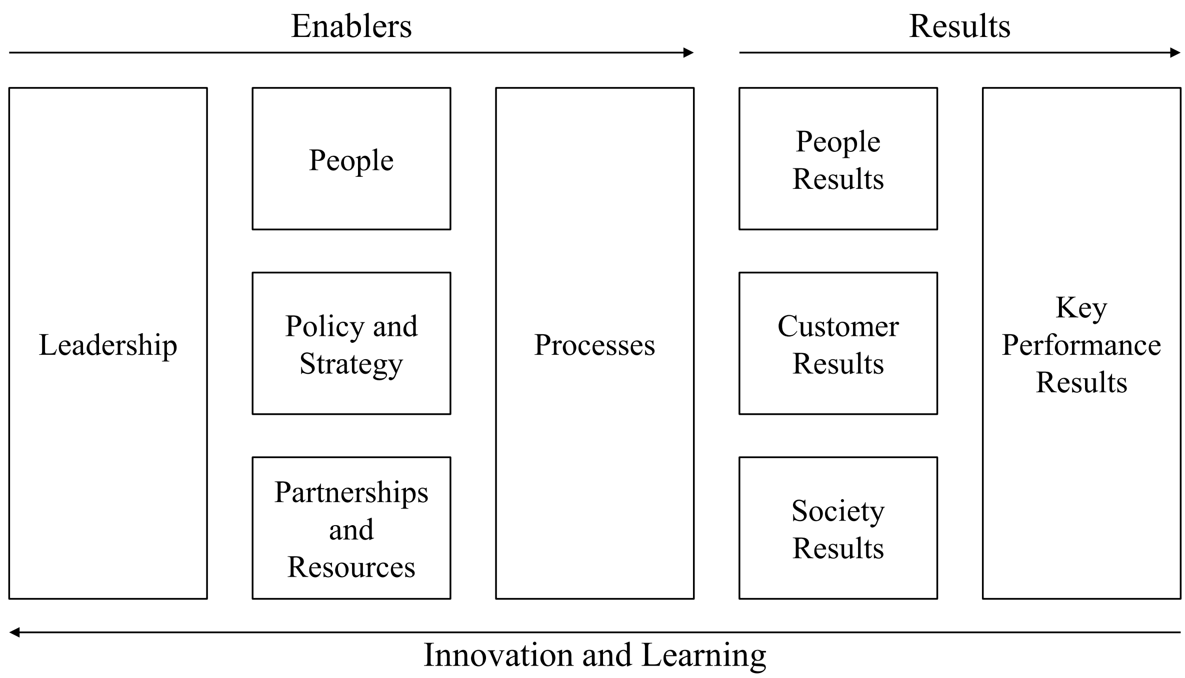

Figure 19 – The EFQM Excellence Model

The model acknowledges that to achieve overall results, first internal enablers need to be set-up in a way that this achievement of aspired results is possible (Friedli and Bellm, 2013). The performance dimensions and measures addressing the enablers section are therefore leading the performance dimensions and measures incorporated in the results section. This means that if a company is performing well in the enablers section, a good performance in the results section should follow. This in turn implies that if a company does not meet aspired results, it first needs to readjust the enablers (Seghezzi *et al.*, 2013). To support companies in their overall improvement, the EFQM developed the RADAR-Methodology (Seghezzi *et al.*, 2013). RADAR stands for:

- Results
- Approach
- Deployment
- Assessment and Review

These four steps form a circular process that begins with the definition of aspired results. Then an approach to fulfil those goals is defined. In the deployment phase, the approach is implemented. In the final phase, the approached and the achieved results are assessed and reviewed. Based on the assessment and review, the aspired results are updated (Seghezzi *et al.*, 2013). In summary, the EFQM Excellence Model is a broad framework that includes overall results and internal enablers in its definition of performance. This definition addresses the needs of a manufacturing environment especially well since many strategic manufacturing decisions address not only results but internal changes as well. This perspective will be incorporated into the definition of a SPMMS for manufacturing networks in Chapter 3.

The Performance Prism

The Performance Prism was developed by Andy Neely, Chris Adams and Mike Kennerley (2002). It is based on the assumption that shareholder value cannot be created without taking an inclusive approach to management, that is incorporating the requirements of all stakeholders into performance measurement and management activities (2008). To do so, the Performance Prise takes over a stakeholder-centric view of performance measurement. In this view, the importance of different stakeholders is not ranked and Neely *et al.* accept that the importance of different stakeholders might vary throughout organisations. Generally, Neely *et al.* (2001) differentiate the following stakeholders as relevant for corporations:

- Investors
- Customers & Intermediaries
- Employees
- Regulators & Communities
- Suppliers

Based on these four stakeholders, the performance prism distinguishes between what an organisation needs from those stakeholders and what it can do to satisfy those stakeholders (Neely *et al.*, 2008). Once the wants and needs of organisation and stakeholders are identified, an organisation can derive strategies to ensure the wants and needs of its stakeholders are satisfied (Neely *et al.*, 2008). Based on the strategies, measures are defined. These measures serve four purposes: a) track the implementation of strategies b) communicate the strategies throughout the organisation c) incentivise the implementation of strategy and d) allow an evaluation of the effectiveness of strategies (Neely *et al.*, 2008). Once the strategies are defined, the Performance Prism looks at corporate processes and how they need to be improved. The processes and improvement potentials are also captured in relevant performance measures. However, processes do not run and improve themselves autonomously. Processes are supported by people with a certain set of skills, policies and standards or physical infrastructure and technologies; in short: capabilities. The existing capabilities and the capabilities that need to be built up are also addressed by performance measures (Neely *et al.*, 2008). The process to measure definition in the Prism is depicted in Figure 20.

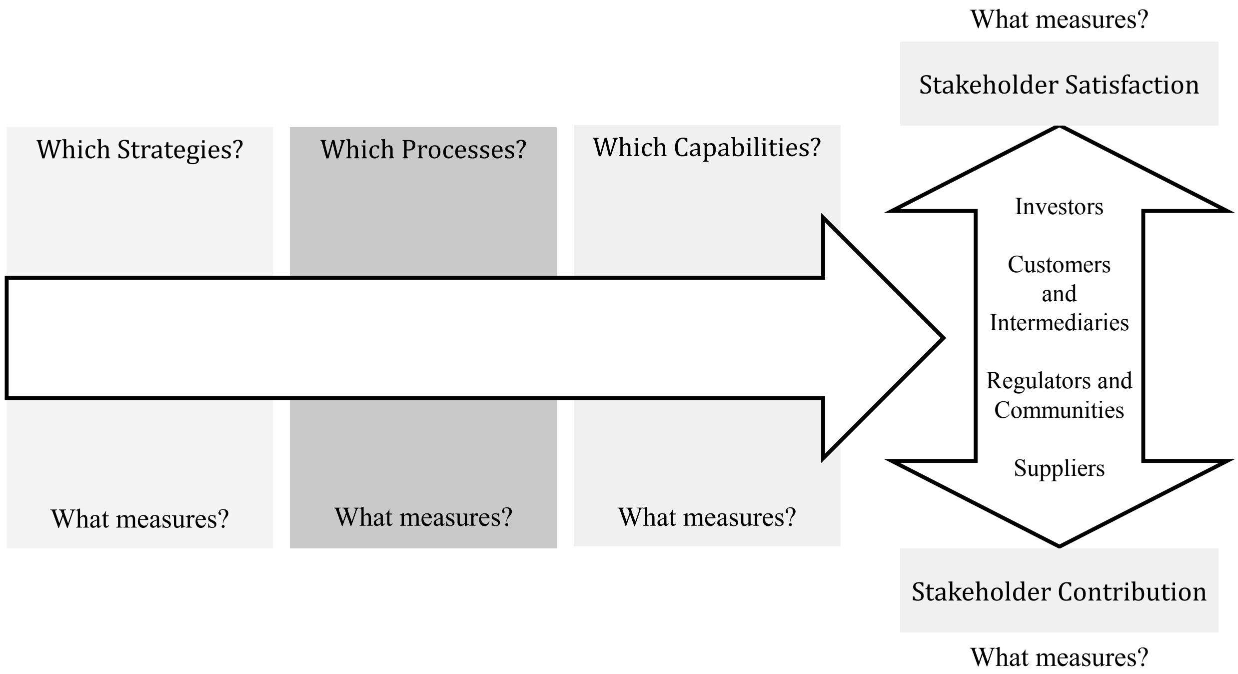

Figure 20 – The Performance Prism

In the Performance Prism, stakeholder satisfaction (results) is a function of determinants. The determinants are the other aspects considered in the prism. The great addition of the Performance Prism to PMS-literature is the acknowledgement of other stakeholders than customers and shareholders and the strong focus on company-internal processes and capabilities.

Performance Measurement and Management in Collaborative Networks

Sanna Pekkola has focused on various aspects of performance measurement and management in collaborative networks (Pekkola, 2013). A collaborative network is a network consisting of different companies that share a joint process with shared information along the process. The different companies furthermore share resources and responsibilities to plan, implement and evaluate activities to achieve a common goal (Camarinha-Matos *et al.*, 2009; Pekkola, 2013). Following the definitions of this dissertation, a collaborative network is an inter-firm network. To define a network-level performance measurement system, Pekkola proposes a horizontal three-step process. Horizontal refers to the fact that a broad range of network partner is involved in the development of the PMS without a strong hierarchy (Pekkola, 2013). In this process, the first step consists of pre-interviews which focus on (Pekkola, 2013):

- Building an understanding of the network
- Defining the joint success factors of the collaborative network
- Identifying the joint purpose and need for measurement

The pre-interviews therefore create a common understanding of the network and its performance dimensions and thus help bypass the most common challenges in performance measurement (Pekkola, 2013). Once this common understanding is established, the actual design of the performance measurement system can begin. The second phase then identifies the relevant performance dimension for the network, before the level of measurement (e.g., process, collaboration, collaboration management) is selected (Pekkola, 2013). This is followed by a brain-storming focussing on possible joint-measures. Based on the brainstorming, the final performance measures are selected. These will then be implemented in adequate reporting tools, and the users of these tools and PMS will be trained for testing (Pekkola, 2013).

The third and final step of the PMS process is a feedback session. In this session, the developed measurement system is evaluated critically and changes and development needs from the testing phase are identified. Furthermore, the benefits and challenges of the use of the PM systems are assessed. These can be used as an argument for the implementation of the PMS with future additional network partners. The overall process is depicted in Figure 21.

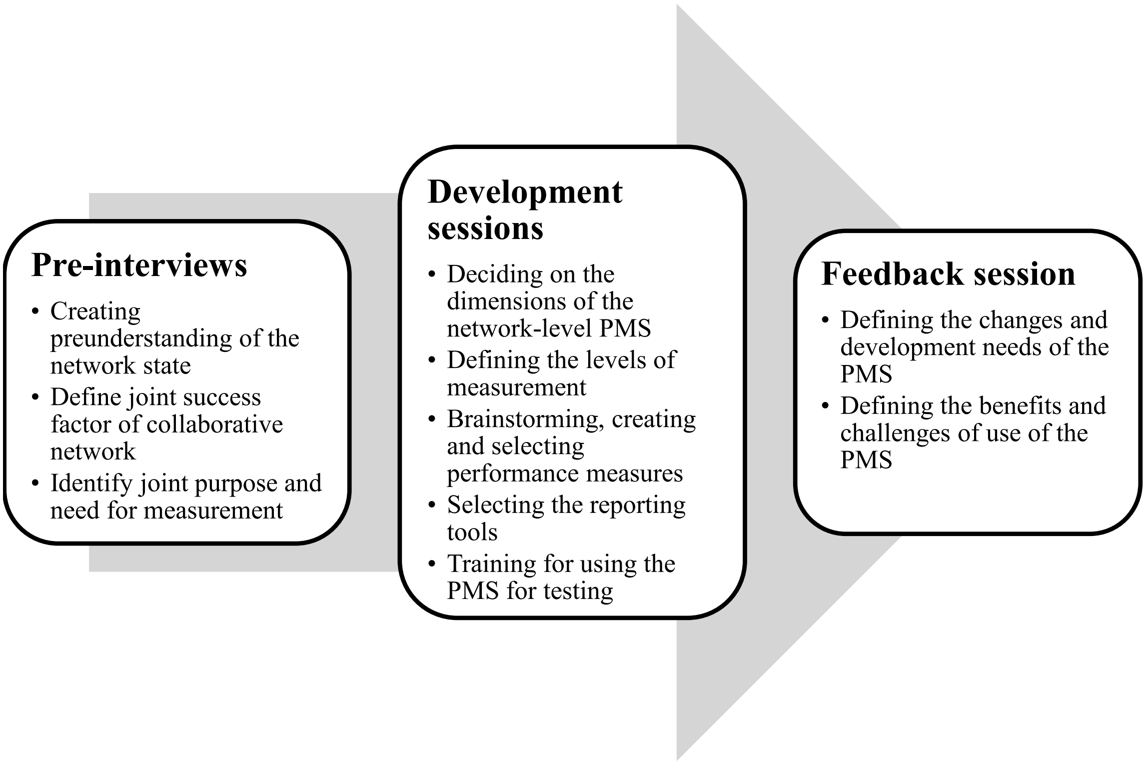

Figure 21 – Performance Measurement Design Process by Pekkola (2013)

Sanna Pekkola was one of the first to develop a process for a performance measurement system on a network level. Although she focuses on inter-organisational networks, core implications can be applied to the research topic of this dissertation:

- An equal understanding of a network has to be established
- There needs to be a differentiation of performance measures on different levels of the network
- Defining the PMS should be an inclusive approach involving representatives from the different entities in the network
- The benefits of the PMS need to be identified and communicated

2.2.6 Summary

Section 2.2 reviewed scientific literature on strategic performance measurement and management. It touched on the historic development of performance measurement, derived a definition of strategic performance measurement and management and reviewed guidelines and existing practices in performance measurement and management. It is evident that the existing literature base on PMMS is vast. The list of guidelines and suggestions is so comprehensive that incorporating all advice at all times is rather difficult. Nonetheless, the following core implications can be derived from this section:

From Subsection 2.2.1:

- Performance measurement systems are sets of performance measures
- PMS can take over different roles in an organisation
- The content and scope of PMS depends on the assumed role
- A performance management system is the meta-system above the PMS. It is used to develop, communicate, implement and re-evaluate a PMS
- A PMMS needs to fit to the organisational structure of an organisation
- PMMS should be integrative and people from multiple organisational levels should be incorporated in the development and implementation of PMS
- PMMS should be seen as learning rather than control tools

From Subsection 2.2.2:

- Performance measures should be connected to strategy
- Performance measures can be financial or non-financial, qualitative or quantitative, internal or external, leading or lagging
- Not every target can be addressed by a quantitative performance measure. Qualitative, audit-based approaches should be incorporated as well.

From Subsection 2.2.3:

- A SPMMS is a system which is used to develop , implement, communicate and re-evaluate a SPMS
- The SPMS integrates long-term strategy
- The SPMS monitors the fulfilment of defined long-term strategies
- Multiple dimensions of performance measures are included
- A sequence of goals/measures/actions is provided in the different performance dimensions
- There is a causal relationship between goals and performance measures

From Subsection 2.2.4:

- SPMMS should be balanced (that is: contain multiple criteria in multiple dimensions)
- S PMMS should reflect the structure of an organisation
- Data for SPMMS should be collected continuously
- Performance should be evaluated regularly and linked to incentives
- SPMMS should be evolving and dynamic
- SPMMS should be transparent and easy to understand
- A SPMMS process should be conducted top-down
- A SPMMS process should break down strategic targets to smaller entities
- A SPMMS process should be institutionalised
- A SPMMS process should be linked to strategy definition
- Performance dimensions in a SPMMS are derived from strategy

From Subsection 2.2.5:

- There are multiple existing SPMMS
- They vary in their focus, popularity, level of detail and applicability
- None of these SPMMS is explicitly focus on manufacturing and manufacturing networks

3 Developing a SPMMS for Manufacturing Networks

This chapter aims at developing the SPMMS for manufacturing networks and answering the research questions formulated in Section 1.4. To do so, the main research question will first be further detailed in Section 3.1. This is important to recap the findings and implications from Chapter 2 and to set the focus for this chapter. Section 3.2 identifies the requirements a SPMMS for manufacturing networks has to fulfil, before Section 3.3 uses these requirements to review and evaluate the SPMMS discussed in Subsection 2.2.5. This review aims at identifying aspects that can be valuable in defining the SPMMS for manufacturing networks. Before the SPMMS can be developed, Section 3.4 reviews evaluation criteria for the quality of scientific models in general and SPMMS in particular. Sections 3.5 and 3.6 will then develop the SPMMS itself. Section 3.5 will develop the structural framework (the identification of the necessary performance dimensions or content of an SPMMS), and Section 3.6 the procedural framework (the process for the use of the SPMMS). The developed SPMMS will not entirely redefine strategic performance measurement and management. However, it will make some innovative and valuable additions to the understanding of strategic performance and strategic performance measurement and management in manufacturing networks. Section 3.7 will summarise these additions so that they can be verified in Chapter 4.

3.1 Review and Detailing of the Research Questions

The goal of this section is to review the research questions presented in Section 1.4 and detail the outcomes that will be developed within this dissertation.

MRQ: What are special requirements of intra-firm manufacturing networks and how do they need to be incorporated into a holistic strategic performance measurement and management system?

- ***What are special requirements of intra-firm manufacturing networks …:*** The developed model will focus on intra-company manufacturing networks. These networks describe manufacturing activities of sites owned by a single company and connected by flows of materials, information or knowledge. This focus is important since the scientific literature on performance measurement distinguishes between inter- and intra-company manufacturing networks (e.g., Bititci *et al.*, 2012). The structural and procedural implications for performance measurement are fundamental when dealing with multiple companies instead of one. The first step towards the development of a SPMMS is to establish an understanding of the demands manufacturing networks place on SPMMS. This

- will highlight why existing SPMMS do not fully serve the needs of manufacturing networks.
- ***…how do they need to be incorporated...:*** Based on the identified requirements, guidelines will be derived for the definition of a generic model that allow practitioners to develop a personalised strategic performance measurement system fitting to their manufacturing networks. The model needs to be flexible enough to be adjustable to (1) different competitive environments, (2) different organisational structures within organisations and (3) different strategies.
- ***… into a holistic…:*** This research proposal takes a holistic approach to manufacturing network management and performance measurement. Network performance incorporates not only solitary output factors of the manufacturing function but also success in the interaction with stakeholders, the environment and internal processes. A holistic perspective allows identifying and discussing trade-offs of performance in different dimensions, instead of focussing on a one-dimensional (e.g., financial) definition of performance.
- ***…strategic performance measurement and management system:*** The developed model will focus on the strategy in manufacturing networks and ways to measure or illustrate the extent to which the strategy has been successfully implemented. In doing so, a distinction between operational and strategic performance is necessary. The term “performance measurement and management system” implies that there need to be (1) multiple dimensions that are used to measure performance, (2) multiple qualitative and quantitative performance measures and (3) a process that allows to define, evaluate, discuss and update how network performance is understood.

Thus, the aim of this dissertation is the following: Based on the review of literature on manufacturing, manufacturing strategy and manufacturing networks presented in Section 2.1, requirements of strategic performance measurement and management will be derived. These requirements will be used to illustrate why existing SPMMS do not suit manufacturing networks. Based on Section 2.2, a SPMMS for manufacturing network will be developed. This SPMMS will contain a structural framework, providing the performance dimensions to be considered, and a procedural framework, providing the step-by-step approach for performance measurement and management. The SPMMS is understood as a tool to implement and manage strategy. It is therefore used to communicate the belief and boundary systems of a network manager throughout the network and thus influence the behaviour of the entities in the network. By engaging in open discussions about targets and the future development of the network, the SPMMS is also used as a tool for learning and improvement.[19] Although the strategic performance of a manufacturing network and manufacturing sites is defined and can be measured through the use of the here developed SPMMS, the SPMMS is not designed to be used as a benchmarking tool for operative performance measures. However, any operative performance measure can become strategic when the manufacturing strategy identifies an operative process as strategically important.

With this detailed evaluation of the main research question, sub question 1 as introduced in Section 1.4 is answered as follows:

The strategic performance of a manufacturing network or a manufacturing site is the extent to which the manufacturing strategy set for the site or the network has been fulfilled while accounting for the influence of contextual factors.

3.2 Requirements towards a SPMMS for Manufacturing Networks

Section 2.2 already reviewed several guidelines and requirements of performance measures and performance measurement and management systems in general. These reviewed guidelines and requirements give guidance on how an ideal (S)PMMS should be set up. Multiple publications have developed evaluation criteria for (S)PMMS and then evaluated existing (S)PMMS based on these criteria (e.g., Hudson *et al.*, 2001; Garengo *et al.*, 2005; Pun and White, 2005; Franco-Santos *et al.*, 2007; Biazzo and Garengo, 2012). The goal of this section, however, is not to derive criteria or requirements to develop an ideal SPMMS but that allow the definition of a SPMMS that suits the needs of manufacturing networks. Although not explicitly addressed in this section, general requirements and criteria for ideal (S)PMMS are clearly still relevant for the definition of a SPMMS for manufacturing networks.

The first group of requirements of SPMMS in manufacturing networks are connected to the fact that the SPMMS should be concerned with strategic performance as defined in Section 1.2. The strategic performance of a manufacturing network or a manufacturing site is defined as the degree of realisation of the manufacturing strategy set for the site or the network. Thus, a SPMMS for manufacturing networks should:

R 1: Focus on the fulfilment of manufacturing strategy through the manufacturing function.

[19] Cf. the roles of an SPMMS developed by Franco-Santos *et al.* (2007) and Micheli and Manzoni (2010) discussed in section 2.2.

R 2: Incorporate different levels for target definition (e.g., network level, site level etc.).

As discussed in Subsection 2.1.1, producing goods in global manufacturing networks for global markets is a challenging task as manufacturing managers are faced with multiple dynamic markets that might lead to changing and possibly contradictory demands on the product and thus also the manufacturing function. A SPMMS for manufacturing networks therefore should:

R 3: Allow a periodical update of performance targets and measures.
R 4: Allow varying performance foci across the manufacturing network.

This market dynamism requires a manufacturing system to continuously improve and adapt. Kaplan and Norton (2000b), Bititci *et al.* (2000) and Krause (2006) recommend to also incorporate performance measures that are linked to performance improvements projects. In line with this recommendation and the fact that manufacturing strategy often addresses changes in manufacturing structure and infrastructure that are implemented based on projects, a SPMMS for manufacturing networks also should:

R 5: Incorporate performance measures that address improvement projects.
R 6: Incorporate performance measures that address change projects in manufacturing structure and infrastructure.

The continuous change in technology and external requirements often leads to the establishment of manufacturing sites that differ in their technology, set-up, competence, strategic advantage and general role. All of these aspects as well as the general development of the product portfolio or process steps a site is assigned have implications for the definition of future targets both in terms of efficiency and effectiveness. A SPMMS for manufacturing networks therefore should:

R 7: Use the concept of site roles and development roadmaps for the definition of site-specific performance targets.
R 8: Consider existing structural and infrastructural differences in manufacturing sites when evaluating and defining performance of different manufacturing sites.

Most performance measurement systems discussed in Subsection 2.2.5 take a hierarchical approach to the definition of performance targets. While the hierarchical approach may be suitable for some manufacturing networks, organisational structures in manufacturing networks are often interwoven and a simple hierarchy such as proposed by Cross and Lynch (1989) might thus not suit all companies. A SPMMS for manufacturing networks therefore should:

R 9: Be adaptable to different organisational structures.

Manufacturing a product is not a simple task and a company interacts with multiple different stakeholders other than customers along the value chain. Often, the quality of this interaction, which might be relevant for future company success, cannot be measured with financial performance measures alone. To prevent sub-optimisation, SPMM in manufacturing needs to be seen in a holistic context with multiple dimensions. A SPMMS for manufacturing networks therefore should:

R 10: Incorporate non-financial performance measures.
R 11: Incorporate performance measures addressing the quality of interaction with relevant stakeholder groups.
R 12: Incorporate a holistic manufacturing perspective.

These requirements will be used in the following section to evaluate existing SPMMS regarding their applicability in manufacturing networks.

3.3 Evaluation of Existing SPMMS

This section evaluates the SPMMS described in Subsection 2.2.5. As pointed out in Subsection 2.1.5, currently no SPMMS is ideally tailored to manufacturing networks. Thus, this evaluation of existing SPMMS does not aim at searching for a SPMMS that is fully applicable to manufacturing networks; instead, it seeks to identify which SPMMS are better addressing the requirements of manufacturing networks and deriving implications and insights for developing the SPMMS for manufacturing networks.

Table 17 presents an overview of the SPMMS as evaluated on the requirements presented in Section 3.4. Harvey Balls were used to illustrate the results. A solid, black Harvey Ball shows that a requirement is met. An empty, white Harvey Ball illustrates that the requirement is not met. If a requirement is partially met, the amount of filling inside the Harvey Ball illustrates the extent to which the requirement is met.

As Table 17 shows, only one requirement is met by all of the reviewed SPMMS; all SPMMS incorporate non-financial performance measures. This is not surprising as this requirement has been discussed in the literature for a long time and is easily applied to SPMMS in general. Three requirements are not fully met by any of the SPMMS. This is rooted in the fact that all three of these requirements are closely linked to the topic of manufacturing strategy and manufacturing networks, and as identified in Subsection 2.1.5 currently no SPMMS addresses manufacturing networks adequately. More specifically, none of the SPMMS has a focus on manufacturing strategy, none of them uses site roles and development paths for target derivation and none of them fully adopt a holistic manufacturing perspective. Only the EFQM Excellence Model and the Performance Prism are somewhat more holistic as they incorporate the perspective of various stakeholders. Although the Performance Prism was not strictly designed for manufacturing networks, the mentioned stakeholders can easily be discussed in the context of manufacturing networks. The EFQM Excellence Model takes a very broad focus on quality; out of the listed SPMMS, it is the model that comes closest to having a manufacturing focus, as it is engineering-driven. However, it does not incorporate a network perspective or a holistic manufacturing strategy perspective as described in Section 2.1.

	Tableau de Bord	*BSC*	*Integrated PMS*	*SMART*	*Performance Measurement Matrix*	*Results-Determinant Framework*	*EFQM Excellence Model*	*Performance Prism*	*PMM for Collaborative NWs*
Focus on manufacturing strategy	○	○	○	○	○	○	◑	○	○
Different levels of target definition	●	◑	●	●	○	○	○	○	●
Periodical update	◑	●	●	●	◑	●	●	●	●
Includes varying performance foci	●	○	○	○	○	○	○	○	◑
Incorporates measures addressing improvement projects	○	●	○	○	◔	○	◑	●	◔
Incorporates performance measures that address change projects	○	●	○	○	◔	○	◑	●	◔
Uses site roles and development roadmaps for site performance targets	○	○	○	○	○	○	○	○	○
Considers structural and infrastructural differences for evaluation	◑	○	○	○	○	○	○	○	◑

	Tableau de Bord	*BSC*	*Integrated PMS*	*SMART*	*Performance Measurement Matrix*	*Results-Determinant Framework*	*EFQM Excellence Model*	*Performance Prism*	*PMM for Collaborative NWs*
Focus on manufacturing strategy	○	○	○	○	○	○	◑	○	○
Different levels of target definition	●	◑	●	●	○	○	○	○	●
Periodical update	◑	●	●	●	◑	●	●	●	●
Includes varying performance foci	●	○	○	○	○	○	○	○	◑
Incorporates measures addressing improvement projects	○	●	○	○	◔	○	◑	●	◔
Incorporates performance measures that address change projects	○	●	○	○	◔	○	◑	●	◔
Uses site roles and development roadmaps for site performance targets	○	○	○	○	○	○	○	○	○
Considers structural and infrastructural differences for evaluation	◑	○	○	○	○	○	○	○	◑
Adaptable to different organisational structures	◑	◑	○	○	○	○	○	○	●
Incorporates non-financial performance measures	●	●	●	●	●	●	●	●	●
Incorporates performance measures for stakeholder interaction quality	○	◔	◑	◑	○	○	●	●	◑

	Tableau de Bord	*BSC*	*Integrated PMS*	*SMART*	*Performance Measurement Matrix*	*Results-Determinant Framework*	*EFQM Excellence Model*	*Performance Prism*	*PMM for Collaborative NWs*
Focus on manufacturing strategy	○	○	○	○	○	○	◑	○	○
Different levels of target definition	●	◑	●	●	○	○	○	○	●
Periodical update	◑	●	●	●	◑	●	●	●	●
Includes varying performance foci	●	○	○	○	○	○	○	○	◑
Incorporates measures addressing improvement projects	○	●	○	○	◔	○	◑	●	◔
Incorporates performance measures that address change projects	○	●	○	○	◔	○	◑	●	◔
Uses site roles and development roadmaps for site performance targets	○	○	○	○	○	○	○	○	○
Considers structural and infrastructural differences for evaluation	◑	○	○	○	○	○	○	○	◑
Incorporate holistic manufacturing perspective	○	○	○	○	○	○	◕	◑	○

Table 17 – Evaluation of existing SPMMS

The requirement that different levels of performance and target definition need to be incorporated is fully addressed by the Tableau de Bord, Integrated Performance Measurement System, SMART Pyramid and the PMM for collaborative networks. The Integrated Performance Measurement System and the SMART Pyramid rely on fixed hierarchical levels (corporate, business unit, business process and activity level for the Integrated Performance Measurement System and business unit, business operation system and department and workstation for the SMART Pyramid). This fixed hierarchy suits the understanding of performance in these two models. However, as soon as a company operates in a different hierarchical set-up, an implementation of such SPMMS is difficult. The Tableau de Bord is more flexible in this regard. As it is a business practice and not so much a well-documented scientific model, it can be adjusted to any organisational structure and allows the definition of level-specific performance measures and targets. The PMM system for collaborative networks is also very flexible as it includes a green-field definition phase for the different levels at which performance targets and measures can be set on. Finally, the BSC is only granted a half-full Harvey Ball as it addresses a derivation of performance targets and measures across the levels of an organisation but does not provide a process to do so in the original publications. From this evaluation, it can be concluded that it is necessary for a SPMMS to have a defining phase in the beginning that allows the structuring of the organisation and the identification of levels for performance targets and measures. This matches with the requirement that a SPMMS needs to be adaptable to different organisational structures. In this category, the SPMM model for collaborative networks is also the only one that meets this requirement. Once again, the Tableau de Bord and BSC can probably be adapted to different organisational structures, but lack a process to do so.

The importance of periodical updates is also acknowledged by and part of all of the reviewed SPMMS. This suggests this aspect can be successfully incorporated into a SPMMS and hence needs to be included in the definition of the SPMMS process in Section 3.6.

However, most reviewed SPMMS are based on the assumption that the definition of what performance consists of and what is to be targeted primarily is homogenous throughout the company. Yet, as Section 2.1 pointed out, different foci of performance might be necessary in a manufacturing network (e.g., one manufacturing site may be a pro-longed workbench and mainly focused on costs while another site serves as a development centre and has the overall target to develop and launch new products; or different regions may require different product specifications, e.g., Europe requires a high-tech and high-quality product whereas Africa requires cheap and low-tech products). Only the Tableau de Bord (TdB) and the PMM model for collaborative networks meet this requirement. While the TdB in theory allows different performance foci, it does not explicitly state how theses foci can be developed and identified. The PMM model for collaborative networks allows the setting of different foci based on the contribution of the different entities involved in the collaborative network. In summary, the flexibility to implement different performance foci into a SPMMS is possible and should be supported process-based while identifying the desired contribution of the entities to be evaluated.

Only the BSC, the EFQM Excellence Model and the Performance Prism meet the requirements that demand the inclusion of performance measures that focus on improvement and change projects. The BSC incorporates the aspect of initiatives in all performance dimensions and has a performance dimension that explicitly addresses organisational growth and learning. The EFQM Excellence Model addresses this aspect through the use of its RADAR-logic. The Performance Prism takes a more refined approach. Here, the change and improvement of an organisation is monitored by asking which capabilities are necessary to fulfil strategies, and by deriving performance measures that measure the build-up of those capabilities.

As none of the SPMMS described above uses the concept of site roles, or a similar concept for that matter, to define performance targets it is also clear why structural and infrastructural differences between entities are not incorporated into performance evaluation. By defining site roles and a site mission, structural and infrastructural levers are set too, resulting in differences in site set-up and capabilities. Most SPMMS simply assume that all different entities are equal in their set-up. As Section 2.1 pointed out, this, however, is rarely the case in manufacturing networks. Only the TdB and the Performance Measurement and Management model for collaborative networks somewhat address differences in structure and infrastructure of entities. The TdB does so by acknowledging a variable block of performance targets and dimensions that can be set individually for all entities and the model of Pekkola (2013) simply uses evaluation of entities based on their contribution.

Finally, the EFQM Excellence Model and the Performance Prism are also the only SPMMS to take a comprehensive approach to stakeholder satisfaction. By explicitly asking what different stakeholder groups want and need to contribute, a satisfactory overall performance is ensured. This is also backed by performance measures and improvement or change measures.

In summary, none of the existing SPMMS fully meet the requirements of manufacturing networks. However, some SPMMS have aspects that can be interesting in defining an SPMMS for manufacturing networks. Specifically, the Performance Prism with its comprehensive stakeholder focus and the Performance Measurement and Management model for collaborative networks with its flexibility and pre-definition phases appear useful in the context of manufacturing networks.

3.4 Evaluation Criteria for Scientific Models

The literature holds numerous lists of evaluation criteria to determine “good” scientific models. Friedli (2000) condenses findings of Fox *et al.* (1993), Vernadat (1996), Weston

(1999) and the ISO/DIS 15704 (ISO, 1999) into a list of six main evaluation criteria for architecture models in inter-company cooperations. While various other fields have developed their own lists of criteria, they can all be linked directly to Friedli's (2000) list (cf. Mundt, 2012). Since the work of Friedli (2000) also addresses networks and more recent work has not significantly added to his list, Friedli's list will serve as a basis for the evaluation of the SPMMS to be developed, amended to focus on performance measurement based on the list of Medori and Steeple (2000). Both lists have been slightly adapted to suit this thesis. A model for manufacturing networks in general should fulfil the following criteria:

- **Holism (Friedli, 2000):** The developed model should be complete and consistent and it should be applicable to all manufacturing networks.
- **Competency (Friedli, 2000):** The model should be able to identify the main object and mission and the (process) structure of the manufacturing network.
- **Efficacy (Friedli, 2000):** Terms and definitions should be clearly defined. The transformation and application of the model to different and more specific applications should be possible.
- **Reusability (Friedli, 2000):** The model should be reusable and applicable to different contexts, modularity, scalability, extendibility, separation of functionality and behaviour and accuracy.
- **Conformity (Friedli, 2000):** The model should be adjustable to evolutionary developments within a manufacturing network over time.
- **Reducing overall complexity (Friedli, 2000):** The model should be designed to reduce the overall complexity of manufacturing networks and allow discussion of its application on different levels of aggregation.

A SPMMS for manufacturing network should include:

- **Selection of Measures (Medori and Steeple, 2000):** The model should support the actual selection of measures
- **Implementation of Measures (Medori and Steeple, 2000):** The model should support the implementation of measures
- **Audit Capability (Medori and Steeple, 2000):** The model should effectively evaluate if the existing measurement system is sufficient, and identify adequate adjustments
- **Strategy Congruency (Medori and Steeple, 2000):** The identified measures should be congruent with the strategy

- **Databank of Measures (Medori and Steeple, 2000):** A list of measures in the relevant performance dimensions should be available for the quick selection of measures
- **Workbook Approach (Medori and Steeple, 2000):** The model should be easy to use and provide step-by-step instructions.

The list of requirements towards SPMMS from a manufacturing network perspective combined with the general evaluation criteria towards models by Friedli (2000) and the list of criteria for SPMMS by Medori and Steeple (2000) is now complete. This list of criteria will be used to evaluate the developed framework in Section 5.1.

3.5 Defining the Structural Framework

This section aims at defining the structural framework for the SPMMS for manufacturing networks. A structural framework provides the dimensions for the definition of performance targets and performance measures to monitor the achievement of the targets. For example, the structural framework of the BSC contains four dimensions (cf. Subsection 2.2.5). Performance objectives, measures, targets and initiatives in all these dimensions can and should be defined (based on the logic of the BSC). A similar structure for strategic performance in manufacturing networks will be defined in this section.

3.5.1 Basic Performance Dimensions for Manufacturing Networks

Both previous findings as well as insights from this thesis suggest that strategic performance dimensions, objectives and targets are to be derived from strategy (cf. Section 2.2). As pointed out in Sections 1.2 and 2.2, strategic performance can be described as the degree to which a strategy has been fulfilled. Therefore, strategic performance dimensions for manufacturing networks need to be derived from manufacturing strategy. As discussed in Subsection 2.1.4, manufacturing strategy for manufacturing networks contains four main dimensions:

- Network Capabilities
- Manufacturing Capabilities
- Structural Manufacturing Levers
- Infrastructural Manufacturing Levers

The Network Capabilities describe how a manufacturing network's different capabilities can be utilised to gain a competitive advantage on a network level. Evaluating a manufacturing network based on a predefined strategy and focus along the network capabilities and comparing it to set targets will therefore identify how a manufacturing network is performing in these dimensions.

The Manufacturing Capabilities describe how a manufacturing line, site or an entire network can be utilised to gain a competitive advantage based on various production outputs. Evaluating a manufacturing line, site or network based on a predefined strategy and focus along the manufacturing capabilities and comparing it to set targets will therefore identify how a manufacturing line, site or network is performing in these dimensions.

These two main dimensions, network and manufacturing capabilities, are determined by an existing manufacturing structure and infrastructure. According to the EFQM Excellence Model, performance in these main dimensions would be located in the "results" section. If aspired targets in these main dimensions cannot be met, the manufacturing structure and infrastructure need to be adjusted. Therefore, the manufacturing structure and infrastructure need to be evaluated as well. As pointed out in Section 2.1, the better part of manufacturing strategy actually consists of aspects targeting manufacturing structure and infrastructure. Being part of a manufacturing strategy, the performance of structure and infrastructure and the fulfilment of adjustments to the structure and infrastructure thus need to be considered when evaluating the strategic performance of a manufacturing network (cf. Subsection 2.1.5). A manufacturing network, site or line therefore performs well on an infrastructural or structural level when the targets in these categories are met. As Subsection 3.5.3 will show, targets in these dimensions can be quantitative and refer to a specific performance measure (e.g., lower inventory levels by 3 %), the adherence to certain standards or principles (e.g., Kanban system is fully implemented) or compliance with a certain action plan or change measure (e.g., new production line fully implemented by October 2014).

3.5.2 Expansion of Performance Understanding

The target of the SPMMS to be developed in this thesis is to provide a holistic perspective on strategic performance of manufacturing network. The different aspects of manufacturing strategy are completely included in the four main performance dimensions described above. However, section 2.2 identified the need for SPMMS to be broader and incorporate the perspective and needs of various stakeholders. This is also described in the requirements for SPMMS in manufacturing networks in subsection 3.2. Therefore, the SPMMS developed here needs to incorporate the interaction with various stakeholders as performance dimensions. As section 3.3 illustrates, this is fulfilled by the

EFQM Excellence Model and the Performance Prism. In the Performance Prism five stakeholder groups are addressed:

- Investors
- Customers & Intermediaries
- Employees
- Regulators & Communities
- Suppliers

The perspectives of those five stakeholders are also incorporated in the EFQM Excellence Model although different terminologies are used[20]. For the development of the SPMMS for manufacturing networks a fifth main dimension will therefore be added that addresses the perspective of the different stakeholder groups.

3.5.3 Defining Performance Dimensions for Manufacturing Networks

The list of the five stakeholders above is complete[21] for manufacturing networks. While the main performance dimensions of structural and infrastructural levers as described in Subsection 2.1.4 include employees and suppliers, it makes sense from a performance measurement perspective to include them in a performance block addressing overall stakeholder interaction instead. This highlights the importance of employees and suppliers and prevents from misunderstanding employees and suppliers as assets that can easily be discarded. Generally, the five stakeholder groups can be divided into those that provide an input for manufacturing (employees and suppliers) and those that evaluate the manufacturing activities and the manufacturing output (investors, customers & intermediaries and regulators & communities). Figure 22 visualises the complete list of performance dimensions.

The performance dimensions listed in Figure 22 reflect the different strategic aspects that can be addressed in the context of a strategy for manufacturing networks. By addressing

[20] Investor demands are incorporated in „key performance results“, customers have their own category, employees are addressed in the “people” category, regulators & communities fall into “society” results and suppliers can be found under “partnerships and resources”.

[21] The completeness is based on the list of stakeholders from the performance prism and the EFQM Excellence Model. Other works provide lists of stakeholders that can essentially be condensed to the five stakeholder groups described above. For example, an especially comprehensive management model that incorporates a wide array of stakeholders is the New St.Gallen Management Model (see Rüegg-Stürm (2005); Dubs *et al.* (2009)). The stakeholders mentioned there are essentially those described in this thesis with the addition of “competitors”. However, the stakeholder group of “competitors” is not added to the list above because a company does not directly interact with competitors and the requirements and needs of competitors are not relevant to derive targets for a manufacturing network.

any of the performance dimensions in a strategy formulation process, a desirable outcome (target) is defined and this target can be used for the evaluation of an existing manufacturing network. Figure 22 also arranges the different performance dimensions hierarchically. The different main performance dimensions are interconnected. This interconnection is addressed by the arrows and guiding questions in Figure 22.

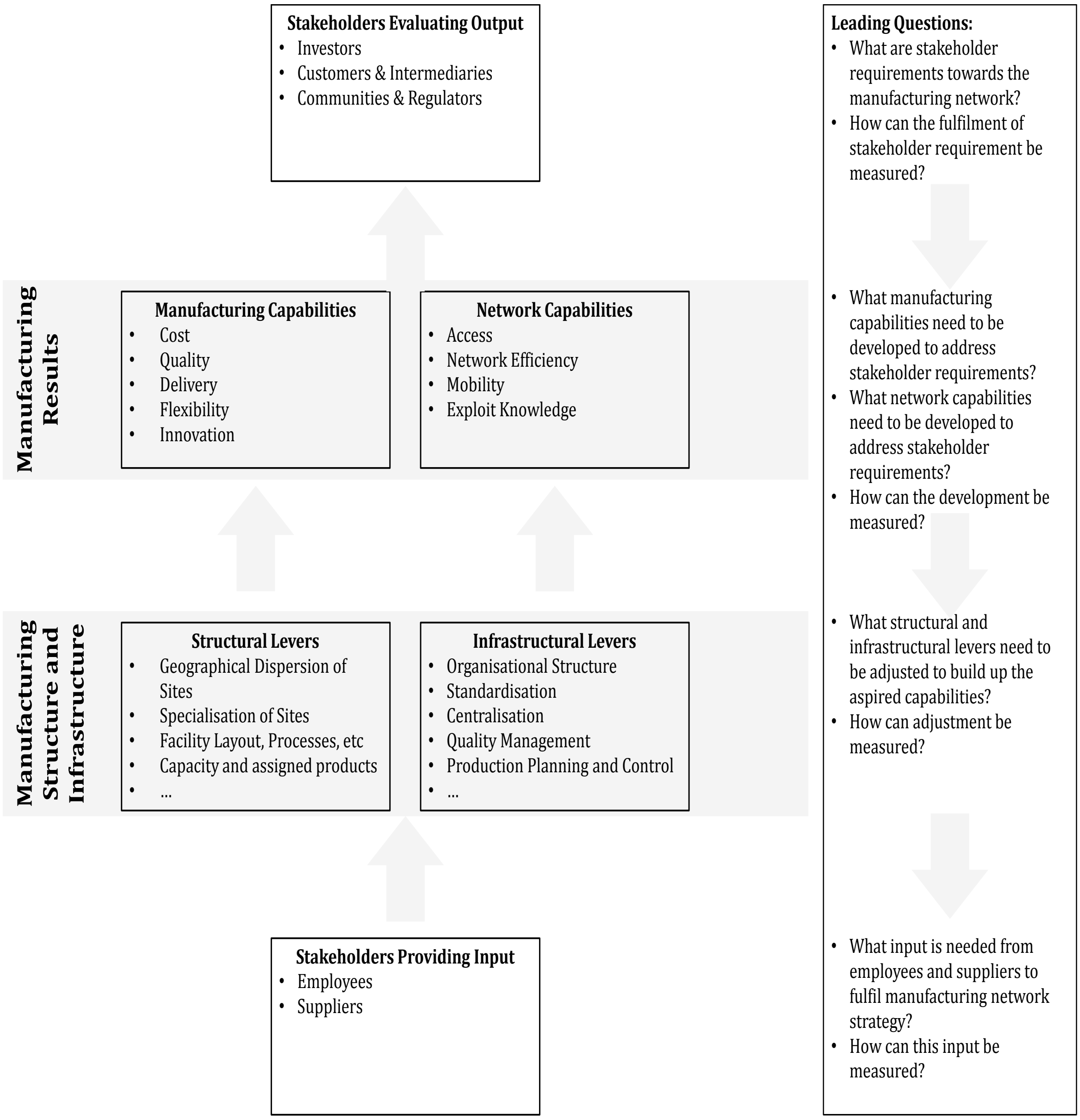

Figure 22 – Performance Dimensions for Manufacturing Networks

A general finding of performance measurement literature (cf. Section 2.2) is that, overall, a company performs well when stakeholder wants and needs are met. The three stakeholder groups that evaluate the output of a company and hence manufacturing network are investors, customers & intermediaries and communities & regulators. If the wants and needs of these stakeholder groups are not met, a product will not perform well in the market and thus a manufacturing network does not fulfil its function. The wants and needs of these three stakeholder groups need to be collected and translated into a) aspired manufacturing results and b) a desired manufacturing structure and infrastructure. The latter might not be fully possible straight away (e.g., customers and intermediaries will not explicitly specify wants and needs regarding internal logistics in manufacturing). However, explicitly specified wants and needs need to be translated into internal implications for manufacturing results and structure and infrastructure. Furthermore, if suppliers and employees are not satisfied, their input might also be faulty and thus may be detrimental to the overall performance of the manufacturing network.

Manufacturing results are the performance dimensions a manufacturing network can perform in as an output. By being set-up in a certain way, a manufacturing network is somewhat cost-efficient, flexible, provides a certain access to markets etc. If a manufacturing strategy determines a change in the way a given manufacturing network needs to perform on the result level, this also makes a change in the manufacturing structure and infrastructure necessary. Implementing that change is again a type of performance as it reflects the fulfilment of a strategic change in manufacturing structure and infrastructure.

On the bottom of Figure 22, two stakeholder groups can be found that provide an input to manufacturing. The fact that these stakeholders are positioned at the bottom is not telling regarding their importance for the manufacturing network. Instead, their position is determined by their position in the value chain. In contrast to the stakeholder groups at the top, the target here is not to fulfil all wants and needs but to identify what these stakeholders themselves need to provide and what they need to receive from the manufacturing network to fulfil their task. Additionally, some strategic results of a manufacturing network depend on the input of suppliers and employees[22]. The SPMMS can therefore be used to evaluate if the suppliers are able to adhere to these aspired results and if not, adequate corrective actions can be taken.

It has to be noted at this point that not all strategic performance dimension in the structural framework have to be addressed at all times when applied in practice. Instead, only those strategic performance dimensions relevant to the manufacturing strategy should be addressed. The structural framework then is complete and holistic as it includes all possible aspects of manufacturing strategy.

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[22] e.g. if a Just-in-time system with low inventories is desired in the manufacturing network, suppliers need to be reliable enough to lower inventories

3.5.4 Levels in Manufacturing Networks and connected Performance Dimensions

As defined in Sections 1.2 and 2.1, the manufacturing function of a company contains one or many manufacturing sites which are organised in one or more manufacturing networks depending on a company's set-up. A manufacturing site can contain multiple production lines. A manufacturing strategy and thus strategic targets can be set at any level of this hierarchy. For this thesis, only the manufacturing network level and the level of manufacturing sites contained within the network are relevant. The process for an SPMMS which will be described in Section 3.6 will cover the topic of interconnection between manufacturing network level strategy and targets and manufacturing site level strategy and targets. However, we also need to address whether the performance dimensions for manufacturing networks in Figure 22 are fully applicable to manufacturing sites.

Looking at the performance dimensions in Figure 22, it is evident that the presented stakeholders are the same for manufacturing networks and manufacturing sites. Therefore, these can be directly transferred to the model for manufacturing sites. However, there are differences between manufacturing networks and manufacturing sites on a result level. While the manufacturing capabilities can also be applied to single sites, the network capabilities apply per definition to manufacturing networks as a whole. Yet, as described in Section 2.1, the overall network capabilities are realised by the sum of all manufacturing sites and their roles and connected contributions. Thus, it needs to be determined which sub-dimensions of the manufacturing network capabilities manufacturing sites can actively support.

To address this question, a workshop with manufacturing executives[23] from the cable company[24] was conducted. In this workshop, the different network capabilities were discussed and it was decided if manufacturing sites can actively contribute and, if so, what exemplary performance measures are. The results of this workshop are listed in Table 18. The capabilities that are not applicable as performance dimensions to a manufacturing site are:

[23] Participants were: Head of global manufacturing, two site heads and a project manager for global manufacturing

[24] Further and detailed description of the cable company can be found in the corresponding case study in section 4.1.

- **Provide access to markets/customers**: This network capability is fulfilled by the sum of site locations in the network. A manufacturing site itself cannot change its location. Therefore, this capability cannot be used as a performance dimension for manufacturing sites.
- **Provide access to competitors**: This network capability is fulfilled by the sum of site locations in the network. A manufacturing site itself cannot change its location. Therefore, this capability cannot be used as a performance dimension for manufacturing sites.
- **Provide access to image:** This network capability is fulfilled by the location of a single site in the network (e.g., a site is located in Switzerland, therefore “made in Switzerland” can be used as an image factor). A manufacturing site itself cannot change its location. Therefore this capability cannot be used as a performance dimension for manufacturing sites.
- **Increase efficiency by…**: All three efficiency dimensions are focused on a network level. This means that certain manufacturing and support activities are either centralised or decentralised in a network. Changing this can be supported by manufacturing sites (e.g., through the relocation of a manufacturing line from one site to another) but this change and the according action plan would fall under the “structure and infrastructure” section of a manufacturing site.

Strategic Network Performance			**Performance Measure Examples for Manufacturing Sites**		
Network Capabilities		Applicable to Site Level?	Example A	Example B	Example C
Provide Access to	Markets/Customers	**No**	n/a	n/a	n/a
	Competitors	**No**	n/a	n/a	n/a
	Socio-political Factors	**Yes**	Volume of subsidies acquired	Financial volume saved through hedging strategies	…
	Image	**No**	n/a	n/a	n/a
	Suppliers/Raw Material	**Yes**	Share of multiply sourced critical components	Amount of long-term contracts with critical suppliers	Delivery reliability of critical suppliers
	Best Cost Labour	**Yes**	Total labour costs	Share of low cost employees	Share of low cost employees
	Skilled Labour	**Yes**	Share of skilled employees	Money spent on employee training	…

Strategic Network Performance			**Performance Measure Examples for Manufacturing Sites**		
Network Capabilities		Applicable to Site Level?	Example A	Example B	Example C
	External Know-How	**Yes**	Number of co-operations with external partners	Applicable results from cooperation projects	Amount of partnerships formed
Increase Efficiency by	Economies of Scale	**No**	n/a	n/a	n/a
	Economies of Scope	**No**	n/a	n/a	n/a
	Reduction of Duplication	**No**	n/a	n/a	n/a
Provide Mobility of	Products, Processes and Personnel	**Yes**	Staff involved in intra-company exchange	Amount of staff with sufficient knowledge of English/education	Time needed to transfer products/processes
	Production Volume and Orders	**Yes**	Capacity available for intra-company order transfer	Volume and orders taken over from other sites	…
Explore and Exploit Know-How and Innovation about	External Factors	**Yes**	Contribution to corporate knowledge regarding external factors	Participation in Know-How exchange meetings	…
	Internal Factors	**Yes**	Contribution to corporate knowledge regarding internal factors	Implementation of best practices	…

Table 18 – Translation of Network Capabilities to Site Level and Exemplary Performance Measures on Site Level

The overview in Table 18 illustrates that only certain network capabilities can be translated into contributions on a site level. Therefore, if targets and objectives can be set on a site level, the contribution to network capabilities can serve as a performance dimension for manufacturing sites.

The last block of performance dimensions in Figure 22 that needs to be evaluated regarding the applicability to manufacturing sites is the manufacturing structure and infrastructure. As pointed out in Subsection 2.1.4, many different aspects are part of the manufacturing structure and infrastructure. Some of these aspects can only be sensibly discussed on a network level (e.g., the geographic dispersion of sites and the specialisation of the network) while others can be directly influenced by manufacturing sites and can, depending on the organisation and degree of freedom of manufacturing sites within the network, also be used as performance dimensions. Figure 23 depicts the resulting overview of performance dimension for manufacturing sites.

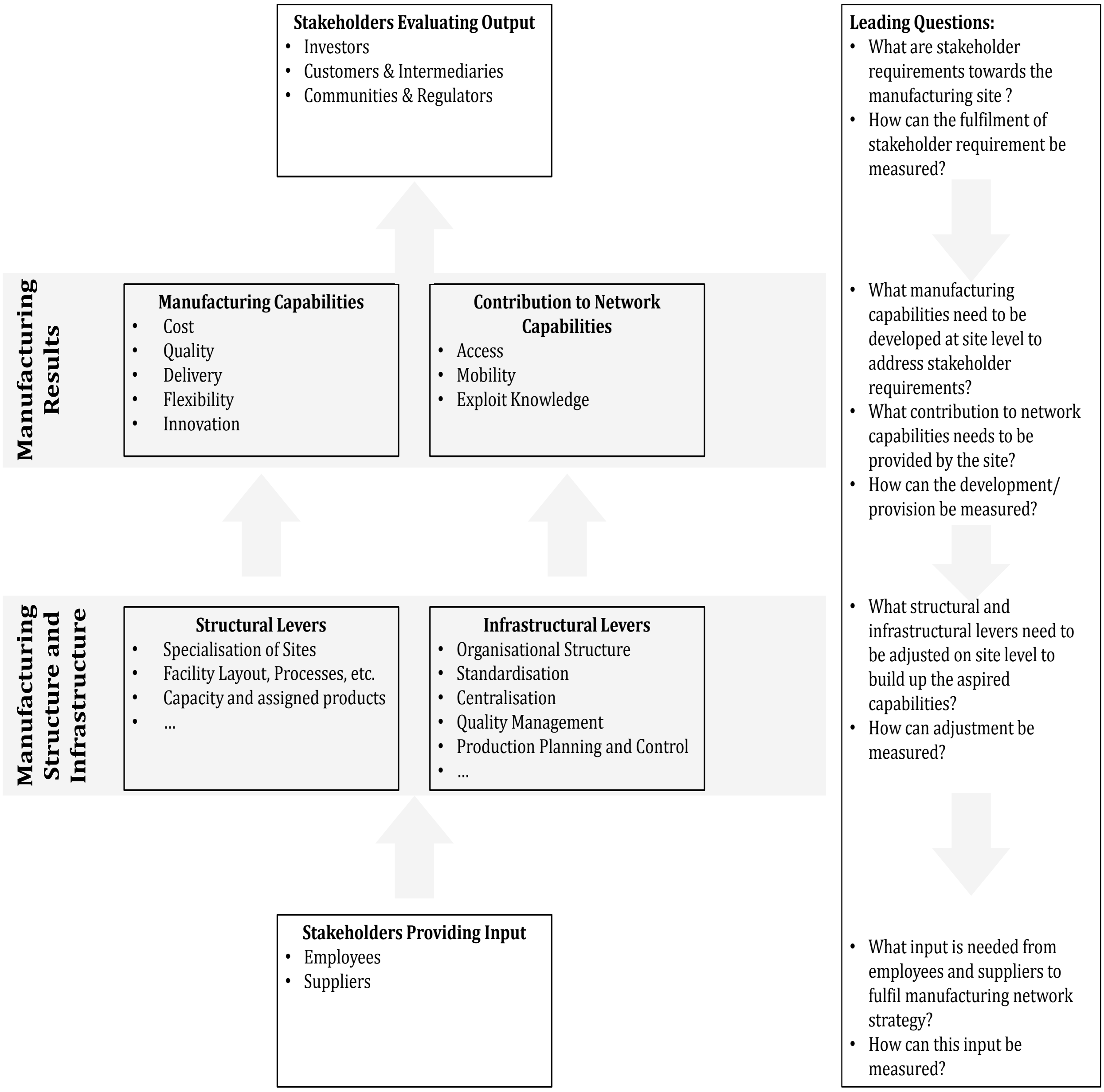

Figure 23 - Performance Dimensions for Manufacturing Sites

In conclusion, performance dimensions for manufacturing sites are closely connected to those of manufacturing networks. This is not surprising as a manufacturing strategy addresses both levels and its content does not change between those levels.

3.5.5 Applying the Model

The following case study will illustrate the overviews presented in Figure 22 and Figure 23 and clarify the underlying logic and interconnection between the performance dimensions. However, it is a basic case study that does not cover a manufacturing network but rather a single-site manufacturing company. This is to highlight the logic between the different performance dimensions while using a simple company as an example that does not have multiple sites with different strategies and performance targets. Therefore, the performance dimension “network capabilities” will not be addressed in this case study.

The **Pharmaceutical Packaging Company (PPC)** is a Swiss, privately owned SME that is a contract packager for pharmaceutical companies. Its main market is Switzerland. It packages a variety of pharmaceutical products, from blisters to bottles and powders. 70 % of the PPC’s revenue is made from its top 10 customers. Based on an internal strategy process, the following strategic objectives and action plans for its manufacturing function were developed along the performance dimensions for manufacturing:

Currently, the main stakeholders place the following demands on the production of the PPC:

Investors: The PPC has been privately owned by the same family since its founding days. The family wants the PPC to increase its revenue sustainably and increase its market share slowly. The vision of the PPC is to be the technology leader in the pharmaceutical packaging market. At the same time, the company aims at being more efficient. To meet the targets of its investors, the PPC manufacturing thus has to build up competences and capacities in the most important technologies and increase production cost efficiency.

Customers & Intermediaries: The customers face different challenges that they pass on to the PPC. Firstly, an increasing amount of their products are victims of counterfeit attempts. Therefore, packaging needs to incorporate protection against counterfeit. Secondly, an increasing amount of medication is administered in parenteral form which needs to be addressed by the packaging capabilities of PPC. Finally, the business with blockbuster drugs is not as dominant as it used to be. Orders size is therefore smaller than in the past and PPCs packaging needs to be more flexible.

Communities & Regulators: In the pharmaceutical industries, regulators are highly important. Without approval of the main regulators, the PPC will not get any orders. The PPC’s production therefore needs to improve and adhere to the standards set by regulators such as the FDA. Additionally, new regulators from emerging markets become increasingly important and the PPC needs to get production approval by those regulators as well.

These requirements can be translated into an aspired set of capabilities and directions of improvement in the manufacturing capabilities.

Manufacturing Capabilities: The management of the PPC reviewed the manufacturing capabilities and agreed that the main areas of improvement lie in the fulfilment of quality superiority and conformance. In order to be certified by various regulators, processes need to be stable on a high quality level. Additionally, delivery reliability needs to be increased. Furthermore, the PPC wants to become more cost efficient.

The demands and targets can further be translated into action plans addressing the manufacturing structure and infrastructure:

Manufacturing structure and infrastructure: The following action plans are implemented to build up the desired manufacturing capabilities and fulfil stakeholder requirements:

1. Value-Stream-Mapping and identification of improvement potential regarding cost savings and increase of flexibility by the end of the year.

2. Reach "FDA-Readiness" and readiness for other regulators by mid next year.

3. Implement new technologies addressing the counterfeit protection and the increase of parenteral medication by mid next year.

Finally, requirements and measures addressing employees and suppliers can be formulated:

Employees: Since employees are a major cost factor, the overall employee utilisation has to be increased. Furthermore, a new packaging specialist has to be hired in order to increase competence regarding the new technologies which will be implemented. Both action plans should be realised by the end of the year.

Suppliers: In order to maintain a high delivery reliability and high quality superiority and conformance, the PPC will increase supplier monitoring in these categories and force suppliers to adhere to new performance levels in these categories.

All the above defined strategic objectives and strategic action plans can be monitored using process-based performance measures and project-based mile stones. By achieving the defined strategic objectives and strategic action plans the manufacturing strategy is fulfilled. Thus the manufacturing of the PPC performs.

This case study has illustrated how the demands of stakeholders are used to define a manufacturing strategy along aspired manufacturing capabilities and action plans. Additionally, strategic objectives addressing the stakeholders that provide an input to manufacturing have been derived. The case study has illustrated how the different main performance dimensions are interconnected and how stakeholder satisfaction at the top relies on objectives and action plans applied to the other performance dimensions. By fulfilling all strategic objectives and action plans, strategy is fulfilled and manufacturing performs on a strategic level.

3.5.6 Summary

This section developed a structural framework for manufacturing networks. The included performance dimensions are complete for manufacturing networks and are based on a) the content of manufacturing strategy and b) the perspectives of stakeholders surrounding a manufacturing network in general. The completeness is also supported by the findings of Subsection 2.2.4 since all identified performance dimensions in Table 15 can be assigned to those included in the models in Figure 22 and Figure 23.

The structural framework classifies performance dimensions for manufacturing networks into four internal main performance dimensions and the stakeholders that surround a manufacturing network. While the manufacturing network management has the means to take direct action with regards to internal performance dimensions, the situation is somewhat different when it comes to stakeholder performance dimensions. Performing well with the stakeholders means satisfying and managing both the demands different stakeholders place on the manufacturing network as well as the demands the manufacturing network places on its stakeholders. The stakeholder groups and their demands and contributions are therefore used to answer the question what a given manufacturing network has to fulfil in order to be successful. The aspects that need to be fulfilled can be described using the performance dimension listed as “manufacturing results”. The aspired manufacturing results are then used to derive performance objectives and action plans addressing structural and infrastructural levers of manufacturing. The final question then is what inputs are required from employees and suppliers to fulfil the aspired manufacturing results and fulfil stakeholder demands.

While the structural framework (Figure 22) is targeted at the manufacturing network, this section has shown that the objectives and action plans can also be translated to manufacturing sites using a slightly adapted version of the structural framework (Figure 23). This is important for the structural framework’s practical application through a procedural framework as defined in Section 3.6. Finally, this subsection has illustrated how the structural framework can be applied to a simple case example and what strategic performance actually means regarding the different dimensions.

By providing a structural framework for SPMMS, including the performance dimensions for manufacturing networks and sites, this section has answered research sub-question 2. Furthermore, this section has addressed several requirements of SPMMS for manufacturing networks as defined in Section 3.2. The structural framework focuses on manufacturing strategy and its fulfilment (R 1) and is applicable to manufacturing site and network level (R 2). By incorporating the manufacturing structure and infrastructure as performance dimensions, the structural framework can also include performance measures addressing change and improvement measures (R 5, R 6). Finally, it takes a holistic manufacturing perspective (R 12) and thus also addresses stakeholder interaction (R 11) and non-financial performance dimensions and measures (R 10).

3.5.7 Measurement and Evaluation of Objectives and Targets

As pointed out in the introduction, performance in manufacturing networks is often seen from an operational and manufacturing process-based or financial perspective only (cf. Chapters 1 and 2). In a 2005 study[25], the Institute of Technology Management asked international manufacturing companies what their top performance measures for the steering and performance evaluation of their manufacturing sites were. 65 % of the 35 companies that reported their performance measures solely used financial performance measures (such as EBITDA, EBIT etc.) to evaluate manufacturing site performance. The remaining 35 % relied mainly on financial measures but also used measures addressing productivity, capacity utilisation, quality and delivery. Only one company included performance measures that focussed on employees. This shows that the reviewed companies lacked holistic strategic performance targets for their manufacturing sites and thus did not make use of the full potential of their strategic performance measurement and management system.

This is in stark contrast to the content of manufacturing strategy identified in Section 2.1 and the dimensions of strategic manufacturing performance defined in this section. As a result, target setting and steering of manufacturing sites in a manufacturing network is seldom holistic and lopsided towards financial targets. Although it has been 10 years since this study was conducted, there is evidence to suggest that strategic performance measurement has not changed much since then. Financial and operational process-based performance measures are still preferred for performance evaluation, as they are easy to collect and handle. Additionally, it is easy to define targets for these measures. Financial results, quality, productivity, delivery performance and capacity utilisation always should be “high”. Interviews, discussions and workshops with manufacturing managers reveal that they are very concerned about the measurement of different strategic objectives in terms of quantitative performance measures. This focus on quantitative

[25] The project title was “Internationalising the value chain successfully” (VELA) it was conducted in cooperation with the Werkzeugmaschinenlabor WZL and the Chair of International Management at the RWTH Aachen University. Overall 48 companies replied, 35 reported their most important performance measures.

measure then leads to the avoidance of alternative and more extensive approaches to strategic performance measurement and management.

To close this gap and utilize the full potential of a holistic strategic performance measurement and management system, this thesis calls for a broader approach to strategic performance target definition and evaluation in manufacturing networks in accordance with the Matrix developed by Melnyk *et al.* (2013) which is covered in Subsection 2.2.2. Manufacturing managers should not only rely on traditional financial and process-based measures but be open to qualitative measures and assessment-based approaches to define strategic targets and evaluate strategic performance. In the context of manufacturing networks this is an important addition to traditional approaches in SPMMS, as it allows the complexity of global manufacturing networks and their environment to be accommodated for.

Importantly, this thesis does not call for the elimination of operational, process-based performance measures from strategic performance measurement system. Instead, the necessity to focus on manufacturing aspects of strategic importance - which are seldom solely operational - is emphasized. In conclusion: Any operational performance measure can be part of a strategic performance measurement system if its strategic importance is given but no operational performance measure is automatically to be included in a SPMMS.

3.6 Defining the Procedural Framework

Subsection 2.2.4 provided several lists of guidelines and suggestions for PMMS in general, and for PMMS processes in particular. As this thesis aims to develop a strategic PMMS and the structural and procedural framework the SPMMS consists of, one requirement is especially important: A SPMMS process should be linked to the strategy development process in a way that performance measures and objectives are co-created with strategy (Pun and White, 2005; Melnyk *et al.*, 2013).

Subsection 2.1.6 provided a summary of the findings on manufacturing strategy content and formulation, which introduced an extended manufacturing strategy process that combined the perspectives of several relevant authors in the field. Similarly, Subsection 2.2.3 provided a consolidated procedural framework for PMMS. This section merges the findings from manufacturing strategy formulation and procedural aspects of PMMS to create the aspired procedural framework for an SPMMS in manufacturing networks and answer sub-question 3. Figure 24 depicts the overall procedural framework for SPMMS in manufacturing networks. The procedural framework differs from the consolidated PMMS process as described in Subsection 2.2.3 based on findings from manufacturing strategy formulation processes. The procedural framework will be described step-by-step in the following.

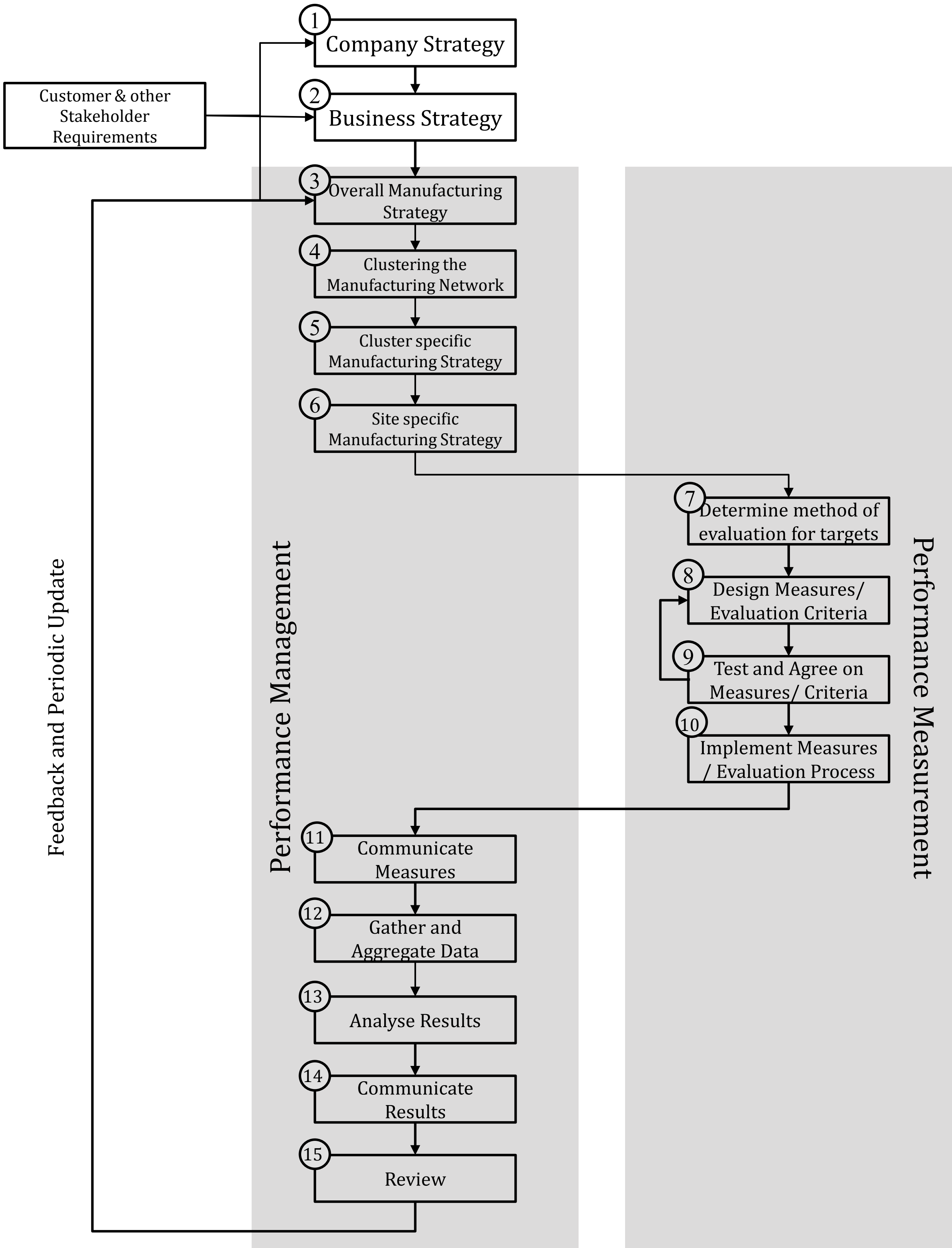

Figure 24 – Procedural Framework for SPMMS in Manufacturing Networks

Steps 1 and 2 comprise the formulation of a company and business strategy. Business strategy is derived from company strategy. While these two steps provide an important and necessary contribution to defining a manufacturing strategy, they are not part of a SPMMS for manufacturing networks. This is due to the fact that company and business strategy are often defined on a higher hierarchical level than manufacturing strategy, outside the manufacturing function. While the manufacturing function might be involved in the definition process of business and company strategy, manufacturing strategy is not the basis for the overall company or business strategy. Instead, the relation is the other way around. In companies that do not have separate business units, step 2 is not necessary. One difference to the overall PMMS process described in Subsection 2.2.3 is that customer and other stakeholder requirements enter the process at different levels. The reason for this is that the different levels might vary in both stakeholders themselves as well as stakeholder demands.

Step 3 then defines an overall manufacturing strategy that covers the entire manufacturing function. In this model, the overall manufacturing strategy refers to the manufacturing strategy of a single business unit within a company. It is defined based on the manufacturing strategy formulation process in Subsection 2.1.6. Step 3, as well as steps 4 to 6, represents a new addition to traditional PMMS processes. The manufacturing strategy describes how the manufacturing function supports the fulfilment of business and company strategy by developing a competitive advantage through the development and utilisation of manufacturing capabilities and network capabilities. However, depending on how a manufacturing company is organised, it might be difficult to formulate an overall manufacturing strategy. For example, companies may be organised in such a way that the manufacturing activities of different business units are interwoven at identical manufacturing sites; the definition of an overall manufacturing strategy across business units might then be difficult as stakeholder demands and the aspired manufacturing and network capabilities might differ. In such a case, it is important to focus on commonalities between the business strategies and derive a common manufacturing strategy. Often, the manufacturing activities of different business units are combined to keep the investments for manufacturing low. While this in itself is a reasonable approach, it hinders the establishment of focused factories as described by Skinner (1974).

With the overall manufacturing strategy for a manufacturing function defined, step 4 clusters the manufacturing network. This step is optional and should be applied to companies with very heterogeneous manufacturing activities. As Section 2.1 showed, manufacturing networks can be organised very differently. This step thus aims at understanding the organisation and dividing the manufacturing sites in homogeneous clusters that allow the breaking down and refinement of the overall manufacturing strategy to a cluster-specific strategy (step 5). For example, a company might have global manufacturing activities that are organised in autonomously operating, regional, market-focused networks. In this case the overall manufacturing strategy has to be broken down to those regional networks, incorporating the regional specificities. Another example would be a company that produces two different product groups in separate global networks. In that case, the overall manufacturing activities would be clustered in those two networks.

Step 5 defines and derives cluster-specific manufacturing strategies. The strategies are based on the overall manufacturing strategy and incorporate the specificities of the clusters defined in step 4. The procedural framework described in Subsection 2.2.6 is a highly valuable support in breaking down the overall manufacturing strategy to the clusters. It allows the challenging of strategic assumptions for the overall manufacturing function and the detailed derivation of targets, principles and action plans for the cluster. If a clustering of the manufacturing function was not necessary, this step only details the manufacturing strategy on a network level along the performance dimension in the structural framework.

Step 6 of the procedural frameworks derives site-specific manufacturing strategies from the cluster-specific or overall manufacturing strategy. To do so, the structural framework and its performance dimensions for manufacturing sites should be used. In this step, the cluster-specific strategy is broken down to the manufacturing sites included in the respective cluster. The sites receive site-specific strategies that take into account their respective site roles and their structural and infrastructural differences. The goal of this step is to have an overall manufacturing strategy that translates to the cluster and site level. The strategy at every level is logically connected and targets, principles and action plans are interconnected across the different levels (e.g., if the manufacturing network is supposed to reduce inventories by 5 %, the sum of all inventory reductions at site level adds up to the 5 % on network level). Figure 25 depicts this connection between the different levels and the downward translation of performance dimensions. The four exemplary performance dimensions and connected targets, action plans and principles are translated into two manufacturing clusters. Not all performance dimensions are relevant for all clusters in this translation process, which is indicated by the dotted frame around the performance dimension. A similar downward translation is conducted to the manufacturing sites in the different clusters. As Section 2.1 pointed out, not all performance targets on network levels translate to site level. Additionally, specialised targets that apply to a single site or cluster can emerge at levels that are not directly covered in the level above. The fulfilment of manufacturing strategy is measured at site level and aggregated to the top.

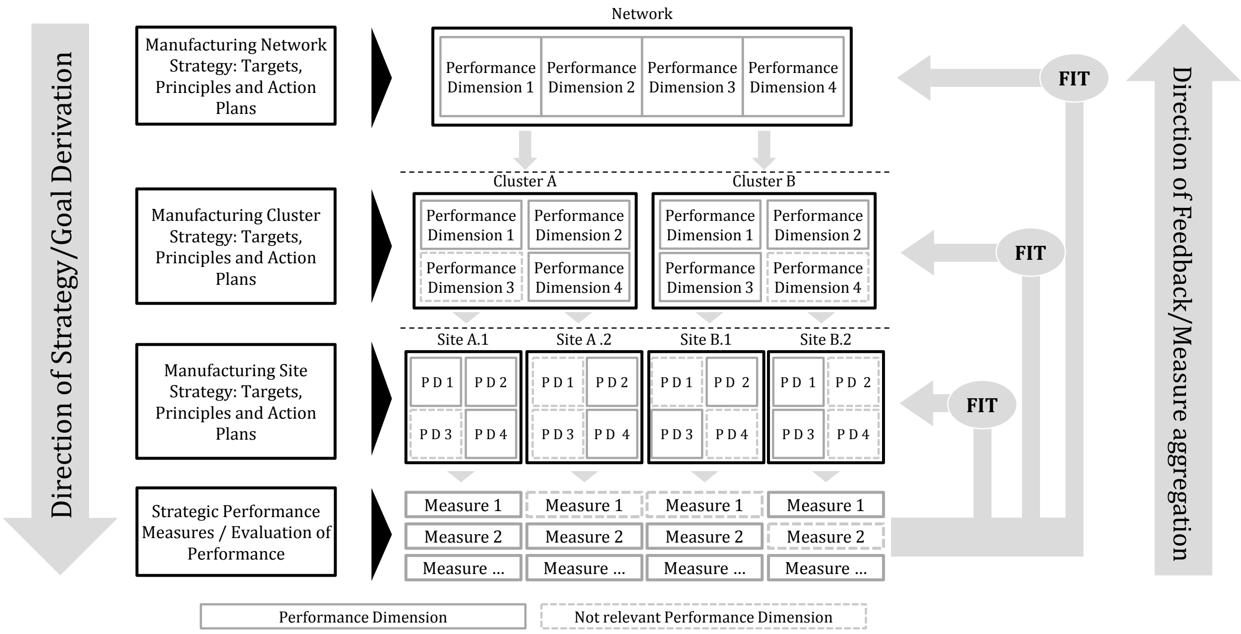

Figure 25 – From Manufacturing Network Strategy to Site Level Performance Measures

As described earlier, steps 3 to 6 constitute new additions to the procedural frameworks for manufacturing networks. They are introduced to tackle the common problem of diversity in manufacturing networks. Most companies struggle to develop unified strategic performance targets and measures across their manufacturing network because the network and strategic external requirements are not homogeneous. The proposed procedural framework clusters the manufacturing network into more homogeneous clusters and site roles, which allows a more refined and cluster-specific definition of strategic targets and performance measures. Steps 3 to 6 therefore aim at establishing a common understanding of the manufacturing network, similarly to the first step of Pekkola's (2013) PMS for external networks as described in Subsection 2.2.5.

Step 7 is the first step in the section performance measurement. It is also a new addition to the traditional PMMS process which is necessary as not all aspects of a manufacturing strategy can always be measured by quantitative performance measures. In this step, the various aspects of the manufacturing site and network strategies are reviewed and it is decided which method of evaluation is used for the different targets, principles and action plans. To do so, the Melnyk Matrix as described in Section 2.2 can be used. Some aspects of manufacturing strategy may require multiple ways of performance evaluation or performance measures.

Step 8 then defines the performance measures and evaluation criteria based on the decisions made in step 7. The guidelines described in Subsection 2.2.4 should be considered in this step. Performance measures and evaluation criteria are tested and agreed on with the different manufacturing sites and clusters in the manufacturing network in step 9. This test and agreement stage is necessary for two reasons: a) It has to be ensured that the performance measures and evaluation mechanisms actually work and reflect the aspired outcomes and b) that the evaluated staff or entities accept the measures. If no agreement can be reached regarding a certain performance measure or evaluation criteria, it has to be redesigned. Step 8 and 9 form a control loop to ensure the creation of tested and accepted performance measures and criteria. These performance measures and criteria are then implemented in step 10. With step 10 and the implementation of the performance measures and evaluation criteria the gathering of performance data can begin.

Step 11 is located in the performance management lane and covers the internal communication of performance measures and evaluation criteria to the relevant employees. This step is important to align the strategic targets of the manufacturing network and their evaluation. Obviously, the most important stakeholders are already aware of the strategic performance measures at this point as they were involved in the definition and implementation in steps 7 to 10. Step 11 targets a broader audience within the manufacturing network. Its purpose is to raise awareness throughout the network down to the shop floor level.

Step 12 collects the data created through performance measurement. Since manufacturing networks are hierarchical and complex constructs, is necessary to find the right level of data aggregation to make conclusions regarding the overall performance of the manufacturing network. Data from different manufacturing sites has to be gathered, formatted so that it is comparable, and aggregated to a network level performance. The aggregated data will then be analysed in step 13. The target of this analysis is to identify areas of manufacturing strategy and targets that have been fulfilled as well as to learn why certain targets might not have been fulfilled. Additionally, deviations of performance between different sites and of single sites over the course of multiple years can also be identified. To do so, the different site roles and infrastructural and structural differences between sites have to be considered.

Step 14 openly communicates the performance measurement results throughout the manufacturing network. This step serves three purposes: a) to educate employees regarding the achievement of strategic targets and the performance of the different manufacturing sites b) to enable a discussion regarding the strategic performance of the manufacturing network and its sites and c) to allow site managers to give feedback regarding the performance of their site.

The final step (15) of the procedural framework thoroughly reviews the overall performance management and conducted measurement activities. This step aims at identifying strength and weaknesses of the performance evaluation, the underlying process, measures and criteria. Therefore, areas of improvement for the SPMMS can be identified. Additionally, the overall strategic performance of the manufacturing network is used as an input for the definition of the future manufacturing strategy. The process then starts again from the beginning. This is important as strategic performance measurement and management is a continuous process that needs to be conducted periodically. Defined targets and the performance measures and evaluation criteria are updated periodically and aligned with changes in manufacturing strategy.

The procedural framework for SPMMS outlined above is a process that supports the development and implementation of a SPMMS for manufacturing networks. It supports the derivation of performance measures and evaluation criteria for manufacturing networks and manufacturing sites from manufacturing strategy. The procedural framework provides an approach to define a holistic SPMMS for intra-company manufacturing networks and thus answers research sub-question 3. The procedural framework further covers the requirements of SPMMS in manufacturing networks defined in Section 3.2 that have not been covered by the structural framework. Firstly, it incorporates different levels of performance target definition (R 2) and also varying foci of performance (R 4) for example for different clusters in the network. Secondly, when evaluating manufacturing site performance, site roles, structural and infrastructural differences between the sites are considered for performance definition and evaluation (R 7 and 8). Finally, by incorporating a cluster level below the network level and leaving the concrete definition of those clusters up to the applying manufacturing companies, the procedural framework is adaptable to different organisational structures in manufacturing networks (R 9).

In summary, the proposed procedural framework, in combination with the structural framework, fulfils all requirements of a SPMMS in manufacturing networks. So far however, these are just theoretically derived frameworks. To validate their practical applicability, Section 3.7 will review the new contributions and use case studies in Chapter 4 to check their practicability.

3.7 New Contributions to SPMMS in Manufacturing Networks

This section will recapitulate the new contributions (NC) to SPMMS in manufacturing networks made in this chapter. These contributions can be related to the content, the process and the measurement and evaluation of SPMMS in manufacturing networks.

3.7.1 Content

Traditional approaches to performance measurement in manufacturing networks have focused on the manufacturing capabilities as performance dimensions. New contributions to the content of performance in manufacturing networks therefore are:

NC 1. Stakeholders as Performance Dimensions: Stakeholders have been introduced as additional performance dimensions. The key questions here are similar to those of the performance prism by Neely *et al.* What do stakeholders require from the manufacturing network, and how can the fulfilment of the requirements be measured? Or: What input is required from the stakeholders and how can the provision of this input be measured?

NC 2. Network Capabilities as Performance Dimensions: Viewing manufacturing activities as networked structures with interconnected manufacturing sites allows the strategic build-up of network capabilities. Setting strategic objectives that enforce and support the build-up is a newly added aspect to the concept of manufacturing network performance.

NC 3. Contribution to Network Capabilities as Performance Dimensions for Manufacturing Sites: The realisation of a manufacturing network capability build-up is not only conducted on a network level. Instead, manufacturing sites need to contribute to the build-up of these capabilities. Setting appropriate targets and measuring the fulfilment of those targets is a new aspect of manufacturing site performance.

NC 4. Structural and Infrastructural Levers as Performance Dimensions: As pointed out in Section 2.1, a significant part of a manufacturing strategy addresses the manufacturing structure and infrastructure. Including change and improvement of these measures into a SPMMS for manufacturing networks constitutes a new contribution to existing SPMMS for manufacturing.

3.7.2 Process

Section 2.2 reviewed several SPMMS and also provided a summary of relevant procedural frameworks for SPMM. The new contributions to the procedural framework of the developed SPMMS for manufacturing networks are:

NC 5. Linking Manufacturing Strategy Formulation with the SPMMS: The procedural framework directly links the formulation of manufacturing strategy to the definition of targets on different levels of a manufacturing function. This is a new contribution to SPMMS, as no SPMMS has focused on manufacturing so far.

NC 6. Setting targets for a Manufacturing Network as a whole: As manufacturing networks are a strategic construct utilised by few manufacturing companies, it has to be shown that strategic performance targets on this level can actually be defined and implemented.

NC 7. Implementing clusters: The concept that organisational clusters need to be created below the overall manufacturing network to allow a more focused strategy formulation an SPMM is a new contribution to strategy formulation and SPMMS in manufacturing networks.

NC 8. Connection of Network level, Cluster Level and Site Level: It is claimed that targets set on a network level can be used to derive targets for clusters and sites within a manufacturing network. This procedure and connection has to be validated.

NC 9. Using the Concept of Site Roles to set Targets and evaluate Site Performance: The SPMMS for manufacturing networks relies on site roles to derive site-specific strategies and targets. Furthermore, site roles need to be considered when evaluating manufacturing site performance, as the role of a manufacturing site is crucial for the definition of site targets.

NC 10. Upward aggregation of Performance Measures and Data throughout a Manufacturing Network: To make a statement about the strategic performance of an overall manufacturing network, data has to be aggregated from manufacturing site to cluster to manufacturing network level. The feasibility to do so has to be verified.

3.7.3 Measurement and Evaluation

NC 11. Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks: Historically, SPMM in manufacturing networks has focused on quantitative, process-based performance measures. Shifting the focus away from this lopsided form of evaluation allows a more flexible and divers approach to strategic target definition and strategic performance evaluation.

NC 12. Allowing varying Foci of Performance across the Manufacturing Network: As manufacturing networks are complex structures that are subject to a variety of different external conditions, the evaluation and target setting has to adapt to different environments of network clusters or sites.

3.8 Summary and Discussion of the Proposed SPMMS for Manufacturing Networks

Chapter 3 so far has developed a structural and procedural framework which allows the definition of manufacturing network-specific SPMMS. The structural and procedural frameworks were developed based on the demands that manufacturing networks place on SPMMS (cf. section 2.1). However, it now has to be tested if the developed frameworks fulfil the criteria for scientific models in general and SPMMS in particular as defined in Section 3.4.

- **Holism:** The developed model covers all aspects of manufacturing strategy and strategic performance. The developed procedural framework is flexible in that it can freely be adjusted to any given manufacturing network, its clusters and sites.
- **Competency:** On a structural level, the main objectives and mission of a manufacturing network and its clusters and sites can be identified as the structural framework is holistic and supported by guiding questions. On a procedural level, the framework is defined to make the the derivation of the main objective and mission of the manufacturing network possible
- **Efficacy:** Terms and definitions are clearly defined throughout this thesis. The terminology is easy to understand and apply.
- **Reusability:** The structural and procedural frameworks are generic enough to be reusable indefinitely. The structural framework contains all relevant dimensions of manufacturing network strategy and performance. By explicitly stating that not all aspects need to be always addressed, users can freely choose the performance dimensions most suitable to them. The structural framework is therefore modular. It is further scalable to manufacturing networks of any sites as any number of sites and clusters can be incorporated.
- **Conformity:** By incorporating a periodical update as a fixed step in the procedural framework, the model can be readjusted.
- **Reducing overall complexity:** By providing a clear structure and a top-down approach to the definition of performance targets, the developed frameworks support managers and reduce complexity by providing a guiding structure.

A SPMMS for manufacturing network should include:

- **Selection of Measures:** Dedicated steps address the selection and evaluation of performance measures.
- **Implementation of Measures:** One step is solely dedicated to the implementation performance measures.

- **Audit Capability:** The developed performance measures and the overall SPMMS are evaluated periodically.
- **Strategy Congruency:** Linking the definition of performance dimensions directly to manufacturing strategy ensures a connection between performance measures and strategy.
- **Databank of Measures:** The frameworks developed in this thesis do not contain a databank of possible performance measures. The reason for this is that performance measures need to be developed individually for each manufacturing network (cf. Section 2.2). However, by supplying different performance dimensions, the definition of performance measures is facilitated.
- **Workbook Approach:** The procedural framework is a list of steps that support the development, implementation and use of a SPMMS for manufacturing networks. Additionally, the performance dimensions in the structural framework are connected logically to help practitioners derive their own and specific performance targets and measures.

Concluding, it can be stated that the developed structural and infrastructural frameworks fulfil the demands manufacturing networks place on SPMMS as well as most of the criteria for the evaluation of SPMMS models. Only one criterion is not met, however the usefulness of a databank of pre-defined measures is questionable. Practitioners might find the lack of ready-to-implement performance measures unsatisfying, but the supplied structural and procedural frameworks force practitioners to think deeply about the content and implication of strategic performance for their manufacturing networks, clusters and sites. The resulting deeper understanding of strategic performance seems superior to a predefined list of performance measures.

4 Testing the Applicability of the SPMMS

This chapter aims at validating the applicability of the developed SPMMS in general and the structural and procedural SPMMS in particular. To do so, several case studies have been selected. The case studies are practice examples from collaborative projects and interviews with various companies. Not all of them will be discussed in equal depth; instead, the most striking aspects from the different cases will be highlighted. It has to be noted that the structural and procedural frameworks developed in Chapter 3 have not been fully applied to the case studies at hand. This is due to the iterative research process and the consequently iterative development of the model. Some of the findings that influenced the final design of the SPMMS were only made after some of the case studies had already been finished. The names and data of the case studies have been altered for privacy purposes.

4.1 Case Studies

Working with qualitative data and using them to derive generalizable results is a difficult task as the control sample is rather small. Therefore, the selection of case studies is pivotal (Eisenhardt, 1989). Case studies should be selected to reflect a diverse set of companies from different environments (cf. Eisenhardt, 1989).

The companies that were selected as case studies for this thesis come from different industries and vary in size regarding both their number of employees and revenue. All of them have been operating for several decades and are considered financially stable. All are directly or indirectly (through a parent company) listed at stock exchanges. Their headquarters are mainly located in Europe, the respective manufacturing networks are focused on regional (European) or global markets and vary in their number of sites. Additionally, emphasis was put on a differing maturity of the network management. Maturity ranges from high with the Pet Food Company (PFC)[26] to low with the Insulation Company (IC). In the context of manufacturing networks, maturity is defined as the degree of implementation of a network perspective into the manufacturing activities of the company. Instead of supporting several autonomous sites that optimise themselves, a company with a high manufacturing network maturity has implemented a manufacturing network level perspective that is supported by manufacturing sites through collaboration. Table 19 gives an overview of the case study companies. The

[26] The PFC was identified as a successful practice company in the 2011 study „Excellence in Global Operations (X-GO)“ conducted by the University of St.Gallen. For more details on the study see Thomas (2013)

evaluated networks cover the entire operations of the company except in the case of the Pet Food Company, the Sanitary Products Company and the Insulation Company, where only the European networks were focussed on.

Case Studies	*Industry*	*Location of Headquarter*	*Revenue (2013)*	*Employees (2013)*	*Number of Sites*	*Dispersion of Network*
Electronic Packaging Company	Electronic packaging products	Germany	approx. 110 Mio €	780	12	Global
Pet Food Company	Pet food	Hungary	approx. 225 Mio. €	800	7	Europe
Cable Company	Connectivity Solutions	Germany	approx. 640 Mio. €	3’500.	15	Global
Materials Technology Company	High Tech Metal Components	Netherlands	approx. 6 Bn. €	20’000	40	Global
Sanitary Products Company	Sanitary Products and Technology	Germany	approx. 2.3 Bn. €	6’500	14	Europe
Pharma Company	Pharmaceutical Industry	Canada	approx. 55 Bn. CAD	70’000	60	Global
Insulation Company	Building Insulation Materials	Switzerland	approx. 3 bn. CHF	8’900	13	Europe

Table 19 – Overview of Case Studies

Each case described in the following sections follows a similar structure although each highlights a different emphasis regarding SPMMS in manufacturing networks.

4.1.1 Electronic Packaging Company (EPC)

The EPC is a globally active manufacturer of products and services for the electronic industry. More specifically, it provides products in three main product lines:

- System Solutions
- Enclosures and Components
- Rotary Switches

System Solutions are customer-specific designed as a combination of chassis platforms, cabinets, storage, backplanes and components. Products in this line are rather engineering intensive. Enclosure and components includes the selling and customisation of sub racks, instrument and compact cases and front panels, handles and plug-in units. Finally, the product line rotary switches incorporates the manufacturing and selling of switching and indicating solutions and control knobs. Two thirds (65%) of the revenues of the EPC are generated by system solutions, 18 % by enclosure and components and

17 % by rotary switches. Products of the EPC are used in a variety of industries such as military, communications, aerospace and industrial applications. This poses a problem of greatly varying demands on the manufacturing of the EPC. Especially the business of rotary switches works very differently to the other two product lines. Rotary switches will hence be excluded from the further discussion.

Manufacturing Network

The manufacturing activities of the EPC are globally dispersed. Manufacturing sites are located in the three regions Americas, EMEA (Europe, Middle East and Africa) and Asia. Figure 26 depicts the location of sites and outline of regions.

Figure 26 – Global Manufacturing Network of the EPC

All global sites are fully owned by the EPC. From an operational perspective, some of the sites are more closely connected than others. For example, the manufacturing site in Hungary is the prolonged work bench for the manufacturing site in Germany. As such, the Hungarian site does not sell any products itself, but only manufactures for the German site. Therefore, the German and Hungarian sites are considered to be one entity regarding strategy definition and performance measurement. Similarly, the American sites will be considered as an entity, as they are managed in unison. Generally, the sites differ in their competences and activities. They can be categorised into three roles: manufacturing sites, assembly sites and sales sites. An overview of the sites and their competences is given in Table 20.

Site	***Site Role***	***Competences***					
		R&D	***Engineering***	***Level 1 Production Processes***	***Level 2 Production Processes***	***Level 3 Production Processes***	***Level 4 Production Processes***
USA	Manufacturing Site	✓	✓	✓	✓	✓	✓
Germany	Manufacturing Site	✓	✓	✓	✓	✓	✓
Switzerland	Manufacturing Site	✓	✓	✓	✓	✓	
United Kingdom	Manufacturing Site		✓		✓	✓	✓
China	Manufacturing Site (starting 2014)		✓	✓ (partly)	✓	✓	✓
France	Assembly Site		✓		✓	✓	
Israel	Assembly Site		✓		✓	✓	✓
Singapore	Sales Site						

Table 20 – Overview of EPC Sites and Competences

The process levels in Table 20 describe competences along the value chain in the EPC's production. Level 1 production processes cover basic manufacturing process steps. Levels 2 to 4 refer to the assembly and testing of increasingly complex products. Although the manufacturing site in the UK does not conduct any basic production processes (level 1) it is still considered a manufacturing site due to its significant size and wide array of competences. Singapore does not have any production competences since it is only a sales site. Generally, all manufacturing sites manufacture/assemble products from the product lines system solutions and enclosures and components.

Manufacturing Strategy

Looking ahead, the EPC faces several general challenges and megatrends that it needs to consider. Firstly, electronics are changing continuously. They become increasingly powerful and smaller, and interfaces are becoming increasingly standardised. The EPC needs to address this ongoing technological change in its manufacturing function. The customers of the EPC have increasingly complex product requests and come from an increasingly diverse set of industries. This forces the EPC to provide more customised product solutions. Additionally, the complexity in product requests increases the internal response time of the EPC; the EPC wants to decrease this internal response time to remain competitive.

Similarly to the approach described in Section 2.1, the EPC ranked manufacturing capabilities based on their importance as perceived by the customers. Therefore, the positioning of the manufacturing function is based on market needs. The manufacturing capabilities were ranked separately for the two product lines system solutions and enclosures and components. Table 21 gives an overview of the ranking and differences between system solutions and enclosures and components.

Manufacturing Capabilities		*System Solutions*			*Enclosure and Components*		
		Order Qualifier	***Order Winner***	***Improvement Necessary***	***Order Qualifier***	***Order Winner***	***Improvement Necessary***
Cost		X			X		
Quality	Superiority	X			X		
	Conformance	X			X		
Delivery	Speed	X				X	
	Reliability	X				X	
Flexibility	Product Range/ Design Flexibility		X			X	
	Order Size/ Delivery Flexibility		X			X	
Innovation			X			X	X
Service			X				

Table 21 – Ranking of Manufacturing Capabilities for EPC

The ranking of the manufacturing capabilities for the two different product lines in Table 21 shows that they share similar priorities. Solely delivery reliability and speed are more important for enclosures and components. In contrast, service is not relevant for the product line enclosure and components, but is an order winner for systems solutions. Service in systems solutions can be described as the provision of engineering support and services and the customisation of products. The EPC also indicated that its product line enclosures and components will have to be more innovative in the future.

In summary, the EPC will try to win orders with an increased delivery performance in speed and reliability for enclosure and components as well as an increased flexibility for systems solutions and enclosures and components. Additionally, the EPC wants to stay innovative and increase innovation. With regards to system solutions, aspects of service/engineering are also of high priority for future competitiveness.

Strategic Performance on Network Level

Based on the manufacturing strategy positioning around the manufacturing capabilities, strategic performance measures for each manufacturing capability were defined. Furthermore, the CEO defined a performance level for each performance measure that has to be valid network-wide. In the past, the EPC has already measured performance in the dimensions quality specification, quality conformance, delivery reliability and flexibility regarding order size/delivery. Table 22 provides a list of manufacturing capabilities, the connected performance measures and the aspired targets as defined by the CEO.

Manufacturing Capabilities		***Strategic Performance Measure***	***Qualitative Target as defined by CEO***
Cost		Total costs for internal supply chain [CHF]	Reduce Costs steadily
Quality	Superiority	Number of customer returns based on quality [#]	Zero tolerance for customer returns based on quality
	Conformance	First pass yield [%]	Increase FPY; find all sources of internal errors
Delivery	Speed	Internal order throughput time [days]	Better than competitors and as good as necessary.
	Reliability	Share of on-time in-full deliveries [%]	95%; Fulfil all aspects of customer contracts
Flexibility	Product Range/ Design Flexibility	Time to create a new product design guideline based on customer demands [h]	Build similar projects faster than competitors by using multipurpose designs; Non-recurring engineering should be covered by customers.
	Order Size/ Delivery Flexibility	average order size [pieces]; minimal and maximal possible order size [pieces]	Standard products: Introduce Minimum Order Quantity (MOQ); Individual solutions: From zero to infinity (if customer bears additional costs).
Innovation	Product	Share of sales on new (< 5 years) products [%]; R&D costs as share of annual return [%] (R&D intensity)	Maintain a sufficient level of R&D even in periods of high cost pressure; Use this investments to build multipurpose platforms;
	Process	Process improvement suggestions per department [#]; Average cost-savings per process improvements [CHF]; Process innovation intensity [%];	Improve processes when necessary or in case of good ideas.
Service/Engineering		Costs of engineering as a share of return per site [%] (engineering intensity)	

Table 22 – Manufacturing Capabilities, Strategic Performance Measures and Qualitative Targets at the EPC

The EPC has chosen to reflect every manufacturing capability with one to three performance measures as described in Table 22. However, it can be problematic and even misleading to interpret performance in a single performance dimension based on only few performance measures. Therefore, the CEO provided qualitative or guiding statements for most categories that aid the interpretation of performance in the different categories.

The strategic manufacturing performance measures described above are accompanied by a set of strategic performance measures focussing on the needs of stakeholders, namely investors and employees. The customer perspective towards manufacturing is considered to be covered by the manufacturing capabilities and their respective measures.

Strategic Performance Dimension		***Strategic Performance Measure***
Financial	Financial Return	Revenue
	Profitability	EBIT
	Profitability	Margin
	Costs	Costs of goods sold
Employees	Employee satisfaction	Fluctuation rate
	Employee know-how	Performance measure not yet defined

Table 23 – Strategic Performance Measures addressing Stakeholder Perspectives

Strategic Performance on Cluster Level

As the EPC is a rather small and homogeneous company, there is no need to define clusters below the network level. Even so, the definition of clusters would be possible; e.g., it seems feasible to cluster based on product lines (unlikely, as all sites are involved with all product lines) or regions.

Strategic Performance on Site Level

Within its manufacturing network, the EPC has assigned competency-based site roles to the different manufacturing sites and site conglomerates as described in Table 20. The measurement and evaluation of performance on a site/site conglomerate level is approached with a site role-specific set of performance measures. Three sets of performance measures are distinguished:

- **The Full Performance Measure Set:** This set was implemented at the big, full-scale manufacturing sites (USA, Germany, Switzerland, Great Britain and China) and includes all the performance measures described above.
- **The Sales and Assembly Performance Measure Set:** This set was implemented at the assembly sites (France and Israel). Since these sites do not cover basic production steps, the performance measures “first pass yield”, “order size”, “engineering intensity” and “R&D intensity” are not measured at these sites. Additionally, the definitions of the performance measures “total costs of internal supply chain” and “internal order throughput time” were adjusted to only cover the activities conducted at the sites.
- **The Sales Performance Measure Set:** This set was only applied to Singapore, as it is the only pure sales site in the network. Since Singapore only conducts sales, the sales and assembly performance measure set is further reduced to only cover performance measures that are relevant to the overall network. That is, “number of customer returns based on quality”, “time to create a new product design guideline based on customer demands” and performance measures addressing process and product improvements have been removed.

The performance in the different performance dimensions is measured at site level and aggregated to network values. Strategic performance measures addressing the investor and employee perspective are measured at every site.

Process

The EPC approaches strategic performance measurement and management similarly to the procedural framework described in Figure 24. Based on the overall company strategy (which only focuses on one business: electronic packaging; therefore, no further business strategy is necessary), the manufacturing strategy of the EPC was defined (steps 1-3). Since the EPC is not a very big company and all products are produced at most sites, an additional clustering of the network below the overall network level was not necessary. However, competency-based site roles were defined and the definition of strategic performance on site level is connected to overall manufacturing strategy and site roles (step 6). The definition of manufacturing strategy and the derivation of strategic performance measures were conducted simultaneously.

Manufacturing strategy was defined by the company top management (CEO and further executives). The strategic focus set for manufacturing strategy was then translated to the set of strategic performance measures described above. The different strategic manufacturing capabilities are addressed by at least one quantitative strategic performance measure and a qualitative statement by the CEO that can be evaluated. The performance measures were presented to an extended executive team who evaluated the measures' strategic feasibility and agreed on a final set of performance measures. Then, measures were discussed with company IT to evaluate whether they could be implemented. After this, the full set of performance measures was rolled out to two sites for a test period. The successful test led to the network-wide implementation (steps 7 – 10).

Unfortunately, the collaboration with the EPC ended before the network-wide implementation of the strategic performance measures was complete. Therefore, steps 11 to 15 of the performance management track in Figure 24 could not be validated at the EPC.

Summary and Findings

The EPC case study illustrated how the EPC developed a strategic performance measurement system for its manufacturing network. Although the process of strategic performance data collection across the network was not conducted in collaboration with the researcher, some important observations could be made that support the structural and procedural framework of an SPMMS for manufacturing networks developed in this thesis. The following new contributions as specified in Section 3.7 were observed at the EPC:

- **NC 1 – Stakeholders as Performance Dimensions:** The SPMMS of the EPC not only includes manufacturing capabilities as performance dimensions but also an investor and employee perspective.
- **NC 5 – Linking Manufacturing Strategy Formulation with the SPMMS:** Manufacturing strategy formulation was directly linked to strategic performance measurement and management. The defined manufacturing strategy was translated into quantitative strategic performance measures and strategy statements for the different performance dimensions were defined.
- **NC 6 – Setting targets for the Manufacturing Network as a Whole:** The performance dimensions, measures and strategic statements are valid for the manufacturing network as a whole. While the performance dimensions at site and network level are essentially the same and no additional network strategy has been defined by the EPC, this case still shows that it is possible to define a network-wide manufacturing strategy and to derive targets accordingly.
- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** While the EPC has not established a cluster level below the overall network level, this case study shows how the manufacturing strategy, strategic performance dimensions

and strategic performance measures at a network level are connected to those at manufacturing site level.

- **NC 9 – Using the Concept of Site Roles to Set Targets and Evaluate Site Performance:** The EPC developed competency-based site roles and connected the performance dimensions and targets directly to these site roles.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** This aspect has not been fully established at the EPC. However, the CEO has provided a vision or performance statement for most manufacturing capabilities as performance dimensions which can be used as a guide. While the achievement of this statement has not been formally evaluated, it serves as a qualitative guidance for target fulfilment.

4.1.2 Pet Food Company (PFC)

The PFC is a leading private label pet food producer in Europe, which provides a full range of complete diets for dogs and cats. It focuses on Europe as a core market and serves all European top retailers. The PFC's products can be divided in two main groups: dry food and wet food. Manufacturing processes and ingredients vary for these two product groups. The PFC sees itself not only as a manufacturer but as a partner of retailers. It provides its products in various sizes with customer-specific packaging and supplies additional marketing concepts for retail and discount customers. The PFC furthermore offers category management and shelf service for retailers. From a manufacturing planning perspective, the PFC operates in an environment with relatively stable monthly demand. In contrast, the time span for a reliable production forecast is extremely short, forcing the PFC to realise flexibility within its network.

Manufacturing Network

The manufacturing activities of the PFC are dispersed throughout Europe. The manufacturing network consists of seven manufacturing sites which are located in four different countries. The seven manufacturing sites produce a volume of approximately 350'000 tons pet food per year and serve customers in 30 European countries. Figure 27 provides an overview of the manufacturing site locations. The manufacturing activities are focussed on four countries in Western and Central Europe. Two manufacturing sites each are located in the Netherlands, the Czech Republic and Hungary, while there is only one manufacturing site in Slovakia.

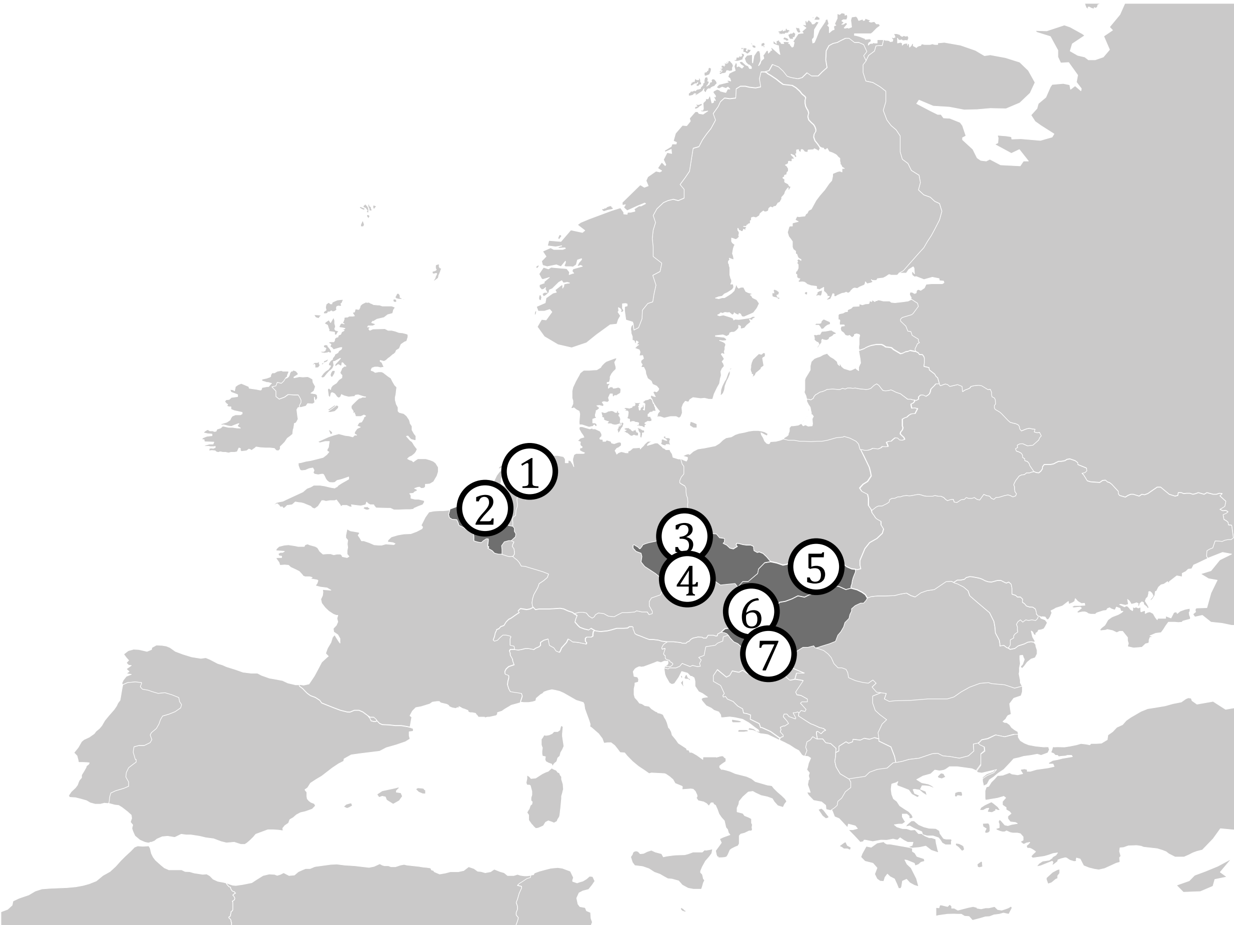

Figure 27 – European Manufacturing Network of the PFC

All sites are fully owned by the PFC and focus on either dry or wet food. The network of dry and wet food sites is managed as a whole to align strategies and ensure efficient usage of company resources. Furthermore, a close collaboration and exchange of knowledge in engineering, product and process improvement and other manufacturing related knowledge is sought. Table 24 gives an overview of the PFC manufacturing sites and their product foci.

Site	***Location***	***Product Focus***
1	Netherlands	Dry Food
2	Netherlands	Wet Food
3	Czech Republic	Dry Food
4	Czech Republic	Wet Food
5	Slovakia	Dry Food
6	Hungary	Dry Food
7	Hungary	Wet Food

Table 24 - Overview of PFC Sites and Product Foci

Besides manufacturing, each site is also responsible for product and process development and improving the fulfilment of regional requirements. However, the local development at the manufacturing site is headed by a European manager to realise synergies. Furthermore, so-called centres of excellence (CoE) have been implemented. These centres have proven their ability in a certain development area in the past and are now responsible for coordinating this activity throughout Europe. For example, the Hungarian site is the CoE for wet food production technology. As such, it screens new production technology, discusses novelties in the field with the other network sites, and helps them implement new technologies.

Furthermore, each site has a current and future role description. For example, manufacturing site 6 is seen as a reliable and flexible plant with a focus on low-cost products. However, it also has an outdated product portfolio and assets. For the future, both assets and product portfolio will be updated. The site should focus on the markets in Hungary and Romania with a continued focus on low-cost product. Manufacturing site 1, on the other hand, focuses on medium or premium products with good assets at the site. As it is located in a high-wage country, the costs of goods sold (COGS) are rather high. In the future, this site is expected to grow profitably and continue its focus on medium and premium product for the Dutch and French market.

Manufacturing Strategy

The PFC has developed a mission for the overall company. It strives to be the number 1 private label pet food company in Europe. The manufacturing strategy is directly derived from that mission. For the manufacturing network, the most important manufacturing capabilities are price and delivery reliability. They are followed by product range and design flexibility, which are also perceived as order winners.

- To achieve a low market price, the PFC focuses on the reduction of production costs. Its target is to maintain cost competitiveness in local markets while maintaining product quality. That is, the target is to achieve the best quality/price ratio in the market.
- Furthermore, the PFC aims at reducing working capital by minimising semi-finished and finished goods stocks as well as by implementing consignment stocks at the manufacturing site level to reduce raw and pack material stocks. The full utilisation of a master production schedule (MPS) is meant to foster these efforts.
- Delivery reliability is a challenge, as delivery has to take place within a short timeframe. Hence, transportation is critical to achieve the strategic target.
- Product innovation in the private label business solely includes the quick following of brand innovation and short time-to-market for new designs. The target is to develop a concept for new products within 14 days of request.
- Furthermore, the PFC focuses on customer service. The target is to achieve an overall service level of above 98 %.

Strategic Performance on Network Level

The manufacturing network of the PFC consists of the seven sites described above which focus on either wet or dry pet food. As the strategic goals and served markets are identical for both types of manufacturing sites, the network is managed as one, i.e. business and management processes are identical, a common set of performance measures is used and supply chain management is executed centrally. Only product development is conducted separately for the two existing technologies. The strategic targets are connected to a set of performance measures which are collected at site level but not aggregated to a cluster or network level. Therefore, network level performance cannot be evaluated based on aggregated data. However, if the overall mission of the PFC and the connected targets for manufacturing are fulfilled, the manufacturing network performs well.

The performance data of the different manufacturing sites is consolidated within the headquarters and communicated throughout the network to create competition between the manufacturing sites which leads to the overall improvement of the manufacturing network. Strategic performance data is collected on a monthly basis.

Strategic Performance on Cluster Level

The manufacturing network of the PFC is clustered into two groups based on the product focus of the manufacturing sites (wet or dry pet food). The performance measures implemented throughout the clusters are identical with the exception of two performance measures that are only relevant for dry pet food. Besides the implementation of cluster-specific performance measures, the clusters are also used for internal benchmarking purposes. While most of the performance measures can be compared across the different manufacturing sites and clusters, performance levels in certain measures are directly linked to the production process. For example, dry food requires the drying of raw material which is very energy-intensive. Dry food sites therefore consume more energy per ton of produced food than wet food sites. Benchmarking dry food sites with wet food sites would therefore be neither fair nor reasonable.

Strategic Performance on Site Level

The strategic performance measures implemented throughout the manufacturing network of the PFC are depicted in Table 25. The implemented strategic performance measures reflect the above defined strategy. Most of the performance measures address quality and costs/efficiency. Furthermore, the various performance measures covering inventory levels address the target of reducing stock. The other targets defined in the strategy (delivery reliability, innovation and customer service) are not included on the score card.

Besides these strategic performance measures, site-specific performance measures based on local market demands can also be implemented but are not used for network-wide benchmarking. Compared to the EPC's SPMMS, the PFC's SPMMS is more specialised and has a less broad understanding of performance. This is due to the competitive environment of the PFC - as a private label supplier, the PFC is mainly evaluated on product costs and quality.

Strategic Performance Dimension		*Strategic Performance Measure*	*Dry Plants*	*Wet Plants*
Manufacturing Results	Costs	Plant Efficiency [%]	X	X
		Production Costs [€/ton]	X	X
		Production Costs [kg/man hour]	X	X
		Electricity Consumption [mJ/ton]	X	X
		Gas Consumption[mJ/ton]	X	X
	Quality	Moisture Content [%]	X	
		Raw Material Rework [%]	X	
		Raw Material Waste [%]	X	X
		Packaging Material Waste [%]	X	X
		Customer Complaints [ppm]	X	X
Manufacturing Structure and Infrastructure	Structural Levers	Production Volume [tons]	X	X
		Inventory of Finished Goods [days]	X	X
		Inventory of Raw Material [days]	X	X
		Inventory of Packaging Material [days]	X	X
	Infrastructural Lever	6 Sigma Score [points]	X	X
Stakeholder Perspective	Employee Perspective	Accidents [#]	X	X
		Absenteeism [%]	X	X

Table 25 – Strategic Performance Measures of the PFC

Furthermore, the PFC has also implemented competency-based site roles. These are mainly limited to Centres of Excellence based on know-how in a specific area. For example, one Hungarian site is the CoE for wet food production technology. CoEs are responsible for the further development of their area of know-how and the network-wide support in that area. This is also evaluated as a part of site performance.

Summary and Findings

The SPMMS of the PFC is noteworthy because it has been implemented network-wide and extensively tested in the field. Furthermore, it clusters the network's manufacturing sites based on their product focus and uses this clustering for strategic performance measurement and benchmarking. The following new contributions as specified in Section 3.7 were observed at the PFC:

- **NC 1 – Stakeholders as Performance Dimensions:** The PFC's SPMMS includes performance measures that focus on employee well-being.
- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** Based on its manufacturing strategy, the PFC monitors production output as well as inventory levels of finished goods and raw materials. Furthermore, 6 sigma scores as an infrastructural lever are measured.
- **NC 6 – Setting Targets for the Manufacturing Network as a Whole:** The PFC manages its manufacturing network as a single entity. Therefore manufacturing strategy, connected targets and performance measures are defined for the manufacturing network as a whole.
- **NC 7 – Implementing Clusters:** Although the manufacturing network is managed as a single unit, the PFC's management has realised that a clustering of the network based on the product focus of manufacturing sites is necessary for effective strategic performance measurement and management. Therefore, it distinguishes between manufacturing sites that produce dry and wet pet food. The manufacturing strategies of both clusters are similar but include product-specific aspects.
- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** The manufacturing strategy and connected strategic performance measures and targets are connected throughout the network from network to site level. Cluster and site-specific strategic performance targets and measures are added according to strategic cluster or site characteristics.
- **NC 9 – Using the Concept of Site Roles to Set Targets and Evaluate Site Performance:** The PFC has implemented know-how-based Centres of Excellence. The fulfilment of CoE tasks is evaluated on top of the standard set of performance measures.

4.1.3 Cable Company (CC)

The CC is a globally active manufacturer of high-quality electrical and optical connections. The product portfolio covers connectors, cables, cable assemblies, cable systems antennas and lightning protectors which are mainly produced by the CC itself. Sales offices exist in over 50 countries world-wide and allow the CC to operate on a global scale while addressing local requirements. Products of the CC are used in a variety of markets such as communications, transportation, military or industrial applications. The CC supplies its products based on three core technologies: radio frequency, fibre optics and low frequency. Each technology is represented by a division in the company organisation. Overall, the company follows a so-called 3^3 strategy. This means it is present in and will answer to the demands of three technological markets (radio frequency, fibre optics and low frequency), three geographical markets (Americas, EMEA and Asia Pacific) and three main industry markets (communication, transportation and industrial applications). The varying requirements of these markets and the fact that the CC carries high-end as well as low-price products make it hard to deduct a focused manufacturing strategy.

Manufacturing Network

The CC has a global manufacturing network which consists of 15 manufacturing sites in 12 countries. Similarly to the EPC, multiple manufacturing sites in one country are often managed as a single entity. Additionally, some sites are offshore sites to manufacturing sites in high-wage countries. The offshore sites and their respective counter-parts in high-wage countries are closely connected and inventory at the offshore site can often be accounted to the high-wage country. However, for this case study manufacturing sites and their offshore sites are discussed separately. The manufacturing network has been extended through the acquisition of companies and the market-driven allocation of manufacturing activities to important countries. Generally, manufacturing sites produce for more than one division and for multiple industry markets. Additionally, the geographic scope of markets served by the manufacturing site also varies from global to regional or local. Figure 28 provides an overview of the manufacturing network of the CC. It only contains the locations of the 12 main manufacturing sites. The other three sites are located in the USA, Norway and China but will not be discussed in further detail as the sites in one country are managed as a single entity.

Figure 28 – Global Manufacturing Network of the CC

Besides the previously mentioned site differences in market scope and technology focus, it is also the extent of value-added activities that differs between the manufacturing sites. This is illustrated in Table 26.

Site	***Market Scope***	***Manufacturing Competences***								
		Low Frequency		***Radio Frequency***				***Fiber Optics***		
		Cables	***Cable Systems***	***Cables***	***Connec-tors***	***Anten-nas***	***Cable Assem-blies***	***Cables***	***Connec-tors***	***Cable Assem-blies***
Germany	Global	✓	✓	✓	✓		✓	✓	✓	✓
Czech Republic	Global		✓		✓	✓	✓			✓
China	Global	✓	✓		✓	✓	✓	✓	✓	✓
USA	Global			✓	✓		✓			
Algeria	Regional		✓		✓		✓			✓
Mexico	Regional						✓			✓
Panama	Regional						✓			
Indonesia	Regional						✓			
Argentina	Regional		✓				✓	✓		✓

Site	Market Scope	Manufacturing Competences								
		Low Frequency		Radio Frequency				Fiber Optics		
		Cables	Cable Systems	Cables	Connec-tors	Anten-nas	Cable Assem-blies	Cables	Connec-tors	Cable Assem-blies
India	Local		✓				✓			✓
UK	Local		✓				✓			✓
Australia	Local		✓				✓			

Table 26 – Overview of CC Sites and Competences

The overview in Table 26 shows the distribution of manufacturing competences. This is important for a future operational performance evaluation of the manufacturing sites, since a high complexity/high variety in products can result in frequent changeovers and machine downtime. As Table 26 shows, none of the manufacturing sites possesses the full range of competences. Additionally, most sites manufacture products of at least two technology divisions of the CC; only Panama and Indonesia focus on a single technology.

The CC manufacturing network is also interesting because of the way it is organised and manufacturing sites are affiliated with entities within the corporate organisation. Generally, the CC is organised into three technology division and a sales division. Additionally, there is a corporate function called "Global Operations". This corporate function is responsible for the global and cross-divisional support of manufacturing sites. The manufacturing sites in Algeria and the Czech Republic directly report to global operations. The other manufacturing sites outside Germany directly report to their local general managers, which report to the head of the sales division. Thus, they are part of the sales division. However, they additionally report to their respective technology division and to Global Operations. The organisational structure is therefore more complex than a standard matrix structure. This leads to a difficult strategy formulation and implementation process.

Manufacturing Strategy

Since the manufacturing network of the CC manufactures goods for three technology divisions and is additionally steered by the global operations function, manufacturing strategy can also be viewed from four perspectives. All three divisions as well as global operations update manufacturing strategy annually based on corporate templates. The manufacturing strategy statements contain a list of action plans addressing the structural and infrastructural levers of the CC manufacturing network as well as a target state for the manufacturing network from the divisions' perspectives. The fulfilment of the action plans is evaluated and updated annually and presented centrally. The division heads also ranked the manufacturing capabilities and network capabilities as described in Section 2.1. While it was possible to rank the network capabilities for each division as a whole, the manufacturing capabilities needed to be ranked differently for different businesses within the divisions. Each division had to distinguish between two businesses as customer requirements in these businesses vary significantly. In order to homogenise the statements regarding manufacturing capabilities and network capabilities, a common focus was derived and used as a guideline for the overall manufacturing strategy. The following description of the CC manufacturing strategy will cover the focus on manufacturing capabilities and network capabilities, the defined site roles and the action plans addressing structural and infrastructural levers.

MANUFACTURING CAPABILITIES

As described above, every technology division ranked manufacturing capabilities as order qualifiers and order winners. Each division had to specify at least two different businesses, to reflect the requirements of customers to them. The rankings varied significantly. Some manufacturing capabilities were highly important order winners for some businesses while they were close to insignificant for other businesses. This makes a unified focus based on the manufacturing capabilities impossible. Besides the order qualifier/order winner ranking, the COOs of the divisions also identified the manufacturing capabilities that needed to be improved the most to ensure future competitiveness. The business-specific rankings of manufacturing capabilities and the estimated improvement potentials were evaluated and a common focus was derived. While all manufacturing capabilities were seen as important, the future improvement focus was put on:

- **Innovation:** The CC wants to produce innovative products with innovative processes
- **Delivery Speed:** Delivery speed is crucial for success. The CC wants to deliver orders faster than its competitors.
- **Costs:** The continuous cost pressure is to be addressed through continuous cost savings.

NETWORK CAPABILITIES

Similar to the manufacturing capabilities, the network capabilities were also ranked based on the network's current ability and the network capabilities' importance for being competitive in the future. However, a single ranking was conducted for each division. The resulting rankings were evaluated based on the average importance and improvement potential. The following three main foci for future development were identified:

- **Bundling of Resources:** Realising economies of scale and scope and reducing duplications in overhead
- **Pushing Innovation:** Enabling exchange of innovation and knowledge to foster product and process innovation
- **Increasing Mobility of Products and Processes:** Quick relocation of production processes to swiftly react to changes in global market demands and labour costs

The focus on bundling of resources and pushing innovation corresponds to the focus on the manufacturing capabilities costs and innovation. The developed foci can be found in the site roles and guidelines for the network development described in the next paragraphs.

SITE ROLES

Despite the above described organisational difficulties, the CC has rather elaborate site roles which can be attributed to the creation of the "Global Operations" function. Firstly, the CC defined the distribution of its manufacturing competences throughout the global network based on the following rules:

- Cable manufacturing: Cable manufacturing is a manufacturing competence which requires high investments in machinery. Therefore, the target is to have only one or few production locations per technology, but a maximum of one site per technology per region.
- Connectors/Components: The manufacturing strategy is to have a "one-location" set-up per product family[27]
- Cable Assemblies and Cable Harnesses: The allocation of the last manufacturing step in the value chain is mainly driven by proximity to customers. The strategy for competence allocation of assemblies and cable harnesses is to have as many manufacturing sites as necessary, but as few as possible conducting assembly. Additionally, this manufacturing step is to be preferably conducted in low-wage countries.

[27] A product family is a group of products within a technology division. Therefore, multiple manufacturing sites can have the competence to manufacture connectors for a certain technology division.

In any case, customers are the key driver of competence and capacity expansion. If a regional market grows to the point that the allocation of expensive manufacturing equipment is justifiable, a detailed evaluation of this possibility is conducted.

Besides guidelines addressing the distribution of manufacturing competences, the CC has also defined site roles that go beyond the allocation of site manufacturing competences and address the manufacturing sites' rights and responsibilities from a network perspective. An overview of the manufacturing sites, their market scope and the complexity and average batch size and is given in Table 27.

Site	*Market Scope*	*Complexity and Batch Size*	*Site Role*
Germany	Global	High Complexity – Small Batches	Lead Factory
Czech Republic	Global	High Complexity – Small Batches	Centre of Competence
China	Global	High Complexity – Medium Batches	Centre of Competence
USA	Global	High Complexity – Small Batches	Centre of Competence
Algeria	Regional	Low Complexity – Large Batches	Offshore Site
Mexico	Regional	Low Complexity – Large Batches	Offshore Site
Panama	Regional	Low Complexity – Large Batches	Offshore Site
Indonesia	Regional	High Complexity – Small Batches	Server Site
Argentina	Regional	High Complexity – Medium Batches	Server Site
India	Local	High Complexity – Medium Batches	Server Site
UK	Local	High Complexity – Small Batches	Server Site
Australia	Local	High Complexity – Small Batches	Server Site

Table 27 – Site Roles at the CC

The definition of site roles was initiated by "Corporate Operations" to foster cross-site collaboration and set guidelines for the future development of manufacturing sites. The site roles are updated periodically and can be used as an incentive for manufacturing sites. The description of the site roles is based on the typology by Ferdows (1997). The CC only wants one lead factory (LF) in its network, which is responsible for global support. Additionally, a centre of competence (CoC) should be established in every region to provide regional support for the LF. Server sites and offshore sites can be established as needed. The site roles can be described as follows:

- **Lead Factory:** The Lead Factory is responsible for the technological governance of all products (especially Product and Process Development). It is also responsible for establishing a standardised level of skills, capabilities and processes to ensure constant and reproducible product quality at all manufacturing sites.
- **Centre of Competence (CoC):** The CoCs are key manufacturing sites in the network serving the customers globally or at least in several geographical markets. Providing a wide range of capabilities, the CoCs can be tasked to take over Process Development responsibility delegated by the LF. Typically, in a CoC not only the assembly of Cable Assemblies or Cable Harnesses is allocated but also Cable and/or Connector/Component Manufacturing, or even additional manufacturing technologies.
- **Server Site:** Server Sites are established to be close to the customer and serve according to customer delivery time requirements. Typically, these sites are concentrating on the last step of the value chain: Cable Assemblies and/or Cable Harnesses. Thus, Server Sites produce in high mix/low batch production with a concentration on the local or the regional market.
- **Offshore Site:** The main motivation for an Offshore Site is the access to low (labour) costs. Offshore Sites strive for cost leadership. Therefore, only a limited range of products is allocated to an Offshore Site and the objective is to produce in medium to high batches with a lean overhead structure at the lowest possible cost level.

The site roles are linked in a hierarchical order. The Lead Factory is located above the centres of competence which are located above the server sites and offshore sites. It is the company's strategy to increase collaboration between the sites by anchoring mutual support in the role descriptions of manufacturing sites.

ACTION PLANS ADDRESSING STRUCTURAL AND INFRASTRUCTURAL LEVERS

The CC's core documents discussing manufacturing strategy focus on the future development of the overall manufacturing activities. Each division and corporate operations provide a list of action plans and projects that address important aspects of the manufacturing activities. As it is not sensible at this point to provide a complete list of action plans and project, exemplary aspects will be listed in the following to illustrate the variety of addressed aspects:

- Relocation of products and processes
- Build-up of competences in employees
- Increase of production capacities
- Alignment/implementation of unified ERP software
- Certification according to customer-demanded standards
- Creation of global support functions
- Achieve operational excellence
- Reduce unnecessary complexity in the network
- Implement process and platform for best-practice exchange
- Regional integration of supply chains

Strategic Performance on a Network Level

As the previous paragraphs have shown, manufacturing strategy is described in much detail and has many aspects at the CC. Generally, the overall strategic performance of the manufacturing networks can be seen from two perspectives. Firstly, the achievement of the strategic action plans and projects as reported by the divisions and global operations is reviewed annually and serves as an evaluation of the overall development progress of the manufacturing activities.

Secondly, the CC strives for the standardised definition of performance measures throughout the manufacturing network which are rolled out to all manufacturing sites and aggregated to the network level. These performance measures, once they are fully implemented and agreed upon, are used for an internal benchmarking within the different site roles groups. The current status of this strategic network performance measurement tool is that the strategic performance dimensions and measures are defined, but it is not completely rolled-out to all manufacturing sites. However, this should be achieved by the end of 2014. The strategic performance measures that are to be collected on site level and aggregated to network level are listed in Table 28.

Strategic Performance Dimensions on Network level	*Strategic Performance Measure*
Complexity	Consolidated Change of Complexity Drivers [%]
Mobility and Flexibility	Average time of Product Transfer [days]
	Share of Flexible Production Capacity [%]
Knowledge and Best Practice Exchange	Number of Total Improvement Ideas (product and process) [#]
	Savings through Process Improvements [CHF]
Employee well-being	Accidents [#]
	Employee Fluctuation [%]

Table 28 – Strategic Performance Dimensions on a Network Level at the CC

The strategic performance dimensions described in Table 28 reflect most of the aspired network capabilities as defined in this section. The mobility of products and processes is monitored by the average time of product transfer and the share of production capacity available for quick order allocation and knowledge. Best practice exchange is also monitored. The realisation of economies of scale and scope cannot be found in the strategic performance dimension at a network level. However, it has already been addressed by the site role strategy. The aspired network capabilities as defined by the joint view of the division was amended with an overall index measuring the complexity within the manufacturing network and two strategic performance measures addressing employee well-being. Therefore, the strategic performance dimensions listed in Table 28 in combination with the annual review of strategic action plans monitor all relevant aspects of network level strategic performance at the CC.

Strategic Performance on Cluster Level

The CC has not implemented a full and institutionalised clustering based on technology divisions or product families within its SPMMS. However, such an implementation is not useful for the CC as most manufacturing sites produce more than one product family from more than one technology division. Still, some performance measures are applied to divisions or product families (e.g., customer complaints, production volumes, inventory levels and average inventory turn). This is due to standard internal controlling processes and serves accounting purposes rather than manufacturing strategy implementation purposes.

Strategic Performance on Site Level

Strategic performance dimensions on site level consist of the strategic performance dimensions used on a network level and an additional set of strategic performance measures that can be used for internal benchmarking. An overview of the strategic performance dimensions collected on site level is given in Table 29.

Strategic Performance Dimension		***Strategic Performance Measure***	***Level of Aggregation***
Manufacturing Results	Costs	Change in Production Costs [%]	Site
		Efficiency [%]	Site
	Delivery	Deliveries on time [%]	Site
		Deliveries on time in full [%]	Site
	Quality	Customer Complaints [#; ppm]	Site
		Costs for Corrective Actions to Customer Complaints [CHF]	Site
	Knowledge and Best Practice Exchange	Number of total Improvement Ideas (product and process innovations) [#]	Site & Network
		Savings through Process Improvements [CHF]	Site & Network
		Number of best practices developed [#]	Site
		Number of best practice implementation supported at other sites [#]	Site
	Flexibility	Average time of Product Transfer [days]	Site & Network
		Share of Flexible Production Capacity [%]	Site & Network
Manufacturing Structure and Infrastructure	Structural Levers	Production Volume [pieces; m]	Site
		Inventory of Levels [CHF]	Site
		Inventory Turnover [days]	Site
		Inventory Provision [%; CHF]	Site
		Consolidated Change of Complexity Drivers [%]	Site & Network
	Infrastructural Levers	Number of Employees [FTE]	Site
		Ratio of direct to indirect manufacturing employees [%]	Site
Stakeholder Perspective	Employee Perspective	Accidents [#]	Site & Network
		Employee Fluctuation [%]	Site & Network

Table 29 – Strategic Performance Measures on Site Level at the CC

The strategic performance measures listed in Table 29 cover the aspired manufacturing capabilities as defined by the divisions' joint perspective (costs, delivery and innovation). They contain interesting details: Firstly, the network level strategy and derived performance dimensions directly translate down to site level performance. Additionally, knowledge and best practice exchange is monitored at site level with further strategic performance measures. Secondly, the utilisation of these strategic performance measures that cover how well a manufacturing site contributes to best practice exchange and how well other sites are supported can directly be used to evaluate if the lead factory and CoCs stand up to their task of supporting the network's other sites. Finally, some of these strategic performance measures are directly linked to the site roles. For example, an offshore site at the CC is defined as a site with a low overhead. Therefore, the ratio of direct to indirect employees should be rather large. These performance measures can therefore be used to evaluate if a given site is still set up according to its role.

The strategic performance measures used above are also used for internal benchmarking at the CC. However, sites are only benchmarked against similar sites based on site roles. This allows to set fair performance targets and to derive appropriate implications through benchmarking.

Process

The CC has taken a derivative approach to the definition of strategic performance targets and measures as proposed in the procedural framework described in Figure 24. Based on the overall corporate strategy, business strategies for each division were defined. Each division COO furthermore defined a division-specific manufacturing strategy containing the action plans for the manufacturing network development in the next year. The same was done by the head of the global operations function. The perspectives of the three division COOs and the head of global operations were merged and the overall manufacturing strategy developed. This manufacturing strategy focuses on manufacturing capabilities and network capabilities as well as a joint list of action plans (step 3 in Figure 24). The manufacturing network was not clustered below the network level but site roles were defined by global operations. The overall manufacturing strategy was merged with the site roles and a site specific strategy was derived (step 6 in Figure 24). This site-specific manufacturing strategy contains a focus on manufacturing capabilities, the site role specific contribution to the network capabilities and the overall strategic performance targets developed.

The method of evaluation for each performance dimension was selected (quantitative performance measures for the manufacturing and network capabilities, project status for action plans). The strategies and connected performance measures were presented to the site heads and discussed. Based on this discussion, the performance measures were then implemented and further communicated (steps 7-11 in Figure 24). Quantitative and process-based performance measures were implemented into the companies ERP-system which is to be harmonised throughout the manufacturing network. The performance in the assessed quantitative dimensions is openly available to all sites in the network. The fulfilment of action plans is reported annually. A review of site and network performance and the overall manufacturing strategy is conducted annually. This review is embedded into a corporate planning process and the so-called global operations meeting. Thus, results are centrally analysed, openly communicated and annually reviewed. The review of the performance also includes a review of the SPMMS in general (steps 12 – 15 in Figure 24).

Summary and Findings

- **NC 2 – Network Capabilities as Performance Dimensions:** The CC has developed a joint perspective on the manufacturing network, including all three technology divisions and the global operations function, and defined three main foci based on network capabilities which are to be pursued throughout the network.
- **NC 3 – Contribution to Network Capabilities as Performance Dimensions for Manufacturing Sites:** The network capabilities and connected targets are translated down to site level and, where feasible, targets for the manufacturing sites are set based on their contribution to the network capabilities.
- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** The core strategy paper defined by the different divisions mainly addresses projects and action plans focussing on change in structural and infrastructural levers throughout the network. This is reported annually and seen as a performance statement of the divisions and the global operations function.
- **NC 5 – Linking Manufacturing Strategy Formulation with the SPMMS:** The process of manufacturing strategy definition and the derivation of a cross-division focus on manufacturing capabilities and network capabilities were directly connected to the definition of performance measures and targets.
- **NC 6 – Setting targets for a Manufacturing Network as a whole:** The CC has defined overall targets for the manufacturing network (complexity reduction, exchange of knowledge, realisation of economies of scale and scope, continuous cost reduction).

- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** Targets at a manufacturing network level are translated downwards to site level. Currently, no cluster level has been established.
- **NC 9 – Using the Concept of Site Roles to set Targets and evaluate Site Performance:** The CC has defined site roles which are based on manufacturing process-level competences and an additional strategic perspective incorporating the development of the manufacturing network. The sites are to be benchmarked and compared only to other sites from similar roles.
- **NC 10 – Upward aggregation of Performance Measures and Data throughout a Manufacturing Network:** The CC aims to implement performance measures top down and aggregate the collected data bottom up.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** The CC's divisions annually report progress in action plans and projects addressing structural and infrastructural levers. The progress report is based on a qualitative project achievement status (finished, on-time, delayed etc.).
- **NC 12 – Allowing varying Foci of Performance across the Manufacturing Network:** NC 12 is only partially established at the CC. The varying perspectives on manufacturing strategy are held by the different technology divisions. Yet, they do not directly apply to different networks or sites within the CC, as the network and sites are producing for all divisions simultaneously. However, if the network was structured differently, the different foci would translate to different performance targets and could be implemented throughout the network.

4.1.4 Materials Technology Company

The Materials Technology Company (MTC) is a globally active manufacturer of components and products for the automotive industry and mechanical engineering. It is part of a bigger international enterprise. The MTC consists of five business units and over 40 manufacturing sites. The different business units focus on product groups and target different industries and markets with partly diverse market requirements. The MTC's parent company has a century-long history; it has purchased many companies and integrated them into its corporate structure. Traditionally, however, it has had rather weak headquarters and allowed the different business units to operate more or less autonomously.

In the last decade, the MTC's parent enterprise has been under considerable pressure from shareholders due to unfavourable economic developments. A decline in stock prices led to the inauguration of a new top-level management which fostered an enterprise-wide restructuring process. As a result of this restructuring process, the MTC was created and an increased central steering and support of the different business units was sought. As a part of this, various projects and initiatives have been launched to induce a new strategic alignment and increase the overall efficiency of the business units and the MTC.

Manufacturing Network

As pointed out above, the MTC consists of five BUs with a total of over 40 manufacturing sites. The BUs further comprise several companies that serve different markets with different products. Accordingly, the companies' manufacturing activities differ significantly. Since the different manufacturing sites focus on different products and markets, the interaction between manufacturing sites across companies and BUs is low. The MTC, however, has chosen to view its diverse manufacturing activities from a network perspective.

Manufacturing Strategy

Section 2.1 pointed out that the content of manufacturing strategy has many dimensions. However, as the manufacturing network of the MTC is extensive and diverse, it is difficult to define a detailed manufacturing strategy addressing all dimensions that harmonises the perspectives of all BUs and companies within the BU. For example, BUs and companies rank manufacturing capabilities significantly different and thus no unified focus on manufacturing capabilities can be formulated. Overall, the MTC's parent-enterprise put an emphasis on cost savings throughout the entire organisation and manufacturing. The MTC has taken up this focus as a strategy and strives for cost reduction in manufacturing by achieving operational excellence (OPEX) and increasing collaboration and exchange of know-how between manufacturing sites. To achieve operational excellence, a program was launched that relies on four pillars:

- **Realising quick wins:** All manufacturing sites were screened by experts from the MTC headquarters, resulting in a list of improvement plans to increase productivity and reduce costs.
- **Developing the MTC Production System:** Previously, all different BUs and companies had defined their own production systems. This hindered cross-BU and cross-company collaboration and exchange of know-how since terms and principles were not harmonised. Therefore, a common production system was defined. This ensures a common understanding of operational excellence throughout the MTC. The production system contains a list of principles that outline the MTCs approach to operational excellence. These principles are:

  - Continuous improvement
  - Process design
  - Lean manufacturing
  - Just in time
  - Supply chain management
  - Qualification
  - Teamwork
  - Visual management
  - Workplace optimisation
  - Sustainability
  - Zero accidents
  - Zero defects
- **Developing a Strategic Performance Measurement System:** Similar to the production system, performance measures and measurement systems previously were not aligned throughout the MTC. Therefore, a strategic performance measurement system was defined that includes performance measures in relevant dimensions that are identically defined and implemented throughout the network. To enable benchmarking, the performance data of the different sites is openly available throughout the network.
- **Implementing an OPEX organisation:** To support the achievement of operational excellence, a supporting organisation is to be developed and implemented throughout companies within MTC.

Strategic Performance on a Site Level

The strategic performance of manufacturing sites within the MTC manufacturing network is evaluated based on two of the four above described pillars. Firstly, the fulfilment of each principle of the Production System is evaluated at site levels with a combination of performance measures and a qualitative maturity scale which illustrates the application of each principle.

An example of a qualitative evaluation along a 5-point excellence scale is given for workplace optimisation:

1. No order visible, ergonomic aspects not considered, time is wasted by searching for materials and tools
2. Little and individually initiated order of workplaces, no standardization, material supplied in large boxes
3. Workplaces ordered in production as well as indirect functions (logistics etc.), tools clearly ordered and labelled, tools set-up close to machinery

4. Shadow-boards used for tool organization, special tools easily accessible, material supply located directly at workplace, ergonomic arrangement of all materials and tools
5. Ergonomic arrangement along work step-sequence in ideal height/distance, minimal operator movement required, first low-cost automation in place

Secondly, network-wide strategic performance measures were defined addressing core aspects of performance throughout MTC. These strategic performance measures are not weighed or emphasized across companies or BUs but each company can set a different emphasis on these strategic performance measures.

Strategic Performance Dimension		*Strategic Performance Measure*
Manufacturing Capabilities	*Costs*	*Value Added / Personal Costs*
	Quality	*Scrap + Rework + Warranties / Value Added*
	Delivery	*Deliveries on Time / Total Deliveries*
	Delivery	*Days of Inventory*
	Delivery	*Special Deliveries*
	Delivery	*Transport Costs/ Sales*
Employees	*Employee Health*	*Health Rate [%]*
	Employee Safety	*Accidents [#]*

Table 30 – Strategic Performance Measures of the MTC

The performance dimensions and performance measures defined above are collected from each site. While they are not directly linked to financial incentives of the site managers, the results of all manufacturing sites are freely accessible throughout the MTC. This open communication of strategic site performance has two results: Firstly, site managers are eager to perform well in comparison to other sites and thus enforce performance dimensions without being provided a financial incentive. Secondly, top performing sites are easily identifiable and are encouraged to support lower performing sites.

Strategic Performance on a Cluster Level

The MTC has not defined an explicit cluster level within its SPMS. However, the different companies or business units within the MTC can add additional company-specific strategic performance measures to the above list and thus set a different, company-specific focus of performance. Additionally, clusters are formed for internal benchmarking purposes. The different manufacturing sites are clustered based on their dominating value added activity (e.g., assembly, forging) and size. By clustering, more accurate performance levels can be identified and improvement potential can be identified more easily. However, these clusters are not seen as strategic entities with a unified manufacturing strategy since the sites are part of different companies with different strategic foci.

Strategic Performance on a Network Level

As described above, the overall network strategy of the MTC aims at saving costs and achieving operational excellence. The annual cost savings can be measured and ongoing achievements regarding operational excellence can be monitored. Additionally, the data collected on strategic performance measures at site level can be aggregated to the network level. However, this is only sensible for some of the strategic performance measures and rarely done in practice.

Process

For the development of the strategic performance measurement system a bottom-up and a top-down approach were combined. The bottom-up approach collected existing strategic performance measures from all BUs, companies and sites. The non-surprising result was that there were many similarities in the assessed performance dimensions (costs, quality, delivery etc.) but the used performance measures used were very different. Additionally, the expectations for a centrally implemented SPMMS were collected and evaluated to form a consistent understanding of the target state for the SPMMS. To unify the strategic performance measures, the top-down approach developed overall targets for the MTC in cooperation with leading managers and connected them to strategic performance measures. The defined strategic performance measures are to be rolled out to all manufacturing sites. So far, the strategic performance measures have been tested at selected manufacturing sites and are now gradually rolled out to additional sites.

The activities at the MTC support steps 9 to 15 of the procedural framework illustrated in Figure 24. After defining strategic performance measures and principles to support the production system top-down, they are tested at selected sites and agreed upon with key stakeholders (step 9) from the manufacturing network before being implemented network-wide (step 10). The strategic performance measures are then openly communicated throughout the network to raise awareness at all manufacturing sites (step 11). The MTC centrally collects raw data from the manufacturing sites. This means that not the values of the different strategic performance measures (e.g. ,“deliveries on time” / “total deliveries”) but the underlying data is reported (e.g. ,“deliveries on time” and "total deliveries" are reported separately). This is done for two reasons: Firstly, the definition of a strategic performance measure can change throughout the years. If such a change in definition is implemented, raw data allows the assessment of past performance of manufacturing sites according to this new definition. Secondly, the raw data allows the network level aggregation of performance measures without overemphasising the performance of small sites[28]. The aggregation of data at a network level supports step 12 of the procedural framework.

Once the data has been collected and aggregated, it is analysed and openly communicated (steps 13 and 14). Every site manager has access to the performance data of all manufacturing sites within the MTC. Finally, the performance measures and principles supporting the production systems are reviewed and can be amended over time (step 15).

Summary and Findings

The SPMMS of the MTC described in the above paragraphs shows similarities to the previous case studies. However, the network it is applied to significantly differs from the other case studies. Firstly, it consists of over 70 manufacturing sites and is therefore bigger than the previously discussed manufacturing networks. Secondly, it consists of multiple BUs and companies. This makes it difficult to define a holistic and detailed manufacturing strategy which translates downwards to the site level including site roles. This might furthermore not be desired by the BUs and companies as they prefer to operate rather autonomously. The SPMMS therefore focuses on aspects that can be commonly agreed upon throughout the MTC: Saving costs and establishing operational excellence. Overall, the case of the MTC supports the following new contributions to strategic performance measurement and management as suggested in this thesis:

- **NC 1 – Stakeholders as Performance Dimensions:** The MTC has incorporated strategic performance measures that directly address employee health and safety. Furthermore, the stakeholder demand of an overall better financial company performance is addressed through a focus on cost savings.

[28] If the strategic performance measure "deliveries on time" / "total deliveries" would be reported as a whole, network performance could only be calculated by using the average of all manufacturing sites. However, without weighing, this implies that small manufacturing sites have the same impact on network level delivery performance as big sites. By collecting the raw data, the ratio of "total deliveries on time in the network" / "total deliveries in the network" can be calculated without overemphasising the performance of small sites.

- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** The MTC evaluates the efficiency of its manufacturing activities based on defined principles in their production system.
- **NC 5 – Linking Manufacturing Strategy Formulation with the SPMMS:** The strategic performance dimensions incorporated in the SPMMS are directly linked to the manufacturing strategy of the MTC.
- **NC 6 – Setting targets for the Manufacturing Network as a Whole:** The manufacturing network as a whole focuses on saving costs and achieving operational excellence supported through the mutual support of manufacturing sites.
- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** The MTC has not explicitly defined a cluster level within their SPMMS. Yet, site level targets induced through the SPMMS are directly connected to network level targets.
- **NC 9 – Using the Concept of Site Roles to Set Targets and Evaluate Site Performance:** The MTC's manufacturing strategy does not explicitly define site roles. However, the sites are clustered based on their characteristics for evaluating site performance and the benchmarking of sites.
- **NC 10 – Upward Aggregation of Performance Measures and Data Throughout a Manufacturing Network:** Network level performance measures can be calculated based on site level performance. Network and site level performance data is therefore directly connected.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** To evaluate operational excellence, the MTC relies on performance measures and qualitative evaluation scales.
- **NC 12. Allowing Varying Foci of Performance Across the Manufacturing Network:** The MTC manufacturing networks consists of different BUs and companies. Each of these companies manufactures different products with different customer requirements. The MTC provides a central set of performance measures and principles for the evaluation of manufacturing site and network performance. However, each BU and company is allowed to add additional performance measures as needed based on BU strategy or company strategy.

4.1.5 Sanitary Products Company

The sanitary products company (SPC) is the European market leader in sanitary technology with a global orientation. The range includes the product areas of sanitary systems and piping systems. The SPC has currently started to expand its activities to Asia and North America. However, its core markets remain in Europe. The SPC trains up to 20’000 external professionals from the sanitary business per year in the correct installation and use of their products. Additionally, these trainings serve a marketing purpose. As a result of the extension to Asian and North American markets, the SPC faces an increased product variety and complexity in market requirements.

The SPC is a traditional manufacturer and has radically altered its manufacturing throughout the last decade. It has comprehensively introduced lean manufacturing concepts like one-piece-flow and a pull system.

Manufacturing Network

The manufacturing activities of the SPC are globally dispersed with a focus on Central and Eastern Europe. Overall, the network consists of 14 manufacturing sites, which are grouped into two networks based on the technologies and process steps conducted at the manufacturing sites. One of the networks is focused on plastics injection moulding, blow moulding and assembly. The other network is focused on extrusion and metal processing. For the purpose of the case study, only the former network will be discussed. The network consists of six manufacturing sites in Germany, Switzerland, Austria, Slovenia, India and China.

Manufacturing Strategy

The overall strategy of the SPC is based on four pillars:

- Focus on sanitary technology
- Commitment to innovation
- Selective geographical expansion
- Continuous optimisation of business processes

For the manufacturing network this means that the requirements superior product quality, innovation, the integration of new products and manufacturing sites for the geographical expansion and continuous improvement of all manufacturing processes and cost savings have to be met. To do so, the SPC has defined a production system that is structured in seven dimensions and underlying performance foci and principles. The overall mission statement of the production system is to be best in class by establishing stable, standardised processes and the reduction of waste. The seven dimensions of the production system and their underlying principles are:

- Consequent leadership
  - Pull system in production processes
  - Continuous improvement process
  - 5S (reduction of waste)
- Material
  - Low touch or no touch material
  - Just the right material
- Design
  - Design to cost
  - Standardisation
- Value adding employees
  - Prevention of accidents
  - Employee qualification
  - Employee flexibility
- Failure-free machinery
  - Total productive maintenance (TPM)
  - Single minute exchange of die (SMED)
  - Systematic problem solving
- Product
  - Quality
  - Delivery performance
  - Costs
- Processes
  - Value stream mapping (VSM)
  - Kanban
  - One piece flow
  - Clear responsibilities for processes
  - Optimal inventory levels

The implementation of the production system and the continuous development of the manufacturing activities constitute the core of the SPC's manufacturing strategy.

Strategic Performance on a Site Level

Similar to the evaluation of manufacturing sites at the MTC, manufacturing sites at the SPC are evaluated based on two mechanisms. Firstly, the above described principles are evaluated at the manufacturing sites based on qualitative assessments. Each site manager has to evaluate how well the different principles are followed and implemented at his manufacturing site. To do so, a colour scale similar to traffic lights is used. This evaluation is critically checked by the central network management and, if necessary, adjusted. Central management has an overview of the activities at the network's manufacturing sites and is thus able to competently judge the implementation degree of the principles at the different sites. Additionally, the central network management is also located at the lead factory. This enables central network management to stay up-to-date regarding latest technological developments. The evaluation is used to define targets for the next year that include the further implementation of the principles of the production system or the adjustment of other connected structural and infrastructural levers.

Secondly, a broad set of strategic performance measures is implemented. These strategic performance measures are partly connected to the principles of the production system and partly reflect important aspects of manufacturing performance as defined by the network management. Depending on the performance measure, the necessary data is collected daily, monthly or annually. The evaluation cycles differ accordingly.

Both the qualitative evaluation and the strategic performance based on strategic performance measures are connected to financial incentives for the site managers. Table 31 gives an overview of the SPC's implemented strategic performance measures at site level.

The strategic performance measures listed Table 31 are interesting for several reasons. Firstly, the SPC has implemented a broad array of strategic performance measures which are linked to various stakeholders' perspectives. For each strategic performance measure, targets relevant to the site managers' financial incentive are agreed upon. Site managers are responsible for the manufacturing activities and sales and thus can be evaluated based on profit and sales volume as well. Even employee sick days and the supplier performance are relevant to the site managers' incentives. The logic behind this is that the site managers are responsible for selecting their suppliers and need to manage their performance in a way that does not endanger a site's manufacturing activities. Similarly, employees need to be able to feel comfortable to reduce excessive sick days.

Strategic Performance Dimension		Strategic Performance Measure
Stakeholder Perspective	Investors/ Company Management	Profit [€]
		Cost Rate [%]
		Sales [pieces]
		Open Orders [pieces]
		Production Volume [pieces; only finished products]
		Number of New Orders at site [ordered pieces]
	Customers	Total Customer Complaints [#]
		Customer Complaints [ppm]
Manufacturing Capabilities	Costs	Production Volume [Finished Piece Equivalents (FPE); including semi-finished products and components]
		Productivity [FPE/ man hour]
		Energy Consumption [l (for Gas; kWh (for electricity)]
		Work Time spent for Non-Value Adding Activities [h]
	Delivery	On-Time Availability of Ordered Products at Site [%]
		On-Time Availability of Ordered Product at Customer [%]
	Quality	Material Waste [t]
		Critical Errors [#]
Manufacturing Structure and Infrastructure	Structural Levers	Inventory Level of Finished Goods [Pieces]
		Inventory Level of Components [Pieces]
	Infrastructural Levers	FTE [#]
Stakeholder Perspective	Employee Perspective	Employee Presence [h]
		Utilisation of Employee Hours [%]
		Employee Vacation Days [#]
		Employee Training Share [% of overall employee hours]
		Sick Days (long and short-term illness) [days]
	Supplier Perspective	Supplier Deliveries on time [%]
		Supplier Quality [ppm]
		Supplier Deliveries in full [%]

Table 31 – Strategic Performance Measures of the SPC

In contrast, the set of strategic performance measures barely addresses manufacturing capabilities other than costs and delivery. The reason for this is that the SPC strongly focuses on its productions system as the implementation of its manufacturing strategy.

From a manufacturing capabilities perspective, the SPC is very focused on quality superiority as it strives for high quality products to provide to its customers. Quality superiority as described in Subsection 2.1.4 does not only relate to products being free of faults, but aims at a higher product value as perceived by the customer. This perception, however, is more strongly influenced by product design and the underlying choice of material than the ability of the manufacturing function. Furthermore, it is very hard to define a performance measure for quality superiority. Therefore, quality superiority is not included in the list of the SPC's performance measures. Finally, as the overall network perspective is not part of the SPC's company, no performance measures addressing network capabilities have been defined.

Strategic Performance on a Cluster Level

The SPC has clustered its manufacturing activities into two clusters based on technology as explained above. One of these clusters is the network described in this case study. There are no explicit clusters defined below that level. Therefore, this level will not be covered in this section.

Strategic Performance on a Network Level

The SPC does not aggregate performance to the network level. The principles of the production system and the performance measures are binding for all manufacturing sites. The sites are evaluated based on their individual strategic performance on the principles of the production system and the strategic performance measures. The discussion of network level performance is therefore not part of the SPC's SPMMS.

Summary and Findings

This case example differs in several aspects from the previous case studies. Firstly, no network thinking has been implemented at the SPC. Instead, each manufacturing site is evaluated autonomously and held fully responsible for sales and supply as well. Secondly, the SPC's extensive focus on stakeholders as performance dimensions is unique among the conducted case studies. Overall, the following findings were made:

- **NC 1 – Stakeholders as Performance Dimensions:** The SPC addresses all stakeholder perspectives as defined in the structural framework except for communities and regulators.
- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** The SPC's SPMMS strongly focuses on the implementation of the production system and the principles addressing structural and infrastructural levers.

- **NC 6 – Setting Targets for the Manufacturing Network as a Whole:** This is only partially applicable to the SPC, as the SPC does not view its manufacturing activities from an overall network perspective. However, the performance dimension, principles and strategic performance measures are binding for the entire network and all sites. Therefore, strategic performance targets for the manufacturing network are set.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** The SPC greatly emphasises the qualitative and assessment-based evaluation of the strategic performance at site level. The implementation of the production system is evaluated qualitatively. This qualitative evaluation affects site managers' financial incentives.

4.1.6 Pharma Company

The Pharma Company (PC) is a globally active, research-based pharmaceutical company that manufactures innovative pharmaceuticals. It mainly produces medicine and vaccines as well as consumer health care products for humans but also animals. In its century-long history, the PC has significantly grown and merged with other companies.

Manufacturing Network

The PC manufacturing network consists of approximately 60 sites which are dispersed world-wide. The manufacturing network has been growing through internal site openings as well as the acquisition of other companies. After the biggest acquisition, the overall manufacturing network consisted of almost 100 sites. This number was then reduced to the current 60 sites. The sites in the manufacturing network belong to different business units/companies within the PC and produce products based on over 2'000 formulas for over 170 regional markets. The manufacturing network is supported and supervised by a central department. This central department is responsible for the monitoring and development of the entire supply chain including suppliers.

Manufacturing Strategy

The PC has continuously developed and improved its manufacturing strategy. Historically, it has developed from an operational, right-first-time perspective to a broader set of strategic objectives and requirements. These strategic objectives and requirements are directly linked to the overall vision and mission of the company and manufacturing. The strategic objectives are:

- Ensure customer satisfaction
- Develop the supply chain
- Increase flexibility of the supply chain
- Increase adaptability of the supply chain

The strategic requirements of the manufacturing network are:

- Deliver value to customers
- Partner with business
- Support business
- Achieve operational excellence
- Deploy transformational technology throughout the network
- Drive accountability

The objectives and requirements are addressed by improving strategic key areas within the PC manufacturing network:

- Drive 0 defects in manufacturing processes
- Reach saving and inventory targets
- Embed flexibility in the supply chain to recognize the segmented nature of the business
- Redefine above site corporate processes and increase value added
- Develop and deploy local and small scale manufacturing solutions
- Develop overall organisational structure

The lists of strategic objectives, requirements and key areas represent a broad array of manufacturing targets. Generally, the core motifs can be identified as increasing quality, saving costs and improving value adding of all sites and entities in the network. Additionally, the PC has realised that certain technologies, production processes and products need to be adapted to local needs. The PC therefore wants to increase the implementation of local and small scale manufacturing solutions and adopt centrally identified solutions to local needs.

Strategic Performance on a Network Level

The PC has developed two main initiatives that continuously evaluate network and site performance. One initiative is based on the qualitative evaluation of principles that describe an ideal set-up of manufacturing activities. The other is based on quantitative performance measures. The qualitative assessment focuses on 20 principles which are arranged in five categories. The principles apply to the overall manufacturing network as a whole as well as to individual manufacturing sites. However, the relevance of each principle can vary between manufacturing sites based on their product portfolio or market. Overall, the following five categories are evaluated:

- Customer focus
- Supply strategy
- Delivery capabilities
- Engaged colleagues/leaders
- Key enablers for manufacturing performance

An example of a principle for the customer focus category would be “goals of network and sites defined by customer needs”. All principles are assessed by a central team and each site and network performance is ranked on a scale from 0 (not fulfilled at all) to 5 (fulfilment is best in class). The results at site and network level are depicted in radar charts and openly accessible to all sites within the network. The full set of principles cannot be shared here due to confidentiality.

The quantitative initiative of strategic performance measurement is based on an adapted balanced scorecard which directly reflects the strategic objectives, requirements and key areas for improvement. The four perspectives of the PC-BSC are customer perspective, financial perspective, the people/capability perspective and internal process perspective. These have been extended by a fifth perspective: Environment, Health and Safety (EHS). Table 32 gives an overview of the different strategic performance measures in the BSC perspectives and matches them with the respective strategic performance dimension of the structural framework developed in Chapter 3.

Several things are interesting regarding the strategic performance measures employed in the PC BSC. Firstly, many of the performance measures address quality and EHS. This is based on the fact that the PC a) has a high focus on product and process quality and b) follows the corporate strategy of focusing on EHS aspects. Core aspects of the overall company strategy are therefore reflected in the strategic performance measures for the manufacturing network. Secondly, the PC deploys several strategic performance measures that are not process-based but focus on the achievement of milestones and thus the development of manufacturing activities. Thirdly, the PC has used the BSC as a framework for their SPMMS. However, as pointed out in Chapters 1, 2 and 3 of this thesis, the original BSC does not fulfil all requirements of manufacturing networks and thus had to be amended and adjusted.

BSC Perspective	***Strategic Performance Measure***	***Strategic Performance Dimension***
Customer	Stock levels	Structural Levers
	Line Item Fill Rate	Structural Levers
	New Product Milestones fulfilled	Structural Levers
Financial	Budget Variance	Investors
	Cost Change	Investors
	Asset Effectiveness (Sites)	Structural Levers
	Inventory Value (per Product)	Structural Levers
	Asset Utilisation (Network Level)	Structural Levers
	Month of Inventory at hand	Structural Levers
People/capability development	Process Robustness/Right First Time	Quality
	Lead Time	Delivery
	Schedule Adherence	Delivery
	Employee Retention Rate	Employees
	Leadership Development (Based on Milestone Fulfilment)	Employees
Internal Process Perspective	Completed Quality Investigation in Time (%)	Quality
	# Repeated Deviations in Quality	Quality
	# Quality Investigations per 100 Batches	Quality
	# of Regulatory Inspections Conducted	Quality
	# work reviews	Quality
	# of Completed Quality Benchmarks	Quality
Environment, Health and Safety	Injury Rate	Employees
	Accidents	Employees
	(#) Regulatory Compliance Issues	Regulators
	Green House Gas Emissions	Communities & Regulators
	Water Usage	Communities & Regulators

Table 32 – Content of the PC BSC

Strategic Performance on Cluster and Site Level

The qualitative and quantitative performance measures described in the previous paragraphs are binding for all manufacturing sites, companies or business units within the PC and the entire manufacturing network. Partially, they are also used to evaluate suppliers. However, the extent to which they are enforced and specific targets for the various performance levels vary throughout the network. Centrally, the PC has defined minimum performance levels along certain performance measures. The site-specific or business unit and company-specific performance targets are then defined in collaboration with sites and business units. This way, sensible and useful targets can be set. Originally, the PC defined identical performance targets for all sites within the manufacturing network. However, it soon became evident that a more individualised approach was necessary.

Process

Although the process of SPMMS was not discussed in detail, the following aspects of the procedural framework defined in Section 3.6 were observed in the PC's approach. Firstly, the overall manufacturing strategy, objectives and requirements are directly connected to company and business strategy (steps 1 – 3 of the procedural framework). Furthermore, the manufacturing network is clustered based on companies or business units which can adjust the strategic performance targets and parts of the strategy to their specific businesses. Similarly, targets and strategies for manufacturing sites can be tailored to their specific situation (steps 4 – 6 of the procedural framework). Finally, measures are openly communicated throughout the network (step 11), data is centrally gathered and aggregated (step 12), analysed (step 13) and openly communicated throughout the network (step 14). In fact, all manufacturing sites have access to the performance data from the qualitative and quantitative assessment of other sites and the overall network. Finally, every September the performance measures are reviewed and, if necessary, replaced in accordance with updates of the manufacturing strategy or general organisational developments (step 15). On average, 3 to 4 performance measures are replaced on an annual basis.

Summary and Findings

The case of the PC shows similarity to the case of the MTC. Both manufacturing networks are rather big (>40 sites) and incorporate several businesses and companies with varying foci. Furthermore, the SPMMS were originally launched based on initiatives to promote product and process quality improvements and cost savings. Finally, both SPMMS allow the adjustment of performance targets and performance measures based on cluster or site specificities. Overall, the following new contributions to SPMMS for manufacturing networks as defined in Section 3.7 can be identified in this case study:

- **NC 1 – Stakeholders as Performance Dimensions:** The PC's SPMMS includes performance measures that address customers, investors, regulators, communities and employees.
- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** The PC includes several measures addressing network structure and infrastructure (e.g., inventory levels etc.) in its SPMMS.
- **NC 5 – Linking Manufacturing Strategy Formulation with the SPMMS:** The content of the strategic performance measurement system and the performance dimensions are directly connected to the overall company strategy and vision.
- **NC 6 – Setting Targets for the Manufacturing Network as a Whole:** The PC has developed performance principles that describe the aspired strategic set-up for the overall manufacturing network.
- **NC 7 – Implementing Clusters:** Based on product groups or companies within the PC, specific adjustments to manufacturing strategy and performance evaluation are implemented. Although no clusters are currently implemented for the SPMMS, existing clusters (companies, product groups) are utilised for effective performance measurement.
- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** Since overall targets for the manufacturing network are defined, the contribution of clusters and sites is translated downwards.
- **NC 10 – Upward Aggregation of Performance Measures and Data Throughout a Manufacturing Network:** Where feasible, performance on site level is aggregated upwards to cluster and network level.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** The performance principles are evaluated based on an assessment approach.
- **NC 12 – Allowing Varying Foci of Performance Across the Manufacturing Network:** The PC allows companies and business units within its network to focus on specifics aspects of performance relevant to their respective product group or business.

4.1.7 Insulation Company

The case of the Insulation Company (IC) serves a different purpose than the other cases discussed in this chapter. While it will illustrate the application of some new contributions as pointed out in Section3.7, its core purpose is to outline what can happen when the focus of strategic performance measures and network clustering are chosen poorly.

General Information

The IC is one of the global leaders in the insulation industry. It produces insulation material from natural resources. All products of the IC are made from the same base material, but vary in their properties and application. Products include insulation materials for residential and non-residential buildings, acoustic ceilings, cladding boards, solutions for the horticultural industry and special fibres for industrial use. The IC has a broad customer base that ranges from private home owners to construction businesses and horticultural businesses.

Manufacturing Network

The manufacturing activities of the IC focus on the European Market. Overall, 13 manufacturing sites are located throughout Europe. The production process at each site is similar. Raw material is molten, spun into wool and the wool is pressed, cut, further processed and packaged according to product specification. The process is fully automated and the production line is split at the end to deliver the wool to product-specific machinery that cuts, forms and packages the final product according to its specifications. The production process is very investment and energy intensive and runs continuously. While running, only one single product at a time can be made since only one product-specific machine can be fed with the flow of wool. The different manufacturing sites then differ according to the overall production volume and the specialised machinery that is located at the end of the production line. The latter defines which products can be manufactured at a given site.

The manufacturing sites are further part of one of 4 regional clusters. These regional clusters are responsible to deliver products to their respective national markets. Each cluster is responsible for 3 to 9 national markets depending on its location. The manufacturing sites of each regional cluster combined produce most if not all of the product range of the IC. Since the product of the IC is very high in its specific volume, logistics become a significant cost factor.

Manufacturing Strategy

The IC has attempted to rank manufacturing capabilities and network capabilities according to their respective importance. Network priorities for the European manufacturing network were ranked and the ranking illustrated the need for an increased mobility of processes (and thus products) and knowledge exchange. However, it was not possible to homogeneously rank the manufacturing capabilities for the entire network. Instead, three product groups with varying requirements towards manufacturing were identified:

- Product group A includes a wide range of commodity products. These products need to be produced at the lowest possible costs while sustaining a good level of quality conformance and specification, delivery reliability and service.
- Product group B contains a wide array of specialised applications which are not as price sensitive. Instead, innovation and service are considered to be order winners. All other manufacturing capabilities are order qualifiers.
- Product group C exclusively aims at construction companies. As storage space is scarce at construction sites, the delivery of the products needs to be done on time. Otherwise, construction activities come to a halt. Therefore, delivery reliability, delivery flexibility and service are ranked as order winners for product group C. All other manufacturing capabilities are ranked as order qualifiers.

Although the above describe product groups have very different foci regarding manufacturing capabilities, all of them are produced at the same sites.

Strategic Performance at the IC

Managing directors as the heads of the regional clusters are mainly incentivised with financial performance measures. 20 % of their incentive is based on EBIT of the IC group, 40 % on regional cluster sales, 10 % on cost optimisations within the regional cluster and the last 30 % are based on individual targets. As 50 % of the incentives are based on regional clusters achievement, the general managers (GMs) strive to:

- Allocate a broad array of products to their regional clusters so that all demands of the regional markets can be fulfilled from the cluster's manufacturing sites
- Increase capacity utilisation at the manufacturing sites to decrease the fixed cost allocation per ton of product produced

Problems with the SPMMS at the IC

There are several problems with the way performance is measured and incentivised at the IC. Firstly, the GMs are mainly incentivised based on financial performance measures. This leads GMs to optimise their regional clusters based on these performance measures. As they want to increase sales, they only sell products produced by their sites within their regions. This is done even if a delivery from a neighbouring regional cluster would arrive at the customer faster. Secondly, the regional clusters strive for covering the full range of products requested in their respective national markets. This leads to the duplication of manufacturing competences and investments as machinery is often purchased multiple times throughout the network. Thirdly, since the GMs strive for a broad range of production competences in their clusters and sites, it is not possible to focus production on a single product group. As each cluster produces all product groups, it is not possible to measure performance and set targets based on manufacturing capabilities. This is further made impossible by the way the manufacturing network is organised. While a market-focused organisation is sensible for a sales network, this is not necessarily true for a manufacturing network. Once different product groups vary greatly in their demands on manufacturing, it is very difficult to meet these demands when all product groups are produced at a single site. Fourthly, network capabilities and the concept of network thinking above the regional clusters are not implemented at the IC; neither in manufacturing strategy nor in the GMs' incentives.

The problems and shortcomings described above lead to a sub-optimisation of the European manufacturing. Supported by the GMs' incentives, each regional cluster strives for an individual instead of the network-level optimum.

Summary and Findings

The case study of the IC was discussed to show the potential outcomes of a sub-optimal clustering and the setting of inadequate performance measures for a manufacturing network. Besides, two of the new contributions for SPMMS were partly identified in this case study.

- **NC 1 – Stakeholders as Performance Dimensions:** The SPMMS of the IC is mainly focused on financial performance measures relevant for investors and company management.
- **NC 7 – Implementing Clusters:** The IC has implemented clusters based on regional markets. The ranking of the manufacturing capabilities suggests that a clustering based on product groups is possible.
- **NC 12 – Allowing Varying Foci of Performance Across the Manufacturing Network:** While the current set-up of the SPMMS is set mainly on financial goals, the IC has recognised that its products require different foci of performance. However, this has not yet been implemented. Therefore, NC 8 can only be partially demonstrated through this case study.

4.2 Summary & Discussion

The aim of this chapter was to show the applicability and validity of the structural and procedural frameworks defined in Chapter 3. To do so, case studies from a variety of industries reflecting different types and sizes of networks were used. Each case study discussed the respective SPMMS and its characteristics. While none of the case studies illustrated both frameworks in their entirety, all performance dimensions of the structural framework, all steps of the procedural framework and all new contributions could be found in the case studies. This section will now provide a short overview of which case study reflects which part of the frameworks and which new contributions. Overall, this section will show that the developed structural and procedural frameworks are comprehensive, valid and applicable. Since the structural and procedural frameworks fulfil both the demands manufacturing networks place on SPMMS as well as general demands on SPMMS (cf. Section 3.2), the proposed SPMMS is superior to existing SPMMS in its applicability to manufacturing networks.

4.2.1 Applications of the Structural Framework in the Case Studies

The structural framework defined in Section 3.5 incorporates four internal performance categories as well as the stakeholders that surround a manufacturing network. It supplies an organisational structure for the collection and organisation of strategic performance targets and measures. The different performance dimensions are interlinked and the derivation of performance targets and measures from manufacturing strategy in the performance dimensions is supported by guiding questions.

When applying the structural framework, a company has to identify which performance dimensions are relevant to its specific set-up and manufacturing network and derive strategic performance measures and targets accordingly. Thus, not all performance dimensions have to be addressed at all times. Rather, the SPMMS has to fit the manufacturing strategy. Not all of the SPMMS described in the case studies contain every single strategic performance dimension. Table 33 summarizes which performance dimensions were addressed in the different case studies.

Performance Dimensions	*Applied in Case Study*
Stakeholders evaluating output	EPC (Investors); SPC (Investors, Customers); PC (Investors, Customers, Regulators, Communities); IC (Investors);
Manufacturing Capabilities	EPC (Cost, Quality, Delivery, Flexibility, Innovation, Service); PFC (Cost, Quality); CC (Cost, Quality, Delivery, Flexibility, Innovation); MTC (Cost, Quality, Delivery); SPC (Cost, Quality, Delivery); PC (Quality, Delivery)
Network Capabilities	CC (Mobility, Knowledge and Best Practice Exchange)
Structural Levers	PFC (Inventories, Production Volume); CC (Inventories, Production Volume, Complexity, Site Specialisation); MTC (Inventories, Value added); SPC (Inventories, Process Layout); CC (Inventory levels, Asset utilisation)
Infrastructural Levers	PFC (Lean Production); CC (FTE at site, Overhead at site); MTC (Production System; Lean Production); SPC (FTE, Production System)
Stakeholders Providing Input	EPC (Employees); PFC (Employees); CC (Employees); MTC (Employees); SPC (Employees, Suppliers); PC (Employees)

Table 33 – Application of Performance Dimensions in the Case Studies

Table 33 shows that all performance dimensions were addressed at least in one case study. This is important as it illustrates the validity of the performance dimensions described at the structural level. Furthermore, all strategic performance measures and targets described in the case studies can be matched to one of the performance dimensions included in the structural framework. Therefore, it is concluded that the structural framework is complete - it incorporates all performance dimensions relevant to the case studies. Table 33 furthermore illustrates which aspects of the different performance dimensions were incorporated into the SPMMS described in the case studies.

Importantly, not all aspects of the different performance dimensions described in the structural framework were incorporated into the examined SPMMS. This is not surprising, as the content for a network-specific SPMMS should be based on the manufacturing strategy of the respective network; however, a manufacturing strategy reflects relevant aspects of the manufacturing activities and the manufacturing environment rather than providing a comprehensive overview and addressing all aspects. The aspects discussed in the manufacturing strategies and SPMMS of the case companies therefore reflect a list of relevant topics for their respective manufacturing networks; thus, the case studies comprise a broad but not exhaustive list of performance aspects.

Compared to the other structural frameworks deployed in SPMMS described in Section 2.2, the structural framework developed in this thesis shows superior applicability to manufacturing networks. Reasons for this are that it a) incorporates the performance dimensions that are eminent to manufacturing networks and b) holistically supports the evaluation of strategic performance by providing a comprehensive list of performance dimensions for manufacturing networks.

4.2.2 Applications of the Procedural Framework in the Case Studies

While the structural framework provides a structure for the derivation of performance targets and measures from manufacturing strategy, the procedural framework illustrates the underlying process of strategic performance measurement and management. As Section 3.6 pointed out, this process is based on existing structural frameworks and was amended to cater to the requirements of manufacturing networks. It incorporates state of the art findings in the literature and was extended by practical experiences. Table 34 illustrates which case study includes which step of the procedural framework.

Step	*Step Description*	*Applied in Case Study*
1	Company Strategy	EPC; CC; PC
2	Business Strategy	CC; PC
3	Overall Manufacturing Strategy	EPC; CC; PC
4	Clustering the Manufacturing Network	PFC; PC
5	Cluster specific Manufacturing Strategy	PFC; PC
6	Site Specific Manufacturing Strategy	EPC; CC; PC
7	Determine method of evaluation for targets	EPC; CC
8	Design Measures/ Evaluation Criteria	EPC; CC
9	Test and Agree on Measures/ Evaluation Criteria	EPC; CC; MTC
10	Implement Measures /Evaluation Process	EPC; CC; MTC
11	Communicate Measures	CC; MTC; PC
12	Gather and Aggregate Data	CC (to be implemented) ; MTC; PC
13	Analyse Results	CC (to be implemented); MTC; PC
14	Communicate Results	CC (to be implemented); MTC; PC
15	Review	CC (to be implemented); MTC; PC

Table 34 – Application of the Procedural Framework in the Case Studies

Table 34 shows that all steps of the procedural framework were addressed at least in one case study. This is important as it illustrates the validity of the described steps. However, the SPMMS process was only fully covered in the case study of the CC. A broader support from further case studies is desirable. Compared to other procedural frameworks as described in Subsection 2.2.5, the procedural framework at hand is more detailed and includes novel additions to the literature on strategic performance measurement and management, namely the inclusion of different levels, clusters and site roles that allows the easier definition of strategy, performance targets and measures.

4.2.3 Applications of the New Contributions in the Case Studies

Being based on a thorough literature review, the structural and procedural frameworks contain previously known procedures and aspects, but have been innovatively extended to be applied to manufacturing networks. Section 3.7 provided a list illustrating the new contributions to both literature and practice. However, as Chapter 3 and the procedural frameworks were of conceptual nature, the new contributions had to be tested.

	Contributions	*Electronic Switch Company*	*Pet Food Company*	*Cable Company*	*Materials Technology Company*	*Sanitary Products Company*	*Pharma Company*	*Insulation Company*
NC 1.	**Stakeholders as Performance Dimensions**	✓	✓	✓	✓	✓	✓	✓
NC 2.	**Network Capabilities as Performance Dimensions**			✓				
NC 3.	**Contribution to Network Capabilities as Performance Dimensions for Manufacturing Sites:**			✓				
NC 4.	**Structural and Infrastructural Levers as Performance Dimensions:**		✓	✓	✓	✓	✓	
NC 5.	**Linking Manufacturing Strategy Formulation with the SPMMS:**	✓		✓	✓		✓	
NC 6.	**Setting targets for a Manufacturing Network as a whole:**	✓	✓	✓	✓	(✓)	✓	
NC 7.	**Implementing clusters:**		✓				✓	✓
NC 8.	**Connection of Network Level, Cluster Level and Site Level:**	✓	✓	✓	✓		✓	
NC 9.	**Using the Concept of Site Roles to set Targets and evaluate Site Performance**	✓	✓	✓	(✓)			
NC 10.	**Upward aggregation of Performance Measures and Data throughout a Manufacturing Network**			✓	✓		✓	
NC 11.	**Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks**	✓		✓	✓	✓	✓	
NC 12.	**Allowing varying Foci of Performance across the Manufacturing Network:**			(✓)	✓		✓	(✓)

Table 35 – Application of the New Contributions in the Case Studies

As Table 35 illustrates, all new contributions were implemented at least in one company. Applied new contributions are marked with a check mark. If a new contribution was only partly identified at a company, the check mark is shown in parentheses. The application of the different new contributions in the case studies will now be discussed in detail.

- **NC 1 – Stakeholders as Performance Dimensions:** All of the discussed case studies addressed performance regarding at least one of the stakeholder groups in their SPMMS. However, in most cases the companies focussed on employees or investors. This is because information relevant to investors is usually measured in internal controlling processes anyway. Performance measures regarding employee well-being and development have entered performance measurement in the manufacturing environment through more holistic SPMMS such as the EFQM model or the Baldridge Award. In some cases, customers were included as performance dimensions. However, in most cases the demands that customers have towards manufacturing were translated to manufacturing capabilities and measured as manufacturing results. Suppliers were only considered as performance dimensions by the SPC. Whether suppliers are included into a SPMMS to evaluate network or site performance greatly depends on the organisational set-up. In some cases, manufacturing sites did not select their suppliers directly. In those cases it does not make sense to evaluate site performance based on supplier performance. Finally, only the PC had included strategic performance measures addressing communities and regulators. This might be due to the fact that a holistic perspective on strategic performance in manufacturing network had not yet been established. Additionally, regulators and communities mostly impose long-term laws and regulations on companies. Once these are implemented, they do not need to be monitored anymore on a strategic basis and therefore are not included in a SPMMS. The illustratory case of the Pharma Packaging Company in Subsection 3.5.5 showed further exemplary strategic targets regarding regulators and communities. As manufacturing strategies increasingly include a focus on sustainability, it is more likely that this will also be included in performance measurement. In conclusion, the defined stakeholders seem valuable extensions to previously discussed manufacturing performance dimensions.
- **NC 2 – Network Capabilities as Performance Dimensions:** Network capabilities were used as performance dimensions in one case study (the cable company). Generally, many companies do not view their manufacturing activities from a network perspective. Thus, they also do not define a manufacturing network strategy addressing network capabilities. This makes it impossible to include strategic performance measures addressing network capabilities into an

SPMMS. That only one case study incorporated network capabilities as performance dimension does not mean that this inclusion is difficult. Instead, it shows that many companies don't yet have network capabilities on their strategic agenda. However, the CC case study showed that the definition of targets and strategic performance measures is possible.

- **NC 3 – Contribution to Network Capabilities as Performance Dimensions for Manufacturing Sites:** The contribution to network capabilities at a site level can only be included in a SPMMS if network capabilities are at all discussed in a manufacturing strategy. Since only one case study included network capabilities, the site contribution to network capabilities was also only included in one case study. However, this case study illustrated that the definition of targets and strategic performance measures addressing network capabilities can be deployed to site-level.
- **NC 4 – Structural and Infrastructural Levers as Performance Dimensions:** Structural and infrastructural levers were included as performance dimensions in most of the case studies' SPMMS. The reviewed strategic performance measures mostly addressed inventories and the production volume in the factories and networks. These aspects of strategic manufacturing performance are discussed in companies on a daily basis and, therefore, included in SPMMS. As the core task of a manufacturing network is the production of goods, it is sensible to have an overview of the produced volumes. Inventory levels are relevant to logistical forecasts and have been increasingly discussed in connection to lean manufacturing as they are considered potential "waste". Further structural and infrastructural levers addressed in the case studies included the employee structure, the production system, site specialisation, complexity etc. It is important to note here that the majority of a formulated manufacturing strategy revolves more around structural and infrastructural levers (i.e. what is produced where with what technology) than the positioning along manufacturing capabilities. Therefore, structural and infrastructural levers should be part of any SPMMS for manufacturing networks.
- **NC 5 – Linking Manufacturing Strategy Formulation with the SPMMS:** Only four companies directly linked the formulation of a manufacturing strategy to the SPMMS. This might seem very few; however, the process of the SPMMS was only covered in four case studies. Therefore, all of the covered processes directly linked manufacturing strategy formulation to their SPMMS. This is only logical as measured performance in a manufacturing network is used to set targets for the next measurement period. These targets should be reflected in the

manufacturing strategy. The SPMMS therefore contributes to the manufacturing strategy formulation.

- **NC 6 – Setting Targets for the Manufacturing Network as a Whole:** Five of the discussed case studies set targets for their manufacturing network as a whole. While targets are generally set for a manufacturing function (e.g., reduce costs by 10 %), NC 6 specifically includes targets that support collaboration between manufacturing sites and targets that incorporate network thinking instead of addressing each manufacturing site individually. By setting network level goals and systematically deriving targets at cluster or site level, companies make the collaborative aspects between their sites visible and support their manufacturing sites in collaborative efforts. Especially the CC case study illustrated that NC 6 can be fulfilled.
- **NC 7 – Implementing Clusters:** Only three case study companies had implemented clusters in their manufacturing networks. Clustering is part of the newly devised procedural framework to generate entities with homogeneous environments and structures that allow for a) the setting of focused targets and thus for a focused development of the clusters and sites and b) the meaningful benchmarking and performance comparison between sites. Two reasons may account for the fact that not more companies had implemented clusters: Firstly, as pointed out in Chapters 1 and 2, manufacturing networks often grow through acquisitions and historic developments. Thus, the structure of sites is often very heterogeneous. As restructuring is expensive, many manufacturing managers follow the pragmatic approach of leaving a running system as it is. The resulting lack of focus makes a clustering difficult. Secondly, even if a company serves very diverse markets and manufactures very different products, the products for the diverse markets are often produced at the same manufacturing site. This is done to save money and to make maximal use of the capacity at different sites. However, this makes it difficult to establish a specific focus at a manufacturing site (e.g., flexibility). Similarly, the implementation of clusters is difficult. In conclusion, the definition of clusters in an SPMMS greatly benefits the strategic focus and target setting but often fails due to the unfocused structure of the manufacturing network. However, three case studies have illustrated that it is possible and valuable to implement clusters.
- **NC 8 – Connection of Network Level, Cluster Level and Site Level:** The logical connection of network level, cluster level and site level performance measurement and targets is a necessity in a structured and transparent SPMMS. It was observed in five of the discussed case studies. Generally, most companies logically connect the different levels of their organisation within an SPMMS. For

manufacturing networks however, this is a novelty, as the network level has been newly introduced in this thesis.

- **NC 9 – Using the Concept of Site Roles to Set Targets and Evaluate Site Performance:** Similarly to the setting of clusters in manufacturing networks, the definition of site roles is often hindered by the historic and unfocused development of manufacturing networks. Many companies do not specifically define site roles for their manufacturing sites and thus cannot utilise this construct in terms of target setting and performance evaluation. However, four of the above provided case studies utilised site roles for strategic target setting and performance measurement and evaluation at site level.
- **NC 10 – Upward Aggregation of Performance Measures and Data Throughout a Manufacturing Network:** Only three of the described case studies aggregated performance measures and data to the network level. Generally, the feasibility of network level aggregation depends on two aspects. Firstly, the aggregation has to be technically feasible. This means that IT-infrastructure, performance measures and targets need to be harmonised in a way that allows for an upward aggregation. Secondly, the aggregation needs to be sensible. A company implementing a network level SPMMS needs to know what questions it wants to answer on a network level.
- **NC 11 – Use of Qualitative and Assessment-Based Evaluation for Strategic Performance in Manufacturing Networks:** The case studies have illustrated that a combination of quantitative performance measures and qualitative, assessment-based evaluation procedures can be implemented into SPMMS in practice. It could be observed that the qualitative approaches complement quantitative performance measures by a) aiding the understanding and evaluation of quantitative performance measures and b) focussing on structural and infrastructural levers. Generally, the choice between qualitative and quantitative measure depends on the specific strategic target under evaluation.
- **NC 12 – Allowing Varying Foci of Performance Across the Manufacturing Network:** Four of the discussed case studies allowed for varying performance foci within their manufacturing networks. Whether varying foci are indeed needed depends on the network's contextual factors (e.g., very heterogeneous markets are supplied) and set-up (e.g., if it is possible to define clusters or site roles).

4.2.4 Concluding Remarks

So far, this chapter has discussed case studies that validated the applicability of the structural and procedural framework developed in Chapter 3. The verification of both frameworks was successful. Furthermore, the new contributions defined in Section 3.7

were validated. To finalise the discussions, this subsection will now present further insights gathered from the work and discussions with the companies who were represented in the case studies as well as project work with companies that were not discussed in the case studies[29].

The case studies described in this chapter reviewed company-specific SPMMS. None of the SPMMS incorporated all performance dimensions and aspects from the structural framework, followed all steps of the procedural framework or addressed all new contributions simultaneously. While this might seem contradictory to the frameworks at first, it absolutely is not. Firstly, both frameworks were developed based on a thorough literature review and accompanied by insights that were added in an iterative fashion during the collaboration with the case study companies. While some of the collaborations aimed at designing a SPMMS for the companies, some companies already had SPMMS that thus just served as illustrative examples for this thesis. Secondly, the frameworks were based on scientific literature and contain all relevant performance dimensions and all relevant steps of strategic performance measurement and management. While the frameworks themselves are complete, their practical application does not need to contain all of the framework's elements. Most importantly, a SPMMS needs to fit the company strategy, company structure and contextual factors. While readers and practitioners are encouraged to consider all performance dimensions of the structural framework and all steps of the procedural framework, company-specific adjustments may be necessary. For example, currently most companies do not consider all performance dimensions of the structural framework when discussing manufacturing site and network performance; but not all of these dimensions might be relevant for any given company. The performance dimensions of a given company's SPMMS should only consist of dimensions of strategic importance. The structural framework then should be used as a basis for internal discussions about which dimensions should be included. Similarly, while the procedural framework outlines a process that should be followed for the implementation and use of an SPMMS, certain steps, such as clustering, can be skipped if they are irrelevant for a given manufacturing network.

Steps 3 to 6 of the procedural framework cover the general strategy formulation, structuring of the manufacturing network and derivation of site-specific manufacturing strategies. While these steps might seem obsolete to practitioners who might think that they have an inherent understanding of manufacturing strategy, clusters and site roles, the same practitioners might be surprised to find that discussion with different members

[29] A general overview of interviews and workshops as foundation for this thesis can be found in section 1.5.

of the same organisation often reveal drastic differences. For example, when asked to rank manufacturing capabilities according to their importance for future business success, the CC's technology divisions, global operations and sites all gave different rankings (even though similar tendencies could be observed). This is not a surprise - one might expect to find similar results in most companies. Thus, steps 3 to 6 of the procedural framework force a company to explicitly define a manufacturing strategy, define the borders of the manufacturing network, structure the network and derive strategic targets for all clusters and sites in the network. Once this understanding has been established and distributed throughout the company, strategic performance targets and measures that are aligned to this understanding will be more easily accepted.

Another reason for the usefulness of a manufacturing network's clustering lies in the complexity a manufacturing network might face. With an increase in internal and external complexity, the definition of a meaningful, significant and effective manufacturing strategy and the derivation of strategic targets and measures become increasingly difficult. For example, the MTC's manufacturing network contains five business units, multiple companies and over 40 manufacturing sites. Each company targets a different market and thus has to follow a different strategy, which also has implication for the company-specific manufacturing strategies. Defining an all-encompassing MTC-top-level manufacturing strategy then can only contain elements that are common throughout the manufacturing strategies of all business units and companies. While such a manufacturing strategy is important to unify the BUs' and companies' approaches to manufacturing within the MTC, it lacks effectiveness at lower levels. By clustering a manufacturing network, however, the overall manufacturing strategy can be used as a basis to be refined at lower levels. This allows both company-wide agreement on critical manufacturing issues as well as cluster-specific refinement of the manufacturing strategy. Furthermore, cluster and site role definition are helpful for internal benchmarking purposes. By defining clusters and site roles, differences within the manufacturing network are acknowledged and strategic performance targets can be set and evaluated accordingly. Generally, it can be stated that strategy definition, strategic performance measurement and management and the steering of manufacturing networks is easier for networks with high homogeneity and low complexity.

The discussion of strategic performance measurement and management in this thesis does not cover the actual selection and implementation of strategic performance measures in depth. Although selection and implementation are part of the procedural framework, definition and implementation of strategic performance measures need to be company-specific, that is they need to fit company-specific processes and structures. During the collaboration with the case study companies it became obvious that companies strive for perfect measures that are suitable as a shop-level steering tool, can be used universally at all manufacturing sites, are easy to measure and implement and can be used for cross-industry benchmarking with the chance to easily derive clear implications through benchmarking. However, no such perfect strategic performance measure exists. Instead, managers need to understand the strengths and weaknesses of a given strategic performance measure and work with it to derive valid implications. This is also the reason why more steps in the procedural framework address aspects of performance management than measurement. The real work in strategic performance measurement and management lies in the correct definition of a detailed manufacturing strategy, the derivation of adequate performance dimensions, the evaluation of data and the derivation of valid implications.

Additionally, many managers solely focus on quantitative performance measures, as they believe quantitative measures to be objective and absolute. While this is not entirely wrong, quantitative measures can only provide a one-dimensional perspective and can be misleading if underlying influential factors remain unknown. Combined with a quantitative performance measure, a qualitative assessment based on principles can deliver more detailed insights. The case studies of the MTC, SPC and PC show that a combination of qualitative and quantitative performance measures can be implemented and successfully utilised to strategically develop manufacturing activities. All three companies are very satisfied with their approaches and see the key for their SPMMS success in the assessment-based support of quantitative performance measurement. This assessment-based support encourages organisational discussions and learning, and leads to an overall better understanding and acceptance of the SPMMS throughout the company.

In conclusion, this chapter has shown that the structural framework, the procedural framework and all of the new contributions to SPMMS that have been developed in this thesis are valid and applicable. However, both frameworks do not answer all questions revolving around the topic of strategic performance measurement and management. Chapter 5 will illustrate research limitations and detail possibilities for further research.

5 Summary and Outlook

This chapter will finalise the thesis at hand and will recapitulate the findings and contributions of this thesis. To do so, Section 5.1 will review the research questions and findings and Section 5.2 will outline the contributions to theory and practice. Finally, Section 5.3 will illustrate the limitations of the current research and point out areas for further research.

5.1 Critical Reflection

Based on the research gaps and practical problems identified in Chapter 1, it was argued that today's manufacturing managers are in need of a strategic performance measurement and management system for the strategic steering of manufacturing networks. The target was to design a SPMMS that would implement a manufacturing strategy and monitor strategy fulfilment in manufacturing networks. The proposed SPMMS is aimed at managers who want to develop their manufacturing network holistically. It is not primarily a benchmarking tool, but a tool for network development and strategy implementation. The following main research question (MRQ) was defined:

MRQ: What are special requirements of intra-firm manufacturing networks and how do they need to be incorporated into a holistic strategic performance measurement and management system?

To answer the main research question, three sub-questions (SQ) were defined. The following paragraphs evaluate whether the thesis' findings answer these sub-questions.

SQ.1: How can strategic site and network performance in the context of intra-firm manufacturing networks be defined?

The initial discussion of the research motivation and the literature review determined the lack of a unified definition of strategic manufacturing network and site performance. To close this gap, literature and interactions with practitioners were evaluated and a generic definition of strategic performance for manufacturing networks and sites was provided (Section 1.2). This definition served as a basis for the further theoretical developments and practice work, and made it easier to differentiate between strategic and operational performance. In all interactions with practitioners and other scientists, the used definition was met with broad acceptance. Thus, Sub-Question 1 has been answered.

SQ.2: What are the performance dimensions of a holistic SPMMS for intra-firm manufacturing networks?

It was found that previous SPMMS consist of a structural framework, which contains the dimensions for target setting and performance evaluation, and a procedural framework, which describes the process of performance measurement and management. Sub-Question 2 can be answered by developing a structural framework. Furthermore, strategic performance of manufacturing networks and sites was defined as the degree of manufacturing strategy achievement. Therefore, the structural framework developed for the application in manufacturing networks needed to contain all relevant dimensions of manufacturing strategy. These dimensions were identified through a three-step process: Firstly, a comprehensive review of literature on manufacturing strategy was conducted. This review resulted in a holistic definition of manufacturing strategy and a comprehensive overview of the content of manufacturing strategy. Secondly, structural frameworks from various SPMMS in the literature were reviewed to identify important performance dimension. These findings were then used to propose a structural framework for manufacturing networks in Section 3.5. Acknowledging that the manufacturing network level and the manufacturing site level place different demands on a SPMMS, a structural framework for manufacturing sites was also derived based on the network level. Thirdly, the applicability of the developed frameworks to manufacturing networks was evaluated. This was done by comparing the content of the structural framework to the content of SPMMS in case studies. All of the performance dimensions of the structural framework for network and site level were identified in the case studies. Similarly, all performance dimensions addressed in the case studies could be matched to performance dimensions of the structural frameworks.

The structural framework is novel as it provides a more holistic understanding of strategic manufacturing performance by including critical stakeholders as performance dimensions. Furthermore, the development of network capabilities can be anchored at network and site level to achieve a better collaboration between sites and prevent network level sub-optimisation by site-level optimisation. Last but not least, the structural framework includes structural and infrastructural levers as strategic performance dimensions which allow the monitoring and implementation of targets for the development of manufacturing networks and sites.

Overall, the structural framework contains all relevant strategic performance dimensions for manufacturing networks and sites. Its holism is ensured by complementing content dimensions of manufacturing strategy with additional dimensions from up-to-date SPMMS and management models. Sub-Question 2 has therefore been answered.

SQ3: How can a holistic strategic performance measurement and management system for intra-company manufacturing networks be designed?

While the developed structural framework provides generic strategic performance dimensions for manufacturing networks and sites, a procedural framework describes a process which is used to select relevant performance dimensions and fill them with targets that can be evaluated with adequate strategic performance measures. To answer sub-question three, this thesis developed a new procedural framework. The starting point for the framework development was a comprehensive literature review of process-oriented approaches to strategic performance measurement and management and manufacturing strategy formulation, as SPMMS and manufacturing strategy formulation should ideally be intertwined (cf. Pun and White, 2005; Melnyk *et al.*, 2013). The review of manufacturing strategy formulation processes ended with a synthesis of relevant formulation processes. This synthesis was adapted to manufacturing networks in Figure 10 in Subsection 2.1.6. Similarly, relevant procedural frameworks were synthesised into a summarising process containing all relevant process steps of SPMMS-processes in Figure 14 in Subsection 2.2.4. Both processes were then merged in Section 3.6 to develop a procedural framework for SPMMS in manufacturing networks.

The developed procedural framework represents relevant and time-proven contributions to manufacturing strategy formulation and processes for strategic performance measurement and management. To test its validity, processes for SPMMS in the case studies were described and the conducted steps were compared to those of the developed procedural framework. The comparison showed that all steps of the procedural framework were identified in the case studies. However, only three case studies covered the processes behind the SPMMS of the case companies. More practice examples could have possibly better supported the validity of the procedural framework.

Overall, sub-question 3 has been answered by the developed procedural framework, as it covers all relevant steps to fill the structural framework with company-specific targets and strategic performance measures. Additionally, the structural framework has been supported by guiding questions that were inspired by the work of Neely (2008).

5.2 Contributions to Theory and Practice

Based on Ulrich's (1983) understanding of business administration, scientific research in business administration should strive to solve real industry problems. The results of this thesis therefore provide a benefit for researchers and practitioners alike. Table 36 gives an overview of the results and utilises Harvey Balls to illustrate the contribution to theory and practice.

Results	*Theoretical Contribution*	*Practical Contribution*
1 Identification of requirements of intra-organisational manufacturing networks towards SPMMS	●	◑
2 Definition of strategic manufacturing performance on a network and site level	●	◕
3 Developing a structural framework to support SPMM in manufacturing networks and sites	●	●
4 Developing a procedural framework for the definition and implementation for a SPMMS in manufacturing networks	◑	●
5 New contributions that extent the previous understanding of SPMMS in manufacturing networks	◑	●

Table 36 – Contribution to Theory and Practice

- **Identification of requirements of intra-organisational manufacturing networks towards SPMMS:** Previous SPMMS are not suitable for an application in manufacturing networks. To prove this, the demands from manufacturing networks were identified and used to illustrate the shortcomings of existing SPMMS. Then, requirements were used to develop the structural and procedural framework in this thesis. The benefit for researchers is that the requirements are clearly defined and can be used for further research. For practitioners, the benefit of identifying these requirements is limited as practitioners were already well aware of shortcomings.
- **Definition of strategic manufacturing performance on a network and site level:** The scientific literature has failed to provide a holistic and generic definition of strategic manufacturing performance in general and strategic manufacturing performance on network and site level in particular. By providing appropriate definitions, this thesis allows scientists to take a more detailed, holistic and, most importantly, unified approach to the evaluation of manufacturing performance. Additionally, the developed definition fuses perspectives from business administration and industrial engineering and thus broadens the understanding of performance in both fields. Practitioners benefit from the definitions in that they now can assess whether or not their manufacturing activities perform well. However, this requires applying the structural and procedural frameworks to the manufacturing activities, which takes effort.

- **Developing a structural framework to support SPMM in manufacturing networks and sites:** The developed structural framework for manufacturing networks and sites provides two main benefits: a) scientists and practitioners are provided with a comprehensive list of possible strategic performance dimensions for manufacturing networks and sites and b) the structural frameworks can be used as a step-by-step aid identifying relevant strategic performance dimension in a practical application. The different strategic performance dimensions are logically interconnected and the connection is transparently illustrated. Furthermore, once the relevant strategic performance dimensions are selected at the network level, they can easily be translated downwards to site level.
- **Developing a procedural framework for the definition and implementation for a SPMMS in manufacturing networks:** While the structural framework includes all relevant strategic performance dimensions, the selection of company-specific performance dimensions, the definition of targets and performance measures, their implementation, evaluation and update needs to be supported by a process. The procedural framework outlines a generic process to develop, implement and update a SPMMS in manufacturing networks. While the main benefactors of this process are practitioners, the procedural framework helps scientists gain a more in-depth understanding of the complexity of SPMMS in manufacturing networks.
- **New contributions that extent the previous understanding of SPMMS in manufacturing networks:** The new contributions to SPMMS developed in this thesis are outlined in Section 3.7. They include aspects of content, the process and the measurement within SPMMS. While practitioners are the main benefactors of these new contributions, scientists also benefit from them as they provide solutions to challenges to SPMMS in manufacturing networks.

5.3 Research Limitations and Potential for Further Research

The final section of this thesis discusses its limitations and potential for further research. It is divided into three subsections. The first subsection will cover limitations and further research potential resulting from the overall research design. The second subsection focuses on the area of manufacturing networks. Finally, the third subsection will address SPMMS in general.

5.3.1 General Limitations and Potential for Further Research

Firstly, this thesis has developed a structural and procedural framework as well as general suggestions which support managers in creating a SPMMS for manufacturing networks. To verify these frameworks, case studies where utilised. However, while all aspects of the frameworks were identified in the case studies, the frameworks themselves have not yet been applied to a company as a whole. Therefore, an application of the frameworks to companies for a more in-depth assessment of framework applicability and validity is needed.

Secondly, the number of conducted case studies was limited. Especially the procedural framework was only addressed in four case studies. Therefore, an extension of testing is desirable.

Thirdly, this research is based on a static observation of SPMMS in manufacturing networks. The procedural framework incorporates a review loop that should be conducted regularly. The long-term application and development of SPMMS in manufacturing networks should be investigated by longitudinal studies.

5.3.2 Limitations and Potential for Research regarding Manufacturing Networks

Firstly, the developed structural and procedural frameworks are generic and applicable to any industry or type of manufacturing network design. However, a focus on a given industry or network type holds implications on the content and direction of the SPMMS. By focussing, a definition of the most important strategic performance dimensions and strategic performance dimensions is possible, which allows for meaningful benchmarking based on industry-specific sets of strategic performance measures. Furthermore, the current literature base on strategic performance measures for the manufacturing network level and the network capabilities is small to non-existent. While each performance measure has to be specifically adapted to a company, a basis to select a suitable measure from will support the spread of network capability assessment throughout manufacturing networks.

Secondly, literature on manufacturing networks has mostly focused on either the network or the site level. This thesis introduced the cluster level between the overall manufacturing network and the site level. While clusters essentially are also networks, their introduction has some implications that need to be evaluated. For example, given a specific industry or product, the ideal way of clustering (e.g., regional market focus, process focus etc.) should be investigated.

Furthermore, the most suitable manufacturing network and site designs to realise certain network and manufacturing capabilities need to be examined. More specifically, it needs to be examined which structural or infrastructural levers need to be adjusted to reach a higher performance level in any given capability. This research would lead to practical management implications for the development of manufacturing networks.

5.3.3 Limitations and Potential for Research regarding SPMM

Firstly, this thesis has provided a broad overview of site role concepts in Section 2.1. While the developed SPMMS then acknowledges and incorporates the concept of site roles, the specific connection between site roles within a typology and strategic performance dimension has not been evaluated. More specifically, research in this area could evaluate what the most important performance dimensions for a given site role are and how they can be used for the long-term development of the site.

Secondly, the developed SPMMS is seen as a tool to monitor the overall strategic development of a manufacturing network. While the procedural framework includes a review and update loop, it remains open how often the SPMMS should be updated remains. Often, companies refrain from implementing further changes because they feel that the companies cannot take more change. Scientific research needs to determine how frequently adjustments in target setting can be implemented.

Thirdly, throughout this thesis a combination of qualitative and quantitative evaluation mechanisms has been suggested. What needs to be examined by scientists is the question which performance dimension is best evaluated using which mechanism. More specifically, it has to be examined which evaluation mechanism yields the best results in evaluating a given target.

Finally, this thesis has not touched the topic of incentives. Future research should evaluate which targets in which performance dimensions are best incentivised with the different incentive mechanisms. This might be influenced culturally and the implications of cultural influences on suitable incentives in global manufacturing networks need further examination.

Appendix A – Lists of Strategic Performance Measures

This appendix provides a short list of publications that contain performance measures that can be applied to manufacturing sites. This list is not exhaustive but can serve as a basis for the development of company-specific performance measures. However, the author would like to remind the reader that the performance measures included in a company-specific SPMMS should be based on strategy. They should not be included because they sound smart or sensible. Strategic performance measures are derived from strategy. Practitioners should ask: "What do we need to measure to fulfil our manufacturing strategy?", and not: "What measures are implemented at other companies or suggested in scientific publications?"

Author Name and Year of Publication	*Title of Publication*
Ainapur *et al.*, 2011	Strategic Study on Enhancement of Supply Chain Performance
Azzone *et al.*, 1991	Design of Performance Measures for Time-based Companies
Bhasin, 2008	Lean and performance measurement
Bititci *et al.*, 2000	Dynamics of performance measurement systems
Chiesa *et al.*, 2009	Performance measurement in R&D. Exploring the interplay between measurement objectives, dimensions of performance and contextual factors
Cousens *et al.*, 2009	A process for managing manufacturing flexibility
De Toni and Tonchia, 2001	Performance measurement systems. Models, characteristics and measures
Devaraj *et al.*, 2004	Generic manufacturing strategies and plant performance
Digalwar and Sangwan, 2007	Development and validation of performance measures for world class manufacturing practices in India
Dossi and Patelli, 2010	You learn from what you measure. Financial and non-financial performance measures in multinational companies
Fischbach and Fischbach, 2006	Lexikon Wirtschaftsformeln und Kennzahlen
Gerwin, 1987	An agenda for research on the flexibility of manufacturing processes
Ghalayini *et al.*, 1997	An integrated dynamic performance measurement system for improving manufacturing competitiveness
Gladen, 2011	Performance Measurement. Controlling mit Kennzahlen

Author Name and Year of Publication	***Title of Publication***
Gomes *et al.*, 2011	Performance measurement practices in manufacturing firms revisited
Gregory, 1993	Integrated performance measurement. A review of current practice and emerging trends
Gunasekaran *et al.*, 2001	Performance measures and metrics in a supply chain environment
Hon, 2005	Performance and evaluation of manufacturing systems
Huan *et al.*, 2004	A review and analysis of supply chain operations reference (SCOR) model
Jaehne *et al.*, 2009	Configuring and operating global production networks
Lapide, 2000	What about measuring supply chain performance
Leong *et al.*, 1990	Research in the process and content of manufacturing strategy
Lohman *et al.*, 2004	Designing a performance measurement system. A case study
Miller and Roth, 1994	A taxonomy of manufacturing strategies
Neely *et al.*, 1994	Realizing strategy through measurement
Neely *et al.*, 1995	Performance measurement system design. A literature review and research agenda
Neely *et al.*, 2005	Performance measurement system design. A literature review and research agenda
Neely, 2008	Measuring performance. The operations management perspective
Ossola-Haring, 2003	Das grosse Handbuch Kennzahlen zur Unternehmensführung. Kennzahlen richtig verstehen, verknüpfen und interpretieren
Preißler, 2008	Betriebswirtschaftliche Kennzahlen. Formeln, Aussagekraft, Sollwerte, Ermittlungsintervalle
Probst, 2012	Kennzahlen. Richtig anwenden und interpretieren ; alles, was sie wissen müssen
Rathje, 2007	Implementierung und Messung von Flexibilität in produzierenden Unternehmen
Schönsleben, 2007	Integrales Logistikmanagement. Operations und Supply Chain Management in umfassenden Wertschöpfungsnetzwerken
Schmenner and Vollmann, 1994	Performance measures. Gaps, false alarms, and the “usual suspects”
Shepherd and Günter, 2006	Measuring supply chain performance. Current research and future directions

Author Name and Year of Publication	***Title of Publication***
Siegwart *et al.*, 2010	Kennzahlen für die Unternehmensführung
Upton, 1994	The management of manufacturing flexibility

Table 37 – List of Publications Containing exemplary Performance Measures applicable in Manufacturing Networks

Appendix B – List of Supervised Research Theses

During the work on this dissertation at the Chair of Production Management at the University of St.Gallen, the author of this dissertation supervised the following theses between May 2011 and September 2014. The theses were supervised with substantial scientific, conceptual, and topic-related know-how by the author of this dissertation. The findings of these theses were partially incorporated in this thesis. The author is thankful for the support of the students in the realisation of this dissertation.

Name	*Title of theses*	*University of submission*
Manuel Opitz	Performance measurement in global production networks	RWTH Aachen University; submitted November 2012
Stephanie Petersen	Entwicklung eines KPI-Modelles für globale Produktionsnetzwerke	University of St.Gallen; Submitted February 2013
Yannick Hofmann	The development of a KPI system to coordinate an internal production network	University of Zurich; Submitted May 2013
Tamara Markert	Performance Dimensions for Sites in Production Networks	University of St.Gallen; Submitted August 2013
Adam Rid	Ganzheitliches Modell zum Performance Measurement in Produktionsnetzwerken	University of St.Gallen; Submitted November 2013
Christoph Stübi	Performance Measurement in Produktionsnetzwerken	University of St.Gallen; Submitted April 2014
Tobias Inglin	Cross-industrielles Benchmarking von Produktionsnetzwerken mittels eines Reifegradmodells	University of St.Gallen; Submitted May 2014

Table 38 – List of Supervised Theses

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