DOCTORAL THESIS

Supply Chain Quality Management

- *Exploring performance of manufacturing organisations*

Aron Chibba

Quality Technology

LULEÅ UNIVERSITY OF TECHNOLOGY

Doctoral Thesis

Supply Chain Quality Management

- Exploring performance of manufacturing organisations

Aron Chibba

Luleå University of Technology
Department of Business Administration, Technology and Social Sciences
Division of Business Administration and Industrial Engineering

Printed by Luleå University of Technology, Graphic Production 2017

ISSN 1402-1544
ISBN 978-91-7583-777-2 (print)
ISBN 978-91-7583-778-9 (pdf)

Luleå 2017

www.ltu.se

Abstract

This thesis addresses the issue of quality performance in supply chains in the manufacturers' context. Research shows that the management and performance of supply chains play a major role in gaining competitive advantage, especially in times of decreasing international trade barriers and quickly evolving information technology. Some researchers claim that it is the supply chain itself that competes on a market and not merely the organisations with their specific strategies and goals. Supply chain performance has been widely discussed in the research literature in recent years. However, this research points out that supply chain quality management (SCQM) and its impact on firm performance (both inter-organisational and intra-organisational) have not been sufficiently understood. Further studies are needed to identify the direct and indirect impact of SCQM practices on firm performance at multiple levels.

A problem that many organisations face is the lack of resources and knowledge on how to manage supply chain quality performance (i.e., which performance to measure, how to control performance, and how to improve performance). Studies show that often even large companies measure effectiveness using key performance indicators (KPI) and that these indicators often do not depict key characteristics critical to organisational performance or customer behaviour. Therefore, such indicators might be inadequate for fully capturing the performance of supply chains. As quality management standards evolve, managers need to adapt to changing requirements. To fulfil the new version of ISO 9001, organisations are required to determine criteria and apply methods to ensure effective operation and control of their processes (both intra-organisational and inter-organisational performance). This includes monitoring and measuring performance indicators. The quality performance of a supply chain is dependent on its ability to improve and thereby enable organisations to stay competitive over time. Good measurements of supply chain quality performance must reflect this ability. To do so, organisations need to know which measures and metrics to use and how to analyse performance of their supply chains.

From the seven studies presented in this thesis we are able to draw a number of more general conclusions that bear on the main research question: *What improves quality performance of supply chains that include manufacturing?* At the process level, it has been found that manufacturers should focus on the quality and delivery performance of each process within the organisation. At the internal, integrated supply chain level, a manufacturing organisation should focus on quality (conformance), delivery performance (on-time delivery), and cost cutting in the internal supply chain. Collaboration using cross-functional teams seems most appropriate when working with product development. The use of a process-oriented mapping tool was found to facilitate description of information flows and physical material flows and also to identify disturbances that could be improved and rationalized to generate a better flow in the total supply chain. At both the upstream and downstream sides of the supply chain, one-sided measures that depict performance over organisational boundaries were found to be the most common. At the downstream side of a supply chain, suppliers could be chosen based on cost, conformance, speed, and flexibility. At the upstream side, procedures that handle changing requirements and information about delays or incorrectness of materials were found to influence flow. The results from these seven studies are the basis for the development of a supply chain quality improvement model. In the literature, supply chain performance is often discussed on a strategic level with measures for quality, flexibility and delivery. Managers also need metrics that can be followed up on at a detailed level (e.g., capacity load, breakdown rates, claims, cost of poor quality, and lead-times). To bridge this gap, a Key Performance Indicators Matrix of supply chain quality performance indicators for manufacturers is proposed.

Sammanfattning
Denna avhandling tar upp frågan om hur försörjningskedjor i en kontext av tillverkande organisationer presterar i termer av kvalitet. Forskning visar att ledning och utveckling av försörjningskedjor spelar en viktig roll när det gäller att erhålla konkurrensfördelar, särskilt i tider av minskande internationella handelshinder och snabba förändringar i informationstekniken. Vissa forskare hävdar att det är leveranskedjan i sig som konkurrerar på en marknad snarare än enskilda organisationer med sina specifika strategier och mål. Prestanda i försörjningskedjor har diskuterats i forskningslitteraturen under de senaste åren. Ny forskning har pekat på att ledning av kvalitetsprestanda i försörjningskedjor (SCQM) har inverkan på företagens resultat (både mellan olika organisationer och inom en organisation) men att detta område ännu inte är tillräckligt klarlagt. Ytterligare studier har behövts för att identifiera direkta och indirekta effekter av SCQM praxis på företagens resultat på flera nivåer. Ett problem som många organisationer står inför är brist på resurser och kunskap om hur man bör hantera kvalitetsprestanda i leveranskedjan, det vill säga vad som ska mätas, hur man styr och hur man kan förbättra denna prestanda. Studier visar att företag, även stora sådana, som mäter effektiviteten med hjälp av nyckeltal (KPI) ofta saknar indikatorer för många viktiga egenskaper av betydelse för organisationens resultat och kundbeteende. Därför kan sådana indikatorer vara otillräckliga för att på ett bra sätt fånga prestandan hos försörjningskedjor. I takt med att nya standarder för ledningssystem för kvalitet utvecklas behöver chefer anpassa sig till förändrade krav. För att möta kraven i den senaste utgåvan av ISO 9001 måste organisationer upprätta och tillämpa kriterier och metoder för att säkerställa en effektiv drift och styrning av processer (både prestanda inom organisationen och mellan organisationer). Detta inkluderar övervakning och mätning av resultatindikatorer. En distributionskedjas kvalitetsprestanda beror av dess förmåga att förbättra och därmed göra det möjligt för organisationer att förbli konkurrenskraftiga över tiden. Bra mätningar av kvalitetsprestanda i försörjningskedjan behöver kunna återspegla denna förmåga. För att göra detta måste organisationer veta vilka underlag som kan användas och hur man analyserar en försörjningskedjas prestanda. Utifrån de sju studier som presenteras i denna avhandling ges ett antal mer generella slutsatser som har bäring på den huvudsakliga forsknings frågan, det vill säga: *Vad förbättrar kvalitetsprestanda i försörjningskedjor som inkluderar tillverkning?* På processnivå har det visat sig att tillverkande organisationer bör fokusera på kvalitet och leveranssäkerhet för varje process inom organisationen. Vad gäller den interna integrerade försörjningskedjan bör en tillverkande organisation fokusera på kvalitet (överensstämmelse), leveranssäkerhet (leverans i tid) och sänkta kostnader för interna försörjningskedjor. Att samverka med hjälp av tvärfunktionella team verkade vara det mest lämpliga tillvägagångssättet när man arbetar med produktutveckling. Användningen av ett processorienterat kartverktyg befanns underlätta beskrivningen av informationsflöden och fysiska materialflöden samt identifiering av störningar som skulle kunna förbättras och rationaliseras för att skapa ett bättre flöde i den totala leveranskedjan. Ensidig mätning som skildrar prestanda över organisatoriska gränser (både nedströms i försörjningskedjan, dvs. mot kunder, och uppströms, dvs. mot leverantörer) befanns vara det vanligast förekommande. På nedströmssidan av en försörjningskedja kan leverantörer väljas baserat på kostnad, överensstämmelse, snabbhet och flexibilitet. På uppströmssidan är det lämpligt med rutiner som hanterar förändrade krav och information om förseningar eller felaktigt material. Resultaten har använts som grund för utveckling av en modell för kvalitetsförbättring av försörjningskedjor. I litteraturen om försörjningskedjor diskuteras ofta prestanda på en strategisk nivå, mätningar som kvalitet, flexibilitet och leverans. Chefer behöver också statistiska underlag som kan följas upp på en lägre nivå, t ex vad avser kapacitetsbelastning, felfrekvens, fordringar, kvalitetsbristkostnader och ledtider. För att illustrera detta har en KPI-matris av försörjningskedjors kvalitetsrelaterade resultatindikatorer föreslagits.

ACKNOWLEDGEMENTS
It has been quite a long research journey, but also a fun and rewarding one. There are several people who made this research journey possible. First, I would like to thank my supervisor, Rickard Garvare, for all his support, knowledge and for not giving up on me during all these years. I really enjoyed our discussions and how he encouraged me to complete the work. I would also like to thank my assistant supervisor, Joakim Tell, for his critical reviews and support. Further, I would like to thank Sven Åke Hörte who initially helped me become a researcher during the work with my licentiate thesis.

Moreover, I´d like to thank my colleagues at Halmstad University, especially Henrik Florén, Fawzi Halila, Gunnar Weber, Hans Löfgren, Bengt Göran Rosén, Pär Johan Lööf and John Lindgren for their support, feedback and ideas during the writing process as well as all the other people who have helped, supported, and encouraged me during my research journey.

Finally, I wish to praise my dear wife who supported me in the day-to-day situations so I could finalize the work. I´d like to send warm hugs to my four beloved children, Emma, Ella, Theo and Aston, especially for their patience during several occasions when I had to complete my doctoral studies. I´d like to express my gratitude to my parents and my sister who supported me with their interest in the area.

Halmstad, Sweden: December 2016

Aron Chibba

Table of Contents

ABBREVATIONS
These abbreviations are used in this thesis.

CAPEX	Capital Expenditure
CIP	Continuous Improvements Projects
EBIT	Earnings Before Interest and Tax
ERP	Enterprise Resource Planning
KPI	Key Performance Indicators
LE	Large Enterprises
NPD	New Product Development
OEE	Overall Equipment Efficiency
OEM	Original Equipment Manufacturer
OM	Operations Management
OTD	Order to Delivery
C-OTD	Customer On Time Delivery
OLT	Order lead-time
PD	Product Development
PPM	Parts Per Million
QM	Quality Management
ROA	Return on Assets
ROI	Return on Investment
SC	Supply Chain
SCM	Supply Chain Management
SCP	Supply Chain Performance
SCQM	Supply Chain Quality Management
SCOR	Supply Chain Operations Reference
SME	Small and Medium Size Enterprises
TQM	Total Quality Management
TSCQM	Total Supply Chain Quality Management

Seven Papers (see the Appendix)

Paper 1 Chibba, A. and Hörte, S. (2003). Supply Chain Performance – A Meta-analysis. *Conference proceedings, 10th International Annual EUROMA conference* in Como, Italy.

Paper 2 Rundquist, J. and Chibba, A. (2004). The use of processes and methods in NPD – A survey of Swedish industry. *International Journal of Innovation and Technology Management,* 1(1): 37-54.

Paper 3 Chibba, A. (2007). Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers. *Conference proceedings, 14th International Annual EUROMA conference* in Ankara, Turkey.

Paper 4 Hörte, S.Å., Barth, H., Chibba, A., Florén, H., Frishammar, J., Halila, F., Rundquist, J. and Tell, J. (2008). Product Development in SMEs: a literature review. *International Journal of Technology Intelligence and Planning*, 4(3): 299-325.

Paper 5 Chibba, A. and Rundquist, J. (2009). Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows. *Journal of Information & Knowledge Management*, 8(4): 331-343.

Paper 6 Chibba, A. (2015). Measuring supply chain performance: A framework for prioritizing measures. *International Journal of Research in Business and Technology*, 6(2): 782-793.

Paper 7 Chibba, A. and Garvare, R. (2011). Supply Chain Quality Management in Wind Turbine Industry - A Case Study. *Conference proceedings, 18th International Annual EUROMA conference* in Delft, Netherlands.

Additional publications

Conference articles
Chibba, A. and Rundquist, J. (2001). Förbättring av produktinnovationsprocesser inom ramen för TQM. Conference proceedings, *2nd HSS Research Conference*, Halmstad University, Sweden, May 9-11, 2001, pp. 249-258.

Technical reports
Chibba, A. and Hörte, S.Å. (2003b). *Information and physical material flows in supply chains – A survey of calculation methods and models*. Centre for Information Logistics in Ljungby, Sweden.

Training material
Andreasson, K., Chibba. A., Larsson, J. (1995). *The Basics of Quality Assurance*, QMI Publications, ISBN 91-88864-04-9.

1. Introduction

This chapter presents the research background and context, the position of the research, the purpose of the research, the research question, the limitations of the research, and the structure of the thesis.

1.1 Background

This thesis addresses the issue of quality performance of supply chains in the context of manufacturers. Research shows that the management of supply chains, including their performance, plays a major role in organisations' ability to gain competitive advantages, especially in times of decreasing international trade barriers and quickly evolving information technology (Ellinger, 2000; Horvarth, 2001; Singh and Power, 2009). Some researchers claim that it is the supply chain itself that competes on a market and not merely the organisations with their specific strategies and goals (i.e., supply chain vs. supply chain) (Boyer et al., 2005; Christopher, 1997; Ellinger, 2000; Ketchen and Guinipero, 2004; Ketchen and Hult, 2006; Lambert and Cooper, 2000).

The literature on Supply Chain Management (SCM) has evolved rapidly in the last 20 years. A simple search for "supply chain" in the databases Ingenta, Emerald, and AOM resulted in 1944 articles in the year 2003 (Chibba and Hörte, 2003b). In the year 2016, the result was 16061 articles. One reason for this increase in the SCM literature, as revealed by the research, is the benefit of competitive advantage for organisations. SCM focuses on issues such as coordinated actions, information sharing, and trust that help create close, collaborative relationships between organisations and suppliers related to competitive advantage (Ellinger, 2000; Horvarth, 2001; Singh and Power, 2009).

Studies on collaboration and the integration of SCM have been a dominant theme in the literature for more than a decade (Opengart, 2015). Several authors (e.g., Croom et al., 2000; Klaus, 2009) describe SCM as a broad theory that can be approached from many different perspectives: purchasing and supply, logistics and transportation, industrial organisation, marketing, quality management, strategic management, and many others. Grimm et al. (2015) point out that SCM is a broad theory and argue that research on thematic areas that cuts across disciplinary silos has gained increased scholarly attention. They also think this type of research tends to be strategic and reflects both intra- and inter-organisational issues. They point out that SCM is largely a cross-disciplinary thematic area.

A problem many organisations face is that they do not always have the resources and knowledge to effectively manage the quality performance of the supply chain (e.g., quality conformance, customer On-time delivery (OTD), and bad quality cost, of which they form a part). For example, how do we measure, control, and improve the quality performance of the supply chain? (Gopal and Thakkar, 2012). Chibba (2007a) argues that often even large companies measure performance effectiveness by Key Performance Indicators (KPI) and that these often do not reflect key characteristics critical to organisational performance or customer behaviour. Such indicators might even be inappropriate and incapable of fully capturing the performance of the supply chain (Chibba, 2007a). Behn (2003) emphasizes that managers at public organisations strive to manage by using measures. This is also valid for manufacturers, for example, organisations that are certified according to the quality management standard ISO 9001.

As quality management standards evolve, managers need to adapt to new requirements. In the new edition (2015) of ISO 9001, organisations shall determine and apply criteria and methods to ensure

effective operations and control of their processes (both intra- and inter-organisational performance), including monitoring and measuring related performance indicators. To measure the quality performance of a supply chain, it is therefore important to know the status and to improve the ability of organisations to meet market requirements in order to stay competitive. In order to do so, organisations have to know which measures and metrics to use and how to analyse the performance of their supply chains using suitable measures and metrics. This new requirement will force process owners at organisations that are certified for ISO 9001 to ask: What should we measure and how should we measure it if we are to track performance?

Supply chain performance has been widely discussed in the research literature in recent years (Gopal and Thakkar, 2012). See Table 1. However, recent research (Quang et al., 2016) points out that supply chain quality management (SCQM) and its impact on firm performance (both inter- and intra-organisational) are not sufficiently understood. However, there are a limited number of studies that deal with performance measures and metrics in the supply chain environment (Gunasekaran and Kobu, 2007). According to Cuthbertson and Piotrowicz (2008), the majority of supply chain measures are financial and quantitative rather than qualitative in nature. Meanwhile other researchers (Brewer and Speh, 2001; Gunasekaran et al., 2001) argue that most metrics suggested for measuring the performance of the supply chain can be ascribed to the logistics discipline (e.g., lead-times, order fulfilment, and costs).

Table 1: *Studies on SCM and performance and their focus (based on Flynn et al., 1995, and Quang et al., 2016)*

Author	**Focus**
Akamp and Muller, 2013; Forslund and Jonsson, 2010; Hollos et al., 2011; Kumar et al., 2014; Wu et al., 2010	Performance, upstream side of the supply chain.
Danese and Romano, 2011; Forslund and Jonsson, 2009, 2010; Mokhtar, 2013; Mukerjee, 2013	Investigation of the impact of downstream performance.
Vachon and Klassen, 2006	Examination of the integration between upstream and downstream performance.
Adam et al., 1997; Ahire and Drayfus, 2000; Ahire and O´Shaughenessy, 1998; Anderson, 1995; Choi and Eboch, 1998; Powell, 1995; Samson and Terziovski, 1999; Saraph et al., 1989	Tests of the effects of internal process on performance.

Forslund and Jonsson (2009) conclude that non-standardized performance metrics do not hinder Performance Management process integration between supplier and customer. They point out that very few standardized metrics exist and, consequently, the use of such metrics is rare. They also point out that the Supply Chain Operations Reference (SCOR) model and the Odette Model present some standardized, logistics performance measures. However, these models are not widely adopted or used. Forslund and Jonsson (2009) argue that further research on how to define standardized metrics and how to increase their use, consequently, would be valuable.

Sila et al. (2006) point out that further studies should focus on identifying which attributes in addition to price, quality, and trust characterise customer-supplier relationships in manufacturing supply chains. They argue that the importance of each attribute could also be compared across different levels of the supply chain. The SCOR model provides a framework for supply chain improvement, from the development of operation strategy to the implementation of new management practices. SCOR (2010), however, does not describe every business process or activity. For example, it does not address sales and marketing, research and technology development, or product development. SCOR assumes, but does not specifically address, quality, information technology, or administration.

Research shows that the performance would benefit from synergies between QM (Quality Management) and SCM. As Rachid and Aslam (2012) conclude, QM and SCM activities support each other's performance and that of the whole organisation. Researchers also suggest that the synergy between QM and SCM is critical for a successful supply chain (Flynn and Flynn, 2005; Robinson and Malhotra, 2005). The SCM and QM efforts improve each other's performance and the integration between the two disciplines, which can be beneficial for an organisation in many ways (Foster and Ogden, 2008). Empirical evidence suggests that the synergy between QM and SCM results in better product quality and customer service (Kannan and Tan, 2007; Sila and Ebrahimpour, 2002), organisational performance (Kaynak and Hartley, 2008; Lin et al., 2005; Ou et al., 2010) and SC performance (Flynn and Flynn, 2005; Igel, 2010; Vanichchinchai, 2014).

Kaynak and Hartley (2008) claim that implementation of SCQM involves not only the internal practices but also the cross-organisational boundaries that integrate a company with its customers and suppliers. As Quang et al. (2016) suggest, the successful implementation of SCQM needs to integrate the practices of upstream and downstream activities and internal processes. To be successful in this integration, information plays an important role, as several researchers have commented (Arunfelh and Tarafdar, 2014; Chibba and Rundquist 2009; Ding et al., 2014; Inderfurth et al., 2013; Wu et al., 2014). The lack of information or the distortion of information can cause significant problems such as excess inventory, poor customer service, lost revenue, misguided capacity plans, ineffective transportation, and missed production schedules, Quang et al. (2016).

Quang et al. (2016) conclude that further studies are needed that identify the direct and indirect impact of SCQM practices on firm performance at multiple levels. They point to several problem areas where many questions remain. Two of these areas, which have not been evaluated simultaneously, are relevant for this thesis: 1) the lack of a research model covering upstream activities, internal processes, and downstream activities; and 2) the various dimensions of firm performance (customer satisfaction, financial performance, and operational performance). Gopal and Thakkar (2012) also note these implications for contemporary researchers and mention the need for metrics standardization and identification of key measures that could be shared among supply chain partners. Forslund and Jonsson (2009) point out that further research is needed on the definition of standardized metrics and how to increase their use.

In sum: The research literature on SCM has evolved rapidly in the last 20 years. One reason is that such research can provide competitive advantage for organisations. SCM seems to be a broad theory that involves several disciplines (i.e., it is cross-disciplinary). And there is also an increased interest in the study of QM from the SC perspective. QM and SCM activities support each other's performance as well as that of the whole organisation. QM traditionally focuses on internal process control and improvement (i.e., intra-organisation improvement) while SCM focuses on inter-organisation improvement. Empirical evidence suggests that the synergy between QM and SCM results in better product quality, customer service organisational performance, and SC performance. The research also suggests that future studies need to identify the direct and indirect impact of SCQM practices on firm performance at multiple levels in manufacturing supply chains. Practitioners often find it difficult to choose the right performance measures and the right metrics for their processes in accordance with the requirements of ISO 9001. The research also suggests that new studies on defining standardized metrics and increasing their use would be of value.

1.2 Position of the research

The focus of this thesis is the research area of QM and SCM in the context of improving the performance of manufacturers' supply chains. However, the thesis also includes theory from other relevant research areas such as operations management, logistics, marketing, and industrial organisation because the supply chain can be viewed from several different academic disciplines (i.e., field of study or branch of knowledge that is taught and researched in higher education). Table 2 presents a comparison of the different disciplines and their relationship to SCM.

Table 2: *Comparison of the different disciplines and their relationship to SCM.*

		Characteristics		
Disciplines	**Focus**	**Definition**	**Subset of SCM**	**Relationship with SCM**
Logistics	Distribution /transportation	The process of planning, implementing and controlling the efficient flow and storage of goods, services and related information from point of origin to point of consumption for the purpose of conforming to customer requirements. (Council of Logistics Management)	Yes	Some researchers claim that SCM is really a logistics concept, while others argue that there are some differences
Marketing	Distribution channels	Activities aim to satisfy needs and wishes through exchange processes (Kotler and Armstrong, 2008)	Yes	The close interrelationship between marketing and logistics activities
Operations Management	Production	Concerned with the task of managing the arrangement of resources in an organisation devoted to the production of goods and services (Voss, 1995)	Yes	The strong connection with the physical material flow, information flow and financial flow
Quality Management	Customer satisfaction/ Stakeholder satisfaction	Organisations that identify the need to adopt quality of product as their guiding strategy will achieve sustainable success if the stakeholder imperatives encompassed by that strategy are optimized; while satisfying all other stakeholder imperatives, at least cost. (Bergqvist et al., 2008)	Yes	Some researchers claim that QM focus on intra-organisational improvements meanwhile SCM focus on inter-organisational improvements. There is a strong connection to customer requirements and competitive advantage
Information Management	Hard and software	Information technology management within and between organisations (O´Brien, 1995)	Yes	SCM requires modern information technology in order to work efficiently
Industrial Organisation	New business opportunities	Characterises how an organisation develops and carries out its business compared to other market competitors (Carlton and Perloff, 2005).	Yes	Focus on strategy, management and organisational aspects of a supply chain
Knowledge Management	To capture and present knowledge so that it can be re-used either by an individual or organisation	The collection and dissemination of knowledge to the benefit of an organisation and its members (Lueg, 2001)	Yes	Strong connection between information and knowledge

Different perspectives on supply chain management (SCM)

Practitioners and researchers have described the concept of supply chain management in journal articles, conference papers, and books. Researchers and practitioners, from various disciplines, who work with definitions of this business concept, take different perspectives. Svensson (2002) listed 28 SCM definitions in chronological order that originated between 1985 and 2001. He found that the researchers who proposed these definitions come from various disciplines including Operations Management, Industrial Organisation, Logistics, Marketing, and Information Management. Therefore, it seems rather difficult to settle on one specific definition of SCM. However, these SCM definitions can be explained by relating them to the researchers' disciplines and to their perspectives on SCM.

A logistics perspective on SCM
There are many different definitions of logistics. An often-cited definition is that by the Council of Logistics Management[1] (CLM) that defines logistics as *"...the process of planning, implementing and controlling the efficient flow and storage of raw materials, in process inventory, finished goods, services, and related information from point of origin to point of consumption (including inbound, outbound, internal and external movements) for the purpose of conforming to customer requirements"*.

Slack (1998) argues that it is not clear from this definition whether "origin" refers to the original source of material or whether it refers to the material and information flow associated with finished products. In this case, logistics resembles Physical Distribution Management. Slack contends there is little evidence to suggest that the term logistics includes operations further upstream in the supply network. Slack also states that authors with a marketing or physical distribution management background publish most of the logistics literature. These authors naturally tend to highlight planning, control, and distribution of finished products. Some researchers such as Halldórsson and Arlbjorn (2001) claim that the real differences between logistics and SCM are difficult to specify since both concepts involve the same content and scope. Others such as Tompkins (2000) argue that SCM is actually a logistics concept. It seems that the definition depends on the affiliation of the researcher who proposes it. The logistics perspective on SCM is obvious due to its strong connection to planning, control, and distribution of finished products.

A marketing perspective on SCM
Svensson (2002) finds there are major similarities and only minor differences in the theoretical boundaries between SCM and Alderson's interpretation of a functionalist theory of marketing. The similarities in dependence are such as the following: vertical-, direct-, indirect-, unidirectional- and bi-directional. Svenson argues that Alderson´s functionalist theory of marketing in a system context is evident. For example, Alderson writes:

> *"...to avoid sub-optimization confronts us with a more embracing problem. We must look at the whole system to learn about any of its parts..."*. (Alderson, 1965, p. 21)

Svensson points out that SCM is an influential factor in the field of marketing theory because of the close interrelationship between marketing and logistics activities.

An operations management perspective on SCM
Researchers and practitioners from the discipline of Operations Management (OM) have also described SCM. Some researchers such as Handfield and Nichols (1999) argue that SCM concerns the flow of products and information between the supply chain member organisations. Voss (1995) describes the evolution of the OM discipline from its origins in factory management, production engineering, and industrial engineering to a more inclusive subject that includes operations and manufacturing strategy, service operations management, innovation, design, and supply chain management.

Slack (1998) argues that SCM is a term that means different things in different contexts. He suggests three different but related definitions that are in common use: 1) "SCM is the

[1]The Council of Logistics Management is a non-profit, professional business organisation consisting of individuals throughout the world who have interests and/or have responsible positions in logistics and the related functions that make up the logistics profession.

management of the internal supply chain"; 2) "SCM is the formation of a long-term partnership or relationship with suppliers", and 3) "SCM is managing the entire network of supply from original source through to meeting the needs of the end customer". The OM perspective on SCM, with its origin in factory management, focuses on operations and manufacturing strategy, which has a strong connection to the physical material flow, the information flow, and the financial flow.

A quality management perspective on SCM

Several researchers today express interest in the study of QM by taking the supply chain perspective (Kaynak and Hartley, 2008; Kuei et al., 2010; Quang et al., 2016; Rachid and Aslam, 2012; Zhang et al., 2011). This area has been described as "supply chain quality management". Rachid and Aslam (2012) observe there is a considerable amount of empirical evidence that suggests QM is positively related to improvements in product quality, customer satisfaction, market share, and competitive advantage (see Awan et al., 2009; Flynn et al., 1995; Fotopoulos and Psomas, 2010; Kaynak, 2003; Mohrman et al., 1995; Nair, 2006; Powell, 1995; Prajogo and Sohal, 2006; Samson and Terziovski, 1999).

However, QM traditionally focuses on internal process control and improvement – that is, on intra-organisation improvement – and lacks a systems view of the supply chain network. Thus, QM has a limited impact on managing the quality of the supply network (Robinson and Malhotra, 2005; Romano and Vinelli, 2001). The research on the synergy of QM and SCM has increased in recent years (Zu and Kaynak, 2012). The QM perspective on SCM is clear owing to its strong connection to customer requirements and competitive advantage.

An information management and information systems perspective on SCM

Information management has emerged as the most commonly used term for information technology management in organisations. In this context, information technology refers to computer and telecommunications hardware and software and associated resources. Information processing is a central theme in information management, irrespective of the perspective. Information processing can be viewed as the actions taken to change the character of the information to, for example, subjective knowledge, different categories of information, and summarised information. O'Brien (1999) argues that an information system is an organised combination of individuals, hardware, software, communications network, and data resources that collects, transforms, and disseminates information in an organisation.

Some researchers (e.g., Huang et al., 2002; Hull 2002) maintain that SCM requires modern information technology in order to work efficiently (e.g., computer-based information systems that use computer hardware and software, telecommunications networks, computer-based data management techniques, and other forms of information technology). For some researchers such as Evans and Wurster (2000), the information management perspective on SCM is appropriate because of the need for software to process information that connects the physical material flow and the information flow (i.e. "the glue" that holds the structure of businesses together).

An industrial organisation perspective on SCM

The industrial organisation discipline is concerned with how organisations develop and conduct their business in comparison with other competitors in a market. The focus is on the strategic, managerial, and organisational aspects of creating new business and maintaining both service and manufacturing organisations (Carlton and Perloff, 2005). As a discipline, industrial organisation includes several different topics such as effective product development processes, change

management, the introduction of new technology, and the development of effective and human-related work models. Therefore, the industrial organisation perspective on SCM focuses on the strategic, managerial, and organisational aspects of SCM.

A knowledge management perspective on SCM

Ruggles (1997) contends that knowledge management covers three main activities: knowledge generation, codification, and transfer. Knowledge generation concerns all activities that result in "new" knowledge, whether on the individual, the group, or the worldwide basis. It includes activities such as creation, acquisition, synthesis, fusion, and adaptation. Knowledge codification is the capture and presentation of knowledge so that it can be re-used either by an individual or an organisation. Knowledge transfer involves the movement of knowledge from one location to another and its subsequent use. Generation, codification, and transfer are on-going processes that management does not initiate. The purpose of knowledge management is to enable organisations to explicitly facilitate and enhance knowledge creation and processing for the benefit of the organisation as well as for the individual.

Several researchers claim there is still no single, universally accepted definition of knowledge (management) (Lueg, 2001; Quinn et al., 1996; Tsui, 2000). Bhatt (2000) argues that knowledge, at best, is a metaphor because it is not the organisation itself but rather the individuals in the organisation who create knowledge. Bhatt, who distinguishes between individual knowledge and organisational knowledge, points out that a majority of studies do not clearly demonstrate how individual knowledge differs from organisational knowledge. Most definitions, however, share the perspective that knowledge management is concerned with the collection and dissemination of knowledge to the benefit of an organisation and its members (Lueg, 2001).

Lueg (2001) thinks that knowledge can be treated in the same way as information because its many knowledge management tools, such as expertise finders or knowledge repositories, resemble information management tools. Information technology facilitates knowledge management. As previously mentioned, a supply chain consists of two flows: the physical material flow and the information flow. If knowledge can be treated in the same way as information (i.e., information regarded as a preliminary stage of knowledge), then knowledge management can be considered an important aspect of SCM.

Figure 1. *The position of the research: "a typical supply chain".*

In sum: There are several perspectives on the concept of SCM owing to the fact that different academic disciplines have different ideas about the supply chain and its management. All perspectives contribute to our knowledge to some degree and can be seen as subsets of SCM. This thesis, which has its base in QM at the manufacturers' level, expands to include both the suppliers and the customers (i.e., the total supply chain).

Several terms and concepts that appear in this thesis relate to these different academic disciplines. The most-used terms and concepts are the following: quality, quality management, the supply chain, the supply chain and its management, supply chain quality management, supply chain performance, supply chain quality performance, and supply chain measures and metrics. As supply chain theory and supply chain management originate with researchers from these different disciplines, it seems relevant to explain and outline the position of the present research. Figure 1 depicts entities in the supply chain involved with quality management, logistics, operations management, and marketing as well as their relative position in this thesis.

1.3 Purpose and research question

The purpose of this thesis is to explore and describe the measures and metrics that should be used in the supply chain, both upstream and downstream, from a manufacturing perspective. The major contributions are the improvement model that is based in previous theory and the seven empirical studies on manufacturers' supply chain quality management and supply chain performance. These studies contribute to the conclusion of the thesis that can be used as a guideline to measure and improve supply chain quality performance for manufacturers. As Kamran and Aslam (2012) conclude, in order to achieve excellence, the scope of QM must broaden. Thus, the SC partners should jointly plan and execute all activities related to the fulfilment of customer requirements.

Based on previous research [e.g., Paper 1 and the suggested research areas identified by Quang et al. (2016), Gopal and Thakkar (2012), Forslund and Jonsson (2009), Sila et al. (2006)], and the new requirements in the Quality Management Standard, ISO 9001:2015, for monitoring and measuring related performance indicators, the general research question (RQ) of this thesis is the following:

RQ: What improves quality performance of supply chains that include manufacturing?

1.4 Limitations

There are some limitations in this thesis related to its purpose and the research question. This research is valid mainly for organisations that manufacture, assemble, and deliver physical products. The ambition is to answer the research question supported by the research in the seven studies presented in this thesis. The ambition is not to present a universal improvement model for all types of organisations. Moreover, in this context, the SC is described from raw materials to end user via suppliers and customers. However, sometimes the SC is described from supplier to end customer. The difference is that the end user may not be the customer who purchased the product, and the end customer may not be the user. This thesis does not deal with the SC activities after the product's life cycle ends (e.g. disposal, waste handling, and recycling). This thesis also does not deal with the metrics that have a more indirect impact on performance or are more abstract as far as handling or measuring (e.g., social accountability, carbon footprint, proximity, trust, information exchange, availability, and sustainability). The thesis does not address qualitative performance measures (e.g. trust and proximity).

1.5 The structure of the thesis

Chapter 1 presents the research question in addition to the background, the research problem, the research context with its limitations, and the research structure. Chapter 2 presents the theory used to support the improvement model and also develops the model as the frame of reference. Chapter 3 describes the research method used to develop the supply chain quality performance improvement model. Chapter 4 summarizes the papers used to support the development of the theory and the model. Chapter 5 presents further analysis and the conclusions from the seven papers. These papers are analysed in the search for findings that can be useful for the thesis conclusion that develops the model. Chapter 6 discusses the findings and SCM and QM from theoretical and practical perspectives and includes commentary on the theoretical and practical implications as well as suggestions for future research.

Figure 2 presents the structure of the thesis and the seven papers that resulted from the research.

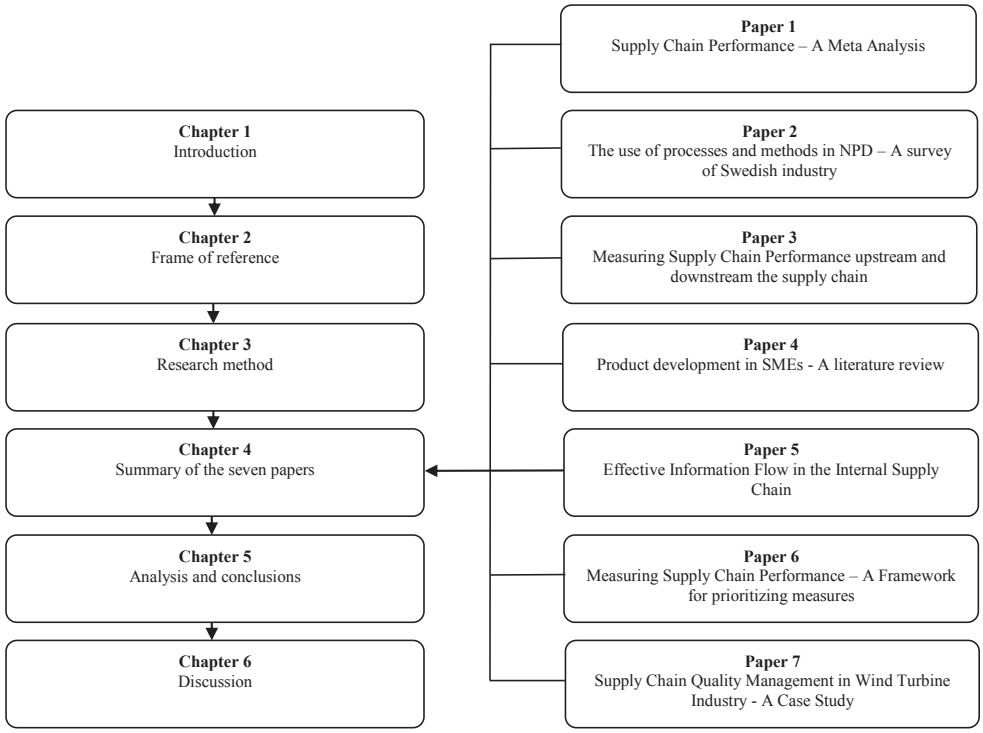


Figure 2. *The structure of the thesis and the seven papers.*

2. Frame of reference

This chapter presents general terms, concepts, and definitions in the theoretical framework for the research presented in this thesis. The chapter begins with an overview of the field of Supply Chain Management and Quality Management in addition to their combination (i.e., Supply Chain Quality Management). The chapter concludes with an overview of the performance of SC.

2.1 Supply chain and its management

Researchers have used the term "supply chain" since the 1970s (e.g., Banbury, 1975). The term "supply chain management" appeared in the early 1980s (e.g., Oliver and Webber, 1982). The term, supply chain, was slow to take hold and the lexicon was slow to change. However, it became more popular in the mid-1990s with the publication of a number of articles and books on the subject. In the late 1990s, supply chain became a management buzzword similar to the way in which Total Quality Management (TQM) was popularized in the 1980s. Operations managers began to use the term in their titles with increasing regularity (Blanchard, 2010; Feller et al., 2006; Jacoby, 2009). Today, a supply chain is described in the literature as a flow of goods, information, or financial data (Christopher, 1998; Mason-Jones and Towill, 1998; Singh, 1996). While the supply chain itself has been widely described and defined, its management is more difficult to describe.

Novack and Simco (1991), Jones and Riley (1985), and Houlihan (1985) produced some of the pioneering work on SCM as a management approach. The term "supply chain management" has been defined in the literature variously, depending on the author and the perspective. SCM has been become an inter-disciplinary subject studied by various academics in which they add their perspective of strategic management to the research on management and operations management, marketing, and logistics (Ketchen and Giunipero, 2004). There are several commonly cited, but not always accepted, definitions of SCM. For example, Sweeney et al. (2015) argue there is a lack of agreement on how SCM is defined. Below are some definitions of SCM:

> *"The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole".* (Christopher. 1998)

> *"All activities associated with the flow and transformation of goods from the raw material stage to the end user, as well as the associated information flows".* (Handfield and Nichols, 1999*)*

> *"Supply chain management is the systematic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole".* (Mentzer et al., 2001)

Supply chain management (SCM) can be viewed as an inter-disciplinary concept (Grimm et al., 2015; Klaus, 2009; Larson and Halldórsson, 2004) that involves several actors in a supply chain (i.e., customers, suppliers, and end users). Or SCM may be viewed as a major inter-organisational practice for gaining competitive advantage, particularly for alliances and networks with suppliers and customers (Janiver-James, 2012; Rungtusanatham et al., 2003). .Halldórsson et al. (2015) argue in their concluding remarks that the inter-disciplinary, interpretive, and integrative nature of SCM makes it a very complex topic for both academics and professionals. They also think that SCM cannot be dealt with or reduced to a single theory. Because SCM has a rather broad scope, it is rather difficult to establish its own "distinct scientific identity" (Klaus, 2009). Halldórsson et al. (2015) argue that SCM suffers from conceptual slack (a term they borrowed from Schulman,

1993). They think that there is a certain divergence in analytical perspectives and methodological approaches among scholars in the field, and the boundaries relative to other disciplines and professionals (e.g., logistics, operations management, purchasing, quality management, and industrial networks) are fluid. This can be seen in the work of Grimm et al. (2015) who conclude that SCM is a natural extension of the Logistics and Transportation discipline. However, they also note that SCM is an inter-disciplinary field.

Stevens (2016) describes the evolution of SCM as a rapidly evolved discipline that began in the 1970s when organisations needed to improve their inventory management and production planning and control. The next phase (approximately to the early 1980s), according to Stevens, was the systematization of materials, production, and transport management. The phase from the mid-to-late 1980s focused on firms' implementation of Japanese practices such as Total Quality Management (TQM) and Lean. The next phase in the evolution of SCM included the introduction of other process improvement practices (e.g., Six Sigma) and the evolution of data handling such as in the development of IT systems.

Traditionally, SCM is a term associated primarily with logistics. In manufacturers, logistics plays a major role in handling physical goods between organisations. Moreover, SCM also relates to the internal SC. Today, many manufacturers use ERP systems (Enterprise Resource Planning) to manage their manufacturing activities (i.e., from order to delivery). An ERP system can, if implemented correctly, provide an organisation with control of its business core processes. However, these ERP systems are supports to the organisation, not solutions to problems. For example, if a supplier sends a defective part/material late, the ERP system can log the arrival and condition of the part/material. However, someone still has to check the part/material to determine its condition. Thus, if used correctly, an ERP system is a tool that can control parts of the supply chain. Forslund and Jonsson (2010) note that several studies reveal that ERP systems can pose major problems to supply chain performance management (see also Brewer and Speh, 2001; Bourne et al., 2000; Forslund and Jonsson, 2007, 2009; Phusavat et al., 2009). Forslund and Jonsson also conclude that implementing an ERP system in SMEs is problematic due to the lack of resources for education and training. These resources are necessities for successful ERP system implementation.

Table 3: *Excellence in supply chain management (Robinson and Malhotra. 2005).*

Management	**Dell computer**
Inventory management	Dell manufactures more than 50,000 computers every day, but carries only four days of inventory (competition carries 20-30 days)
Supplier management	Only about 30 Dell suppliers provide 75% of direct material purchased. If supplier levels exceed 10 days, Dell works with the supplier to lower inventory.
Production management	Dell took a make-to-stock (MTS) industry and shifted it to make-to-order (MTO). Orders are pulled through manufacturing based on actual orders.
Information management	More than 50,000 orders come through the Internet. Dell's legacy order management system records all the orders and releases them to manufacturing. Production lines are scheduled every two hours.
Technology management	Technology in Dell's supply chain process provides efficiencies, immediate communication with suppliers and improved operations internally.
Quality management	To address quality issues Dell launched the Critical Supplier Partnership Program resulting in improvement in quality metrics and continuity of supply. This program reduced early field failures by 37% and manufacturing line failures fell from 15,000 to 3000 defective parts per million (dppm).

Robinson and Malhotra (2005) describe several examples of excellence in supply chain management. As particularly good examples, they call attention to the companies, Dell and Walmart. They used the following sources for their examples: Jacobs (2003), Institute of Management and Administration (2002) and Moore (1993). Table 3 is their Dell example.

Essentially SCM is an inter-disciplinary concept with a broad scope that makes it difficult to establish its own "distinct scientific identity". Definitions of SCM, which are rather similar, involve at least two flows – physical material flow and information flow. However, as theory, SCM is still evolving and cannot yet be called mature.

2.2 Quality management

The concept of quality management (QM) has been very influential worldwide since the 1980s (Casadesus and de Castro, 2005). Nair (2006) points out that QM is one of the major research areas in the operations management literature. Further, the term "quality" has been widely discussed and defined by both researchers and practitioners (Garwin, 1988). While there are several definitions of "quality", only one definition seems used by all member countries in the International Organisation for Standardization (ISO). That definition is found in the Quality Management Standard ISO 9001:2015, which defines quality as the *"degree to which a set of inherent characteristics of an object fulfils requirements"*. However, this is only one definition of many. Various researchers and consultants have offered their own definitions. Garwin (1988) classified some of these definitions of "quality" from several sources. These definitions include the following: "*Quality is fitness for use*" (Juran, 1974) and "*Quality means conformance to requirements*" (Corsby, 1979).

The development of QM over the years can be described in many ways. Zairi (2002) presents the evolution from quality control to TQM (Total Quality Management) as a two "step" process between quality assurance and quality management. Other researchers describe steps that include quality inspection, quality control, quality assurance, and total quality management. See Andreasson et al. (1995), Bergman and Klefsjö (2012), Garvin (1988), and Sandholm (2000). Weckenmann et al. (2015) present an overview of concepts in QM and include a step between quality assurance and total quality management.

Although there are some differences in the presentation of the development of QM, generally the development is described as a series of steps such as quality, quality control, quality assurance, quality management, and total quality management plus some new practices (e.g., supply chain management) and new methodologies (e.g., Six Sigma). Traditional QM, which focuses primarily on internal process control and improvement, stems typically from an internal supply perspective (i.e., intra-organisational issues). Madu (1998) describes QM as a broad field with many inter-faces. One definition of QM that seems to capture the broad field is the following: "*Application of managerial tools to plan for quality, attain and control quality, follow up and improve quality, as well as organize for quality and develop competence in the field"* (Juran, 1999, Section 37).

The practical work with QM, with its focus on the internal SC, deals with how to control quality in different functions from order to delivery. Often manufacturers have an appointed function (quality manager) for handling the management system (e.g., ISO 9001, ISO/TS 16949). The work often consists of monitoring the results from other processes such as production. In the QM standard ISO 9001 (year 2000), there is a requirement on process management: *"The organisations shall… monitor, measure where applicable, and analyse these processes"*. In the

new edition of ISO 9001 (year 2015), the requirement for measuring performance is even clearer: "*The organisation shall determine the processes needed for the quality management system and their application throughout the organisation, and shall: ... determine and apply the criteria and methods (including monitoring, measurements and related performance indictors) needed to ensure operation and control of these processes"*. This means from a practical point of view that different process owners define the measures and metrics that describe performance in their processes (e.g., purchasing, on-time delivery, quality, and defects).

Mellat-Parast (2015), in contrast to Rachid and Aslam (2012), argues that despite the importance of supply chains and their role in enhancing the competitive position of organisations, little attention has been given to quality issues in supply chains. They point out that there is a need to move beyond the scope of an organisation and address quality within its supply chain and network (see also Aboelmaged, 2010; Agus and Mohd, 2012; Foster, 2008; Mellat-Parast, 2013; Sun and Ni, 2012; Teng et al., 2006).

In sum: QM is one of the major research areas in the operations management literature. The evolution of QM can be presented as steps that include quality inspection, quality control, quality assurance, quality management, and total quality management as well as new practices (e.g., supply chain management) and new methodologies (e.g., Six Sigma). QM focuses primarily on internal process control and improvement. However, little attention has been paid to quality issues in supply chains. Weckermann et al. (2015) observe that today's globalization and its resulting complex cross-linked supply chains place new requirements on QM. These requirements include technical-oriented quality, social responsibility, and sustainability. Using supply chain management, there is a need to address quality in firms' supply chains and networks.

2.3 Supply Chain Quality Management

In recent years researchers have shown more interest in the study of QM from the SCM perspective (Kaynak and Hartley, 2008; Kuei et al., 2010; Quang et al., 2016; Rachid and Aslam, 2012; Zhang et al., 2011). This area is usually referred to as "supply chain quality management" (SCQM). Rachid and Aslam point out there is a considerable amount of empirical evidence that suggests QM is positively related to improvements in product quality, customer satisfaction, market share, and competitive advantage (see Awan et al., 2009; Flynn et al., 1995; Fotopoulos and Psomas, 2010; Kaynak, 2003; Mohrman et al., 1995; Nair, 2006; Powell, 1995; Prajogo and Sohal, 2006; Samson and Terziovski, 1999).

However, QM traditionally focuses on internal process control and improvement (i.e., intra-organisation improvement) and lacks a systems view of the supply chain network. Therefore, QM has a limited impact on managing the supply network's quality (Robinson and Malhotra, 2005; Romano and Vinelli, 2001). The research on the synergy of QM and SCM has increased over the years, according to Zu and Kaynak (2012). Table 4 classifies this research by the synergy of QM and SCM.

Rachid and Aslam (2012) observe that while research exists in the area of QM in SCs from the last decade, there is still a need to develop a framework for managing quality throughout the SCs. They argue that previous QM research has focussed on aspects related to operational excellence, while the SCQM research has mostly focussed on identifying the common themes between SCM and QM (Foster, 2008; Robinson and Malhotra, 2005), on studying relationships between SC-related quality practices (i.e., supplier QM and customer integration), and on various aspects of

organisational performance (Kannan and Tan, 2007; Kaynak and Hartley, 2008; Levy et al., 1995; Sila et al., 2006). Rachid and Aslam argue that in order to realize the full benefits of QM and SCM efforts, it is imperative that QM practices throughout the SC share a common focus. They think this focus can lead to joint quality policymaking and strategy execution, a phenomenon that can be called "total supply chain quality management" (TSCQM).

Table 4: *Research on the synergy of QM and SCM, adapted from Zu and Kaynak (2012).*

Researcher	**Type of synergy of QM and SCM**
Robinson and Malhotra (2005)	From a theoretical perspective defined the concept of SCQM.
Foster and Ogden (2008)	Compared the differences in the ways operations managers and supply chain managers approach QM. SCC and QM efforts improve each other's performance and integration between the two functions, which may be beneficial for an organisation.
Kuei et al. (2008), Roth et al. (2008)	Proposed various frameworks for SCQM with critical dimensions
Flynn and Flynn (2005), Forker et al. (1997), Kaynak and Hartley (2008), Lin et al. (2005), Lo et al. (2007, 2009), Sanchez-Rodriguez and Martinez-Lorente (2004), Sroufe and Curkovic (2008), Tan et al. (1998), Yeung (2008), Kannan and Tan (2007), Levy et al. (1995), Sila et al. (2006), Rachid and Aslam (2012)	The relationship between QM and SCM and the impact on performance (various aspects of organisational performance).
Prado-Prado (2009), Romano and Vinelli (2001), Wong and Fung (1999)	How quality is managed in a supply chain context.
Fynes and Voss (2002), Fynes et al. (2005)	How buyer-supplier relationships affect the effectiveness of QM in supply chains.

Kuei et al. (2008) argue that SCQM can be described as an SCM extension designed to help firms establish a competitive supply chain through the application of QM practices. As Quang et.al (2016) conclude, SCQM is the orientation, coordination, and implementation of all activities smoothly occurring in the supply chain. It is useful for improving operational quality and product quality as well as increasing customer satisfaction.

Several researchers have concluded that supply chain management (SCM) may be regarded as a major inter-organisational practice for gaining competitive advantage, business stability, and growth (Chin et al., 2010; Janvier-James, 2012; Li et al., 2006; Rungtusanatham et al., 2003). The goal in SCM is to achieve a higher level of synchronization between the SC partners (Zhang et al., 2011). Meanwhile, Robson and Malhotra (2005) define SCQM as "the formal coordination and integration of business processes involving all partner organisations in the supply chain channel". Kuei and Madu (2001) defines SCQM using three simple equations: SC = a production-distribution network, Q = meeting market demands correctly, and achieving customer satisfaction rapidly, and profitability, and M = enabling conditions and enhancing trust for supply chain quality. Some other definitions of SCQM are the following:

> *"The participation of all members in a supply chain to improve all processes, services and work cultures, etc. It will result in increasing productivity, competitiveness and customer satisfaction".* (Frederick, 1998)

> *"Formal coordination and integration of business processes involving all partner organisations in the supply channel to measure, analyse and continually improve products, services, and processes in order to create value and achieve satisfaction of intermediate and final customers in the marketplace".* (Robson and Malhotra, 2005)

After presenting several definitions of SCQM (Fredrick, 1998; Kuei et al., 2001; Robinson and Malhotra, 2005), Quang et al. (2016) state the following: *"SCQM is the orientation, coordination and implementation of all activities smoothly taking place in the supply chain. It is helpful to improve operational quality as well as to increase customer satisfaction"*

Zhang et al. (2011), who argue that little attention has been paid to quality issues in supply chains, point out some indicators (e.g., product recalls) of the vulnerability of supply chains to risk and disruptions. In contrast to firm level quality management, quality issues across supply chains have not been fully implemented. Mellat-Parast (2013) argues that more research is needed to address the concept of quality in supply chains and thus to move beyond the scope of an organisation by addressing quality within a network of firms.

Kaynak and Hartley (2008) argue that the implementation of SCQM refers not only to the internal practices, which are contained within an organisation, but also to the external practices, which cross functional boundaries by integrating a company with its customers and suppliers. See Figure 3. Kuei and Madu (2001) propose three critical elements that SCQM strategy must focus on: 1) the customer, 2) the supplier relationship, and 3) the quality of the IT system. This seems to be relevant for managing the internal and external supply chain shown in Figure 3.

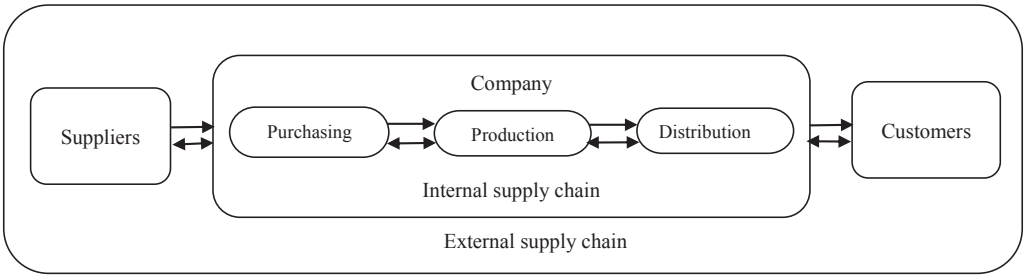


Figure 3. *Internal and external supply chain, Kaynak and Hartley (2008).*

In sum: The research on the synergy of QM and SCM has increased over the years. There still is a need to develop a framework for managing quality throughout the SCs. In contrast to firm level quality management, quality issues across supply chains have not been fully examined. The theory of SCQM is rather immature although the definitions presented in the literature are rather similar. They include "all partners in the supply chain" or "all activities in the supply chain". This means SCQM includes both intra- and inter-organisational issues.

2.4 Relationship among QM, SCM, and SCQM

Several researchers have described the synergy of QM and SCM by taking various research perspectives. Lin and Chai (2012) argue that traditional QM measures should be applied to supply chains in order to facilitate good relationships among members while continuing to improve quality. They also point out that SCQM itself is a part of SCM that includes quality management concepts. SCQM is the integration of QM and SCM in that it considers issues related to inter-organisational supply chains. Traditional QM, which lacks the perspective of a supply chain network, thus has a limited impact on managing the entire supply network quality (Robinson and Malhotra, 2005; Romano and Vinelli, 2001).

Zu et al. (2012) write that the research suggests that the synergy between QM and SCM practices is critical for a successful supply chain (see also Flynn and Flynn, 2005; Robinson and Malhotra, 2005). Mellat-Parast (2013) points to the evidence in the literature that proposes a firm´s QM approaches and SCM practices, which complement each other, should be integrated to achieve superior financial and business performance (Kannan and Tan, 2005; Kaynak and Hartley, 2008; Lin et al., 2005; Ou et al., 2010; Sila and Ebrahimpour, 2002; Yeung et al., 2006).

In sum: SCQM, which is at the intersection of SCM and QM, has significant impact on firm performance (Kannan and Tan, 2005; Kaynak and Hartley, 2008; Lin et al., 2005; Ou et al., 2010; Sila and Ebrahimpour, 2002; Yeung et al., 2006). SCQM deals with upstream activities, internal processes, and downstream activities (Quang et al., 2016) and involves both intra- and inter-organisational issues. This is in contrast to QM that focuses on intra-organisational issues (Lin and Chai, 2012; Robinson and Malhotra, 2005; Romano and Vinelli, 2001) and to SCM that focuses on inter-organisational issues. This description of SCQM seems fairly clear (Robinson and Malhotra, 2005; Quang et al., 2016). See Figure 4.

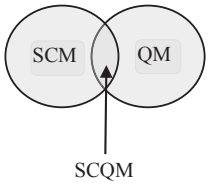


Figure 4. *Supply chain quality management at the intersection of SCM and QM.*

2.5 Performance – in a SCQM context

Cai et al. (2009) point out that performance monitoring and improvement in a supply chain has become an increasingly complex task. Gopal and Thakkar (2012) pose several questions about this complex task (summarized): Which measures should practitioners use? When should they use them? How should they analyse the performance of supply chains using suitable measures? In posing these questions, they remark there is no "right supply chain strategy" because the complexity of performance differs from context to context. In their literature review of articles published in peer-reviewed international journals, they analyse the development of the research on SC measures and metrics from year 2000 to year 2011. They identify several implications for contemporary researchers and for practitioners. Table 5 presents some of these implications that relate to performance measurement and to the research question of this thesis.

Table 5: *Selected implications for researchers and practitioners (Gopal and Thakkar, 2012).*

Implications for contemporary researchers	**Implications for practitioners**
Research should develop a measurement index (combinations of system dynamics operations research, logistics marketing, organisations and strategy perspectives) for getting optimum supply chain performance.	Intangibles measures can be use at the higher levels decision -making such as strategic level, but the tangibles measures can be used at operational level decision-making. A mix of intangibles and tangibles can be used at the tactical level decision-making.
Need for metrics standardization and identification of key measures that could be shared between supply chain partners.	Organisations should conceive that supply chain performance measures change according to change of competitive business strategy and technology.
Understand the synergies between the various (Total quality management (TQM) and knowledge management) management practices	Management information system and change management plays a significant role in the success of Performance measurement system (PMS).

Several researchers have described the theory on measures and metrics, as reviewed next.

Quang et al. (2016) describe firm performance dimensions such as customer satisfaction (customer evaluation, response to customer standards), financial performance (bad quality costs, manufacturing unit costs, market share, sales revenue, and return on sales) and operational performance (delivery on-time, quality inputs, rate of defect products, lead-time, and flexibility). Other researchers (Harrison and New, 2002; Huang et al., 2004) argue that supply chain performance metrics provide organisations with a standard framework for evaluating supply chain performance including internal and external firm links.

Piotrowicz and Cuthbertson (2015) conclude that four economic metrics are the most important in comparison with other supply chain key performance indicators. Their metrics are on-time delivery, customer satisfaction, total costs, and transport costs.

Still other researchers (Brewer and Speh, 2001; Gunasekaran et al., 2001) argue that most metrics used to measure the performance of the supply chain can be ascribed to the logistics discipline (e.g., lead-times, order fulfilment, and costs).

Beamon (1999) argues that the most difficult area in performance measure is the development of performance measurement systems (PMS). This involves the methods an organisation creates for its measurement system as it addresses issues involving what to measure, how to measure it, how often to make measurements, which multiple individual measures can be integrated into measurement systems, and how to evaluate the measurements. Beamon (1999) presents a list of supply chain output performance measures that capture performance from the customer side of the SC (e.g., sales, profit, on-time delivery, customer response time, manufacturing lead-time, and customer complaints).

The two most common PMS are the Balanced Score Card (Kaplan and Norton, 1992) and the Performance Prism (Adams and Neely, 2000). The former PMS balances outcomes and internal process performance while the latter PMS includes stakeholders such as employees, suppliers, intermediaries, regulators, and communities. However, Najmi et al. (2012) criticize both PMS because of their evaluation deficiencies. They recommend a feedback-loop so that both the implementation and effectiveness of relevant metrics are evaluated.

2.6 Measures and metrics

This section presents measures that can be described as numbers derived from a measurement. Examples from manufacturers include delivery performance, quality performance, flexibility in production, efficiency, and supplier performance. Metrics are a calculation involving two measures (e.g., on-time delivery, customer satisfaction, total costs, robustness, and effectiveness). Typically, the calculation is a form of division. The format of the calculated result can be a percentage, a ratio, a fraction, a decimal, or a multiple. Metrics are useful for evaluating compliance, processes effectiveness, and success against established objectives, as required by the new Quality Management Standard ISO 9001:2015. With measures, you can evaluate the results of an activity; with metrics, you can compare the performance of activities.

Foster (2013) argues that a major consideration in performance improvement involves the creation and use of performance measure indicators. These measures or indicators are measurable

characteristics of products, services, processes, and operations that a company uses to track and improve performance. Foster also argues that these measures or indicators should be selected to best represent the factors that lead to greater customer satisfaction and to improved operational and financial performance. Foster lists eight important categories of measures (key business factors) that are often used in benchmarking studies. These eight categories are combined with other researchers' suggestions on the use of metrics and offer a view of some performance metrics that can be used to track performance in supply chains. These eight categories are described next.

Financial ratios (1) include Return on Assets (ROA) and Return on Investments (ROI). They are probably the easiest to obtain and use in benchmarking since they can be calculated from a firm's income statement and balance sheet. Table 6 presents some financial ratios/metrics.

Table 6: *Financial metrics*

Financial ratio / metrics	**Unit**
ROA, Return on Assets	kSEK
ROI, Return on Investment	kSEK
EBIT (IFRIS), Earnings Before Interest and Tax	kSEK
EBIT-Margin, Earnings Before Interest and Tax margin	%
CAPEX, Capital expenditure	kSEK
Uninsured receivables	Number
Uninsured receivables	kSEK
TCO/IT workplace	kSEK/IT WP
Cash-to-Cash cycle time	Days/weeks/months

Productivity ratios (2) include three different calculations for measuring important total productivity. To understand the *total factor productive measure,* Foster argues that we first must understand a *single factor productivity measure*. Single factor productivity measures are computed as: Single factor productivity = output/(a single input).

Example: The cost of goods sold to scrap ratio is a single factor ratio in that it focuses on scrap material alone. Multi-factor productivity measures use multiple inputs in their computation. For example: Multi-factor productivity = output/(the sum of multiple inputs).

Foster describes multiple inputs as scrap, labour, energy, materials, equipment, and other measures of inputs. Hayes and Wheelwright (1984) argue that it is better for firms to use multi-factor productivity measures due to their robustness. The *total productivity measure* is similarly computed as: Total factor productivity = output divided by sum of all inputs to production. Table 7 presents some productivity metrics.

Table 7: *Productivity metrics*

Productivity ratios / metrics	**Unit**
Total factor productivity	Output/(sum of all inputs to production)
Man hour/machine	Hours
Units produced/employee	Number

Customer-related results (3) include customer satisfaction, customer dissatisfaction, and comparisons of customer satisfaction to that of relative competitors. These measures can take different forms such as retention, gains, losses, customer-perceived value, competitive awards, competitive customer ratings, and independent organisation evaluations. From a logistics perspective, the order-to-delivery (OTD) or order lead-time (OLT) is one of the most important

management processes. Mattsson (2004) defines OTD as four sub-processes: customers' ordering, suppliers, delivery logistics service providers, and transportation and customer goods receipt. This should not be confused with on-time delivery that often is mentioned as OTD. Table 8 presents some customer-related metrics.

Table 8: *Customer-related metrics*

Customer-related results / metrics	**Unit**
Quality conformance/complaints	kSEK/BY
OTD, order-to-delivery	Days/weeks
OLT, order lead-time	Days/weeks
Warranty	kSEK/BY
Customer OTD, on-time delivery	%
New customers	kSEK/BY
New customers	Number
Lost customers	kSEK/BY
Lost customers	Number
Service after delivery	Hours, days
Total lead-time	Days, weeks
Total cost	kSEK
Order fulfilment cycle time	Days, weeks

Operating results (4) are important for monitoring and tracking the effectiveness of company operations and presenting cycle times, waste-reduction measures, value-added measures, lead-times, time from concept to market, setup times, and per cent reduction in setup times. Jonsson and Lesshammar (1999) note that the Overall Equipment Effectiveness (OEE) is a measure of internal efficiency (availability, performance, and quality). They conclude that the most important objective of OEE is not to obtain an optimum measure, but rather to obtain a simple measure that tells the production personnel where to spend their improvement resources. Table 9 presents some operating metrics.

Table 9: *Operating metrics*

Operating results / metrics	**Unit**
OEE, Overall Equipment Effectiveness	%
Net value added per Employee adjusted by temporary staff	kSEK/FTE
Capacity load	%
Actual Rate: Actual vs. Planned	%
Lead-time	%

Human resources (5), which are essential as a measure of employee satisfaction, are significantly related to business performance. Employee satisfaction measures include training expenditures, training hours per year, work system performance, employee effectiveness measures, turnover, safety statistics, and absenteeism. Table 10 presents some human resource metrics.

Table 10: *Human resource metrics*

Human resource measure / metric	**Unit**
Health rate, attendance rate	%
Fluctuation rate	%
Training time per FTE (Full Time Equivalent)	Hours/FTE (Total Hours of Training Undertaken within a Year) / (Total Number of Full-Time Equivalents)
Employee satisfaction	%

Quality measures (6) can include conformance-based quality information such as reject rates, capability information, performance information, scrap and rework measures, percentage of defectives, field repairs, and cost of quality. Foster argues that quality measures include data on the performance of processes and time-related statistics such as percentage of customers whose phone calls are answered within seven seconds, average response time for phone inquiries, and the number of people a caller must contact to resolve a problem. Table 11 presents some quality metrics.

Table 11: *Quality metrics*

Quality metrics	Unit
Breakdown rate	%
Claims	Number
Claims Acceptance	%
External PPM-rate	SEK
Bad Quality Cost	SEK
CIP, Continuous Improvement Projects	Numbers
Perfect order fulfilment	%
Field repairs	Number
Field repairs	kSEK

Market share data (7) are essential indicators of business success. Market share data include shares in the different markets in which the firm operates. Market share comparisons are made to determine where the initiator firm ranks in the market. For market share, the unit is a per cent of the market.

Structural measures (8) include the firm's objectives, policies, and procedures. These measures may include measures related to safety, production, accounting, financial, engineering, and others.

Other sources of measures and metrics exist. For example, the Supply Chain Council, which is a non-profit organisation, has developed some 250 SCOR metrics that are organized in a hierarchical (and codified) structure from organisation Level 1 to process Level 2 to diagnostic Level 3. The metrics in the SCOR model version 11.0 are categorized as five performance attributes: reliability, responsiveness, agility, costs, and asset management efficiency. The first three attributes are customer-focused; the latter two are organisation-focused. The challenge for a company is to define, align, and prioritize the competitive requirements for each attribute knowing that it will have to choose where it will be best and where it is acceptable to be average.

Katiyar et al. (2015) present 20 key factors related to supply chain performance measures and connect these to their sources. These key factors are identified based on a literature review and a brainstorming session with 16 experts in automotive SCM. The study concludes that these key factors are helpful in measuring SCP (Supply Chain Performance) in automotive SC. Most factors presented are similar to the factor Foster describes: quality, on-time delivery, delivery lead-time, and customer query time.

In sum: Performance measures in a SCQM context are measures intended to represent both inter-organisational and intra-organisational performance. Foster's eight categories of measures can be used when complemented with other research findings on supply chain performance. See, for example, Beamon (1999), Brewer and Speh (2000), Gunasekaran et al. (2001), Jonsson and Lesshammar (1999), Katiyar et al. (2015), Piotrowicz and Cuthbertson (2015), and Quang et al. (2016). The SCOR reference model v.11 can be used a framework for deciding which metrics to use.

3. Method

This chapter presents the method used in the thesis to develop the model and also describes how the method was used in the studies that support the model (i.e., in Papers 1-7).

3.1 Research process and methodological issues

Kallet (2004) argues that the methodology section of a research paper should answer two main questions: How was the data collected or generated? How was it analysed? The method of data collection in this thesis can be described as follows: Studies 1 and 4 are literature reviews. The case study method was used in Studies 3, 5, (6), and 7. (Studies 3 and 6 are based on same case study). We primarily used interviews for these three empirical case studies. The empirical data in Study 2 was collected by a survey.

Case studies are often associated with descriptive and exploratory research. Therefore, the case study approach was taken in order explore and describe which metrics should be measured in the supply chain, both upstream and downstream, from a manufacturing perspective. Each of the seven papers (see the Appendix) presents its method and analysis in greater detail. However, the results from these studies were revisited in order to develop further insights that contributed to the thesis's conclusion, which is presented in Section 5.8.

Our reasons for choosing mainly case studies are several. Eisenhardt (1989) concludes that theory developed from case studies is particularly well-suited to new research areas (SCQM is such a new research area). Voss et al. (2002) argue that case study research is one of the most powerful research methods in operations management, particularly in the development of new theories. Simon and Sohal (1996) argue that case study research may provide rich and deep insights into quality management practices. They note several benefits of case study research, including the following:

- One or several cases can lead to the identification of a range of further research areas.
- Case study research helps bridge the gap between academia and industry.
- The findings from case study research tend to be widely accepted in industry.
- The use of interviews allows the researcher to gain rich insights into issues that are normally not amenable to questionnaires
- Case studies often unearth new issues, insights, and directions in the research that provide the basis for further work.

Lee et al. (2007) argue that the capacity of case studies to draw from different data sources allows several levels of simultaneous analysis of the dynamics in a single setting. Eisenhardt (1989) says case studies create the potential for a richer understanding of organisational phenomena than can be conveyed by statistical analysis.

Grünbaum (2007) presents several researchers' definitions of a "case study" (see Eisenhardt, 1989; Merriam, 1988; Stake, 1995; Yin, 2003) and shows how the differences in these definitions can be explained by different axioms. Generic characteristics can, nevertheless, be identified across paradigmatic positions (Grünbaum, 2007). Hill et al. (1999) argue that case study research in operations management differs from case study research in the wider social science field because researchers in operations management are interested in analysing manufacturing and service processes and systems. However, it seems that the aims of case study research are similar, irrespective of the research discipline.

The following definition of a case study by Yin (2009, p. 18) is used in this thesis.

> *"A case study is an empirical enquiry that: investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident. The case study inquiry: copes with technically distinctive situations in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result benefits from prior development of theoretical propositions to guide data collection and analysis".*

Yin (2009, p. 8) explains that case studies are preferred when "how" or "why" questions are posed, when the investigator has little control over events, and when the focus is contemporary phenomena. Meredith (1998) describes some outstanding strengths of case study research as derived from Bebensat et al. (1987). Case study research allows the questions of "why", "what", and "how" to be answered.

Yin (2003, p. 10), however, points to the following three disadvantages with case study research (summarized). 1) Case studies may lack rigor because case study research has a poor reputation when some investigators have been sloppy and have allowed equivocal evidence or biased views to influence the direction of their findings and conclusions. 2) Case studies, which provide little basis for scientific generalisation, may be regarded as "samples". 3) Case studies take too long and may result in massive amounts of unreadable documents.

Stuart et al. (2002) also argue that case studies may lack research rigor. However, it is also argued that case studies do not represent a "sample" and the investigator's goal is to expand on and generalise about theories (i.e., using analytic generalisation).

To avoid these disadvantages in our case studies (Studies, 3, 5, and 7), we took several actions. In Studies 3 and 7 two researchers with different roles were involved. This arrangement allowed the two researchers to observe each other's work. The observing researcher evaluated the effects of the more active researcher's interventions. We documented the analysis process and the respondents' statements. The answers were transcribed verbatim for Study 7 and documented by the researchers for Studies 3 and 5. Yin's (2009) analytic generalisation was used for the case studies in order to generalise from a particular set of results to a broader theory. In Study 3, the topics addressed in the interviews were selected from previous supply chain performance research. In Study 5 we used semi-structured interviews and a research protocol. This protocol was developed from a process-oriented model described by Harrington (1991).

In Study 7, we constructed a set of operational definitions for use in the interviews. We also used direct content analysis. Content analysis, which takes a directed approach, is guided more by a structured approach than by a conventional approach (Hickey and Kipping, 1996). In content analysis, using existing theory or prior research, researchers begin by identifying key concepts or variables as initial coding categories (Potter and Levine-Donnerstein, 1999). Next, operational definitions for each category are determined using the theory. We also strengthened the reliability of our research by using multiple data sources (i.e., by triangulation). We used interviews, protocols, and cross-case analysis.

Gummesson (1991) states that in case studies the researcher may influence the study because of access and pre-understanding. Access refers to the ability to get close to the object under study in order to see what is happening. Pre-understanding refers to the researchers' knowledge, insights,

and experience as they conduct a research project. For the case studies of this thesis, my access and pre-understanding facilitated a mature, open, and honest approach as well as more effective work with a strong sense of discipline. My more than 20 years of management consulting and my ten-year accreditation as a Quality Management Certification Auditor gave me access to the research subjects and a pre-understanding of their situations.

However, some researchers argue that the dual role of management consultant and researcher could result in a biased perspective (Alvesson and Svenningsson, 2008; Helms and Mills, 2009). I was aware of the possibility of bias and therefore discussed the relevant issues with my university colleagues and advisors. I believe the risk of bias was minimised owing to these discussions and also by my clearly documented research process.

Yin (2009) categorizes case studies as exploratory, explanatory, or descriptive. This thesis takes a descriptive and exploratory approach rather than an explanatory approach. The research question begins with a "what" question. The thesis conclusion (see Section 5.8) answers the research question. Further, in Chapter 6, the conclusion is again discussed, and both theoretical and practical implications are presented. The thesis does not answer the "why" question. The aim of this thesis is to explore, describe, and present quality performance in manufacturing supply chains by further developing Kaynak and Hartley´s (2008) view of the internal and external supply chain, by drawing conclusions from the seven studies, and by proposing a supply chain quality performance improvement model.

3.2 Method - step by step to develop the model

The method used to develop the supply chain quality performance improvement model in this thesis is based on the scientific principle of adding small pieces of theory to well-known existing theories. The proposed model is based on a model by Kaynak and Hartley (2008) – their internal and external supply chain. See Figure 3. The results from the studies are then connected to that model with insights and knowledge about performance in certain parts of the supply chain (i.e., upstream, downstream, or within the organisation) that could be improved in the effort to establish better quality performance in the total supply chain (the degree to which a set of inherent characteristics fulfils requirement ISO 9001:2015).

According to Lee (1999) and Lee et al. (2007), Yin's (1994) case study methodology is predominantly used in qualitative research. Figure 5 presents the research method used in this thesis that follows Yin's case study methodology. It is a methodology that is similar to Eisenhardt's (1989) steps for building theory from case study research (i.e., Getting started, selecting and crafting instruments and protocols). This is similar to Yin's "define and design phase". Entering the field, analysing data, and proposing hypotheses or research questions are subsequent steps similar to the phases "Prepare, collect and analyse". In the final step, the relevant literature is considered as conclusions are drawn: "Analyse and conclude".

Study 2, which is a survey (a quantitative method), also contributes to the thesis conclusion presented in Chapter 5. Study 1 was conducted to create an understanding of the SCM and supply chain performance measurements. Study 4 is a literature review and contributes to the awareness of supply chain and product development issues. Studies 3, 5, 6, and 7 were conducted to advance our knowledge about the SCM and performance issues. In Figure 5 the studies are linked and modified to the case study approach presented by Yin (2009).

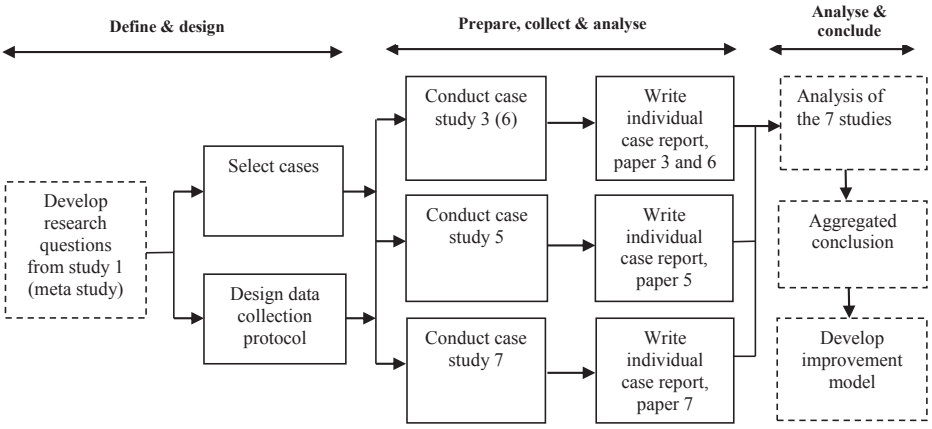


Figure 5. *The path towards the thesis conclusion and the improvement model, based on Yin (2009).*

3.3 Studies performed – collection and analysis of data

The empirical evidence presented in the seven papers (see the Appendix) is mainly based on case studies. Given the research conditions, case studies were the most appropriate research method for the investigations. As described earlier, several researchers (Simon and Sohal, 1996; Voss et al., 2002) agree that case study research is a powerful research method in both operations management and quality management. Moreover, several researchers note the several benefits associated with the case study approach including the following: bridging the gap between academia and industry; gaining richer insights from interviews than from questionnaires; and discovering new issues, insights, and directions for further work (Simon and Sohal, 1996). Different data sources can create the potential for richer understanding (Eisenhardt, 1989; Lee et al., 2007).

The seven studies have an explicit research question/s. The quality of the data was discussed with colleagues and senior academics in the research group and at seminars at our university. The method was discussed at conferences with both national and international academics in the field (Quality Management, Operations Management, and Logistics Management). The descriptions of the studies explain how the data were collected and how the data were analysed. Further details on how the studies were performed are described in each paper. Table 12 presents the method used in the studies in more detail: an overview of the method, the research questions, the data sources, the number of investigators, and the intended output.

Study 1 is a literature review (i.e., a quantitative meta-analysis) on supply chain management and performance. The research team concluded that the approach was appropriate owing to the two research questions: 1) What does research literature say about different types of supply chains performance? 2) What does research tell us about the impact of different types of SCM on the performance of supply chains? Meta-analysis is a methodological approach that can be used to answer these types of questions (see Lipsey and Wilson, 2001; Paterson et al., 2001).

Table 12: *The studies performed and method: inductive or deductive. Based on Eisenhardt (1999).*

Study	Method	Research question	Data sources	Investigators	Intended output
Study 1, Literature review – A meta analysis of supply chain performance	Deductive approach, Literature review, meta study	What does research say about different types of supply chain measures on supply chain performance?	25 research articles investigated	Research team (two researchers)	Contribution to the SCM (Supply chain management) literature
Study 2, A survey – The use of processes and methods in NPD (New product development)	Deductive approach, Survey	1) Determine the current status of NPD Practice in Swedish firms and 2) compare the result with those of the 1995 PDMA study (Griffin, 1997)	Questionnaire: 57% of 80 randomly selected firms	Research team (two researchers)	Contribution to the PD literature, i.e. current status of NPD in Sweden and comparison with the 1995 study
Study 3, A case study – supply chain performance	Deductive approach, Two case studies	Questions related to the supply chain and questions related to supply chain performance measures	Interviews with 7 managers within the supply chain	Single investigator	Description of how two international manufacturers measure their performance
Study 4, A literature review – Product development in SMEs:	Deductive approach Literature review	Questions related to Product development	149 research articles investigated	Research team (11 researchers)	Contribution to the PD literature
Study 5, A case study – Flows in the internal supply chain	Inductive approach, Eight case studies	Questions related to the supply chain	31 interviews within two organisations	Research team (two researchers)	Contribution to the SCM literature
Study 6, A case study – Measuring supply chain performance: A framework for prioritizing measures	Deductive approach, Two case studies	Questions related to the supply chain	Interviews with 7 managers within the supply chain	Single investigator	Contribution to the SCM literature, i.e. theoretical framework
Study 7, A case study – Supply Chain Quality Management	Deductive approach, Three case studies	Questions related to the supply chain	Interviews with 9 managers within the supply chain	Research team (two researchers)	Contribution to the SCM and QM literature

Articles were selected and collected in three steps. The first step consisted of two phases. In the first phase, we searched for articles in three literature databases: Ingenta (SAGE Publications), Emerald, and AOM (Academy of Management). We used the following keywords as search criteria: supply chain, value chain, logistics alliances, supplier, and subcontractor). The number of articles identified in these databases exceeded 14 million. Of these, 6 452 articles (including duplicates) met our search criteria. In the second phase of the first step we searched for articles that, in addition to the above-mentioned search criteria, also included references to performance, metrics or measures or to empirical evidence. Ultimately, this first step resulted in 154 articles.

The second step also consisted of two phases. In the first phase, we removed all duplicates. This left us with 90 articles. In the second phase, we read the articles' abstracts in order to identify articles that met the following three criteria: 1) deals with Supply Chain(s) or SCM; 2) contains empirical material that derives from surveys or case studies; and 3) presents performance results in metrics or measures. This step reduced the number of articles from 154 to 49.

In the third step, we analysed the 49 articles to ascertain that they met the selection criteria and especially that they presented performance results about the five areas of interest: delivery, quality, price, cost, or flexibility. This step reduced the number of articles from 49 to 25.

The 25 articles were then analysed and classified on the basis of the following criteria: 1) connects evidence to theory; 2) uses a sampling technique as the appropriate methodology; 3) relates to operational performance); and 4) supports the results by the analysis. Based on these criteria, the articles were classified at three levels: articles of high quality, medium quality, and low quality. The 25 articles had either high quality or medium quality.

The 25 articles were then re-classified according to the four types of performance measures: delivery, quality, price, cost, or flexibility. We discussed the measures in each article. This analysis resulted in many interesting research questions about the performance of supply chains. These questions were useful for the case studies conducted. See Figure 5.

Study 2 is a survey of New Product Development (NPD). The aim was to determine the current status of NPD practice and to compare the results with a similar survey conducted in 1989. A mail survey was used to determine the current status of product development practices at medium-sized, Swedish manufacturers. The main reason for using a mail survey was the possibility of reaching a large number of respondents with a broad range of questions.

Another reason was the opportunity to compare some of the results with the PDMA (Product Development Management Association) study of 1995 (Griffin, 1997). The questions from the PDMA study were used although the questionnaire was supplemented to include the topic of outsourcing. The questionnaire was tested on a sample of academics and practitioners and then simplified to improve the response rate. The firms targeted were medium-sized, Swedish manufacturers with between 200 and 800 employees. Of the 338 potential respondents, a sample of 80 respondents was randomly selected. The response rate was 57%, which may be considered a reasonable response rate for a mail survey.

The first set of questions aimed to classify the firms according to industry and to categorize them in two ways. The first category distinguished between firms with a high emphasis on NPD and firms with a low emphasis on NPD. For this purpose, two variables were used: (A) sales from products developed at the firm as a turnover percentage; and (B) sales of products commercialized in the last five years as a turnover percentage. Respondents were asked to respond with a turnover percentage. The “best practice” firms are those firms that responded that the turnover percentage was at least 50% on both variables. Of the sample, 33% of the firms met these criteria.

The second set of questions aimed to classify the firms according to eight competition factors for acquiring new customers (order winners). These factors were lower price, better product design, higher product quality, reliable deliveries, faster deliveries, better after sales service, broader product lines, and frequency of new product launches. The respondents rated each competition factor on a five-step Likert scale: from Not important (1) to Very important (5). This rating was compared with the use of NPD processes in the population.

The findings from the study gave us an understanding of how collaboration between the members in the internal supply chain affects performance positively. The use of cross-functional teams in the internal supply chain is more complex at the firms identified in the “best practice” category. This was a useful result for the manufacturing perspective of this thesis.

Study 3 is a two-part study on two multinational, heavy vehicle manufacturers. The study aimed to present the supply chain performance measures and metrics these manufacturers use. The unit of analysis was the firm. The following four measures were analysed in-depth: quality, delivery, cost (price), and flexibility. The study also describes the type of supply chain performance measures that should be evaluated, depending on the supplier's or the customer's position in the supply chain (e.g., upstream or downstream).

A case study was used because it allowed us to access detailed data on performance measures directly from the operations managers. The interview questions were based on earlier supply chain performance research (Chibba and Hörte, 2003a) and supply chain performance theories (Cigolini et al., 2004; Robson, 2004). The main theory discussed above provided the necessary framework for sorting and analysing the data. The SCOR model, combined with various supply chain performance measurement situations, was used to classify the supply chain performance measures and the metrics used by these two manufacturers.

The two manufacturers gave us their full support. Top executives allowed us to access data from personnel records and meetings. We took a qualitative research approach as our aim was to present the manufacturers' supply chain performance measures and metrics as a result of their position in the supply chain. We limited our interviews with the managers to 2-3 hours per interview. At an early stage, we emphasized that we wanted to interview the "owners" of the performance measure (i.e., those who were responsible for measuring the supply chain performance, including its quality, delivery, cost (price), and flexibility). We identified our respondents as follows: Company A´s "Quality Assurance Purchasing Manager, Production Manager, and Purchasing Manager"; Company B´s "Quality Manager (also Production Manager at Site 1), Production Manager at Site 1, Production Manager at Site 2, Purchasing Manager at Sites 1 and 2, and Operating Purchasing Manager at Site 1)". We interviewed seven respondents. This study gave us insight into how the two manufacturers characterize and measure the performance of their supply chains.

Both large enterprises (LE) win orders as a result of their good reputation and history as well as their focus on quality, delivery, and cost. One can say they are in the premium industry segment for their products. While quality (metric: quality conformance, the degree to which a product is manufactured to the agreed specifications) is the most important measure, according to the respondents. After sales service is also important. A respondent stated: "Quality is important but so is service after the first 50 hours of use" (metric: quality serviceability, the ease of servicing (planned or breakdown) to include the speed and provision of after sales service). The measure of delivery (metric: delivery reliability), the ability to deliver consistently per the agreed due date, was rated as the second most important measure by the respondents. However, one respondent said that all measures are equally important because they connect to each other.

Study 4 is a review of the literature on Product Development (PD). The purpose of this study was three-fold. First, to obtain an initial understanding of the area of PD in SMEs by describing and analysing the existing work on the topic. Second, to discuss the development of PD research in terms of degree of maturity. Third, to suggest research themes to be addressed in the future. The study follows Hart's (2001) suggestions for reviews of scientific journal articles.

The journal articles were selected in four main steps. Eleven researchers were involved in the selection process. The first two steps were performed individually; each researcher searched one

or two databases and deleted articles from the list according to specified criteria. Teams of researchers conducted the third step. Each article was read by a team of at least two researchers and deleted from the list if two researchers on the team agreed. Some articles were difficult to evaluate in terms of our criteria: when this situation arose, the decision to remove a paper was discussed by the complete team of researchers. We used multiple teams for the classifications to increase the reliability of the classification procedure.

Study 5 is a multiple case study of two multinational manufacturers and eight cases. The study aimed to develop and test techniques for mapping information flows in an internal supply chain (i.e., information flows that support the physical material flow). The study also aimed to identify factors that could improve and rationalize information flows and generate a better flow in the internal supply chain. The unit of analysis was the firm.

We used the case study approach retrospectively for all eight cases (i.e., research on cases that are closed) in order to gain in-depth understanding, contextual knowledge, and data related to the actors' perceptions of the chain of activities. The selection of a few cases offers a good opportunity for in-depth observations (Voss et al., 2002), while the selection of more cases offers more generalizable results if they support the same standpoint (Meredith, 1998).

Company A manufactures laundry appliances for industrial companies and hotels. Company B is a printing company that prints various products, from credit cards to invoices. A project group was formed at each company to identify suitable cases. These groups consisted of researchers, managers, and employees. After two meetings at each firm, we identified eight suitable cases: four at Company A and four at Company B. We used semi-structured interviews and a research protocol to collect our field data.

The protocol was developed from a process-oriented model (Harrington, 1991) that allowed us to map the information flow, starting with the order and ending with the delivery of the product or service. The middle-field in the protocol was reserved for a description of the activity conducted by the respondents. We piloted the research protocol at each firm and made some appropriate changes. We tried to map all information input and outputs as well as all information-related activities prior to output based on the protocol. Then we chose the next respondents: the individuals who supply input and receive output. We concluded when all respondents in the process were interviewed. We also analysed the document connected to each case, which regulated the process and activities, such as the ISO 9001 quality documents. We conducted 31 interviews in the eight cases.

We conducted two major types of case analysis. First, the documented models were compared with official documentation, for example, in the Quality Management System, which provided results indicating whether the official documentation was used. Second, the problems indicated by the respondents were categorized and compared among the cases. This analysis gave us a set of problems that could be compared with our theoretical framework.

Using a case study approach retrospectively may make it difficult to determine cause and effect because participants may or may not recall important events. Events may be subject to bias, particularly post-rationalisation. In this study, reliability was strengthened by use of multiple data sources. Cross-case analysis was used to increase the internal validity of the findings from the study (Voss et al., 2002). We compared the eight cases with each other. We also compared the

four cases from the first firm as one group and the four cases from the other firm as the second group.

External validity refers to whether findings can be generalised beyond the immediate case study (Yin, 1994). By identifying moderator variables and keeping these as similar as possible, generalisation can be achieved within the context. Extended generalisation can also be achieved by the researcher's knowledge of and reflection over moderator variables (Schwab, 2005). The moderator variables were kept similar in this study by using four cases from each firm. This means that external validity in a reasonable range could be achieved at each firm. Some judgmental claims of generalisations might be possible in the concluding discussion if patterns identified are valid for both organisations because replication is the only way to establish generalisation across potential moderator variables (Schwab, 2005). In this study, external validity was achieved by comparisons among the eight cases and between the two manufacturers.

Study 6 is a case study, based on the results from Study 3, which aimed to develop a framework for measuring supply chain performance based on the research literature and on the Studies 1 and 5. This study analyses the supply chain performance of manufacturers (i.e., the measures and metrics used to describe it). Theory supporting the development of the framework was mainly collected from well-known theoretical literature and from the empirical evidence obtained at two large, multinational manufacturers of heavy vehicles. The study begins with an overview of the product life cycle (PLC) as a concept and then proceeds by connecting different types of products with individual PLC phases. Supply chain theory is then described and linked to the PLC as far as supply chain performance measures and metrics and the manufacturer's position in the supply chain where performance is measured. The empirical evidence that supports the development of the framework was collected from Study 3. The two manufacturers are part of a "heavy vehicles" group and also support CIL, the Centrum for Information Logistics, in Ljungby, Sweden.

Study 7 is a three-part case study that uses findings and evidence from Studies 1 through 6. The aim of this study was to examine the relationships between different stakeholders, the supply chain, quality performance, and aspects of quality assurance in the supply chain. A case study approach was used that included interviews with various manufacturer stakeholders (i.e., actors upstream and downstream in the supply chain). The unit of analysis was the supply chain.

We used direct content analysis (see Hsieh and Shannon, 2010) as a qualitative research method to interpret meaning from the content of the data and, hence, to follow the naturalistic paradigm. We chose direct content analysis in order to use the theory and relevant research findings as guidance for our initial codes. The codes were defined before and during data analysis. We constructed a set of operational definitions (codes) that were the basis for the interviews.

The stakeholders in the supply chain were the following: Customers, suppliers, sub-suppliers and the government, Empirical data were gathered in interviews with representatives for the stakeholders. The customer is the organisation that owns the wind turbines and sells electrical energy on the market. The supplier is the producer of wind turbines for the global market. The sub-supplier provides goods and services to manufacturers of wind turbines.

We used semi-structured interviews to interview nine respondents in the supply chains. First, we identified and coded different key concepts and variables with support from theory. Second, we derived operational definitions for each category, using theory. Finally, all highlighted passages

were marked using the predetermined codes. To increase the study's reliability, we interviewed respondents from the customers' supply chain in order to strengthen the data. With one exception, the interviews were recorded and transcribed verbatim. The interviews were analysed for themes using QRS N9 software. This software is intended to help users organise and analyse non-numerical or unstructured data.

4. Summary of the seven papers (see the Appendix)

This chapter is a summary of the research results from the seven papers. The summary gives a short description of the background and purpose of the papers as well as the methods used and the main results and conclusions. The connection between the papers is explained at the end of this chapter.

4.1 Paper 1: Supply Chain Performance – A Meta-analysis

Chibba, A. and Hörte, S. (2003). Supply Chain Performance – A Meta-analysis. *Conference proceedings, 10th EUROMA conference* in Como, Italy.

Introduction

This study examines what we know about the performance of supply chains. The aim of the study was to review the identified articles and to describe the types of performance measures presented in theory. We focused on five performance measures: delivery, quality, cost, price, and flexibility. The research questions we posed in this paper are: What does the literature say about different types of supply chain performance? What does it tell us about the impact of different types of supply chain measures on supply chain performance?

Meta-analysis is a methodological approach that can be used to answer the type of questions we list above. Meta-analysis is used to analyse research findings, as typically presented in research reports, in a structured way. It provides an organised way of handling information from a large number of published studies. There are two ways to conduct meta-analysis: the quantitative approach and the qualitative approach (meta study). In quantitative meta-analysis, the key is to define an effect size statistic (i.e., the index used to represent study findings that are capable of representing the quantitative findings in a standardized form, thereby permitting meaningful numerical comparison and analysis across the study). The quantitative meta-analysis is mostly used in medical and natural sciences research where the same research question can be statistically analysed. In a qualitative meta-study, the primary goal is to develop mid-range theory from a substantive body of qualitative research (Paterson et al., 2001). Paterson et al. (2001) argue that qualitative meta-study is an interpretive constructivist approach and that research may go beyond presented conclusions and synthesis presented in the reports.

Main results and contributions

The study reveals that it was not possible to perform meta-analysis because the measures and metrics vary. All 25 articles present supply chain performance measures. However, they are not comparable such that they could be included in a quantitative meta-analysis. From a quantitative meta-analysis perspective, it was inappropriate to compute an effect size value to analyse the statistical results. One reason is that most of the articles had different research designs and different statistical forms.

The paper contributes to the literature on supply chain performance with the following conclusion. The analysis of the articles clearly shows that the most frequently presented performance measures are one-sided, integrated measures that depict performance across organisational boundaries and assess chain performance across supplier or customer boundaries. Total supply chain measures, which include supplier-organisation-customers, are the least common even though it is important to increase our knowledge about the total supply chain if supply chain performance research is to have a managerial impact. The study also shows that measures (e.g., quality, delivery) are presented more often than metrics (e.g., number of defects and on-time delivery in percentages).

4.2 Paper 2: The use of processes and methods in NPD – A survey of Swedish industry

Rundquist, J. and Chibba, A. (2004). The use of processes and methods in NPD – A survey of Swedish industry. *International Journal of Innovation and Technology Management*, 1(1): 37-54.

Introduction

This paper presents the results of the survey conducted at medium-sized, Swedish firms during the Fall of 2001. In recent decades, numerous researchers and practitioners have tried to identify best practices in order to create different models for describing the New Product Development (NPD) process. Griffin (1997) presented the results of a study conducted by PDMA (Product Development Management Association) in US firms on product development best practices in 1995. The objective was to determine the current status of product development practice and to compare the results with a similar survey conducted in 1989 by Page (1993). As the PDMA study was performed in US firms, we decided to conduct a study based on the same survey in a different context, for example, at Swedish firms. The goals of the study presented in this paper are largely the same as those in the PDMA study. However, to define a framework for complementary topics, previous research in the areas was reviewed. The study's goals were the following:

- To determine the current status of NPD practice in Swedish firms (for example, use of formal NPD processes, type of processes, and use of reward systems for NPD teams); and
- To compare the results with those of the 1995 PDMA study.

A mail survey was used to determine the current status of product development practices at medium-sized, Swedish firms. The questions from the PDMA study were used although the questionnaire was supplemented to include outsourcing because the PDMA study was conducted five years earlier when outsourcing in NPD was not an issue.

Main results and contributions

The managerial contributions of this paper are presented as three recommendations, based on the findings from the best group of firms.

1) The use of formal NPD processes is recommended for best practice firms. A documented and widely known NPD process will help all functions coordinate and participate in activities in a cross-functional way. All functions should know when and how they are expected to contribute to the NPD process.
2) The use of an NPD Department with permanent staff members is recommended at best practice firms. Permanent staff members can provide an opportunity to work continuously with the NPD process and prevent interruptions to and divisions of concentration among different tasks. Shared responsibility for the NPD process is recommended between various functions.
3) A single function with sole responsibility for the NPD process is less widespread at the best practice firms. Thus, it is recommended that awareness be increased of the importance of experience from various functions in the development and improvement of the NPD process. The different functions should be used not only for executing activities in the NPD process but also for evaluating the use of the NPD process.

4.3 Paper 3: Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers

Chibba, A. (2007). Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers. *Conference proceedings, 14th International Annual EUROMA conference* in Ankara, Turkey.

Introduction

The primary aim of this paper is to present the Supply Chain Performance measures and metrics used by two heavy vehicle manufacturers (Kalmar Industries and Dynapac) as a result of the type of supply chain (efficient, quick, lean, hybrid, or agile) they operate in and their position in it. Moreover, the paper describes the types of supply chain performance measures that should be evaluated depending on where in the supply chain the supplier or customer operates (e.g., upstream or downstream)

The secondary aim of this paper is to present suitable measures, sub-measures, and metrics with which such manufacturers can measure and track performance in their supply chain. A case study methodology was used for two cases. In-depth interviews with seven managers were conducted. Top executives gave us access to data related to personnel and meetings. We took a qualitative research approach because our aim was to present the supply chain performance measures and metrics in focus at these manufacturers as a result of their position in the supply chain.

Main results and contributions

The results show that both manufacturers have an identical type of supply chain, which can be characterized as a *hybrid supply chain*. Both manufacturers focus on shorter lead-times but not at the expense of increased cost. They also operate in the same position in the supply chain (downstream and near the sales company and end customer). Their supply chain measures and metrics are almost identical. Both use consistent and well-defined internal supply chain measures.

The main contribution of this paper is the knowledge it reveals on how two international manufacturers of heavy vehicles measure the performance of their supply chains. Quality (product quality) and delivery (on-time) are their most important measures and metrics. They define their Key Performance Indicators (KPI) as measures that describe "how well the organisation manages to deliver to market". Most of these KPI can be defined as "one-sided, integrated measures" that include 1st tier suppliers, the organisation, the sales company, and the end customer. However, they do not measure the total supply chain (i.e., from 2nd and 3rd tier suppliers to end customer). It would be interesting to make that measurement, especially with regard to the critical components of engine and transmission parts. They measure delivery reliability, quality, cost, and lead-time, and interact with their suppliers to some extent. Kalmar Industries interacts systematically with 1st tier suppliers. The company does not have the resources to interact to a greater degree with other suppliers upstream in the supply chain. The respondents were clear that the most important supply chain measure is quality with the following metric: "the degree to which a product is manufactured to the agreed specification", followed by delivery and its sub-measure: delivery reliability (time). Dynapac and Kalmar Industries both focus on quality, delivery, and cost in their supply chains, which accounts for their order success in the market. It is more important to their customers to receive their orders on time, even with the risk of some problems, than late without the risk of some defect or malfunctioning part. Therefore, it is extremely important for these two companies to provide after sales service.

4.4 Paper 4: Product Development in SMEs: a literature review

Hörte, S.Å., Barth, H., Chibba, A., Florén, H., Frishammar, J., Halila, F., Rundquist, J. and Tell, J. (2008). Product Development in SMEs: a literature review. *International Journal of Technology Intelligence and Planning,* 4(3): 299-325.

Introduction

The purpose of the paper, which is a literature review of articles on Product Development (PD), was three-fold. First, to obtain an initial understanding of the area of PD in SMEs by describing and analysing the research on the topic. Second, to discuss the development of the research in PD in SMEs. Third, to suggest research themes to be addressed in the future.

The journal articles were selected in four main steps. The first step aimed to create a database consisting of articles on PD in SMEs. The second step aimed to 'clean up' the database by removing all papers that did not meet a set of predefined criteria. The third step consisted of a second clean-up operation as well as a quality assessment review of the remaining 149 articles. The articles that 'survived' the three steps were used in the analysis. The main selection of articles was conducted between September 2003 and December 2004, with some subsequent updates in the Fall of 2007. Eleven researchers were involved in the selection process. The first two steps were conducted individually; each researcher searched one or two databases and removed papers according to the criteria described above. Research teams conducted the third step. Each paper was read by a team of at least two researchers and removed if both researchers in the team agreed. A few papers were difficult to evaluate. In this situation, the decision to remove an article was discussed by the complete team of researchers.

Main results and contributions

An analysis of the articles reveals that management and operations are the most common topics: 97 (65%) articles discuss management issues while 93 (62%) articles discuss operations issues. Many of the articles cover both themes: 56% of the management articles also discuss operations issues. Only 11 articles (7%) discuss performance while approximately two of three articles discuss management or operations. The most common analytical approaches of the articles are the explorative and descriptive approaches, regardless of the articles' topics. There are, however, many articles that take an explanatory approach. The use of empirical evidence dominates in the articles: 85% of the management articles, 92% of the operations articles, and 100% of the performance articles. In these articles, the quantitative approach is favoured; 61% of the management articles, 57% of the operations articles, and 91% of the performance articles.

This paper contributes to the literature on PD with its calculation and categorization of PD articles. It is of interest that only 7% of the articles examine performance issues. If this field of research is to deliver results of high importance for the development of sustainable new products and to contribute to economic growth and societal welfare, there should be an increased focus on performance. A greater consensus on performance measures is needed to make it possible to use more integrated research approaches, for example, meta-analysis. In addition, the number of articles on supply chain dependence relations issues is low. Only 6% of the articles have this focus. This focus is inappropriate in an immature field of science when the necessary consensus on concepts and measures is lacking.

4.5 Paper 5: Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows

Chibba, A. and Rundquist, J. (2009). Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows. *Journal of Information & Knowledge Management*, 8(4): 331-343.

Introduction

The main purpose of this paper was to develop and test techniques for mapping information flows in an internal supply chain (i.e., the information flow that supports the physical material flow). An additional purpose was to identify factors that could improve and rationalize information flows and create a better flow at the organisation. These factors could be further tested and used to develop supply chain performance measures covering the most important information flow aspects. In this research we took a retrospective case study approach (i.e., research on cases that were closed). The reason for studying cases retrospectively was to acquire an in-depth understanding, contextual knowledge, and data related to the actors' perceptions of the supply chain. In order to collect the field data, we used semi-structured interviews and a research protocol (a checklist).

Main results and contributions

The paper presents an inductive, process-oriented mapping tool that can be used to easily map and describe information flows and physical material flows. Many methods frequently used in the industry for mapping information flows are theoretically based. These methods assume a deductive perspective, as the model already exists before the mapping process begins. Our methodology offers an inductive approach, which is based on interviews and which has been used to produce a model in line with our empirical evidence. We identified three areas associated with the proposed mapping technique (i.e., disturbances) that could be improved upon and rationalized to create a better flow in the integrated supply chain. These areas are the following:

- Procedures for handling changes in customer orders such as delivery time and order size.
- Procedures for collecting information in the internal supply chain such as information about changed delivery times, changes in stock, and missing machines.
- Procedures for handling information about delays in internal production or the delivery of wrong materials such as different packaging or products. All respondents reported they only worked with direct information that is directly connected to the physical material flows. The 31 respondents stated they do not receive indirect information.

The paper contributes to the literature by presenting an inductive, process-oriented mapping tool for describing information flows and physical material flows. Moreover, the paper contributes to our knowledge about what is needed to create a better flow in an integrated supply chain.

4.6 Paper 6: Measuring supply chain performance: A framework for prioritizing measures
Chibba, A. (2015). Measuring supply chain performance: A framework for prioritizing measures. *International Journal of Research in Business and Technology*, 6(2): 782-793.

Introduction
This paper analyses the supply chain performance of manufacturers as far as their use of descriptive measures and metrics. While the findings of this paper are relevant for all types of manufacturing organisations, they are particularly relevant for Original Equipment Manufacturers (OEM). The aim of this paper was to acquire knowledge that can be used by organisations for developing and improving their supply chains, both upstream and downstream. The method used to develop the framework in this paper is based on the scientific principle of adding small pieces of theory to well-known existing theories (i.e., deductive reasoning).

The point of departure is the well-known product life cycle (PLC) model with its four phases: introduction, growth, maturity, and decline. This model was used for adding both old and new theory such as the following: the types of products and supply chains connected to each phase of the product life cycle,; the types of performance measures and metrics suitable for assessing manufacturers; and the positions in the supply chain used for making performance measures. The empirical evidence supporting the development of the framework was collected from a case study at two large, multinational manufacturers of heavy vehicles.

Main results and contributions
The paper contributes to the literature by presenting the framework that was developed on the basis of the empirical work conducted and the knowledge acquired from previous research. See Figure 6. The type of supply chain (1) is firmly supported by theory (Aitken et al., 2003; Christopher and Towill, 2001; Cigolini et al., 2004; Fisher, 1997; Huang et al., 2002). The type of supply chain performance measure (2) is also supported by theory as described by De Toni et al. (1994), Gadde and Håkansson (2001), Hayes and Wheelwright (1984), Lambert and Pohlen (2001), Pagell and Krause (2002), Saad and Patel (2006), and Stewart (1995). The scope of the measurement situation in the supply chain (3) is firmly grounded in theory as described by Stewart (1995) and the SCOR (Supply Chain Operations Reference) model.

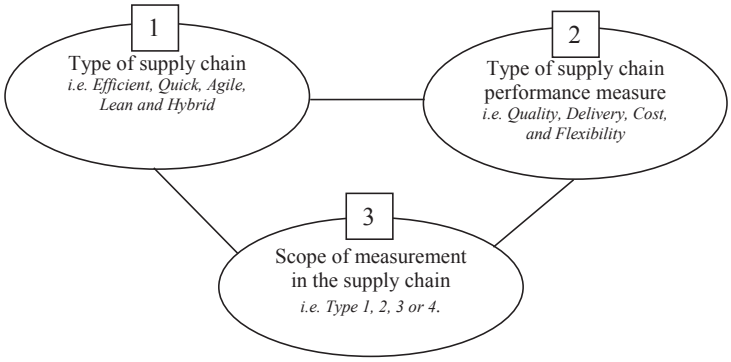


Figure 6. *Framework for prioritizing supply chain performance measures*

4.7 Paper 7: Supply Chain Quality Management in Wind Turbine Industry - A Case Study

Chibba, A. and Garvare, R. (2011). Supply Chain Quality Management in Wind Turbine Industry - A Case Study. *Conference proceedings, 18th International Annual EUROMA conference* in Delft, Netherlands.

Introduction

The purpose of this paper was to examine the relationships between different stakeholders, the supply chain and quality performance, and aspects of quality assurance over the supply chain (i.e., manufacturing, installation and service of wind turbines in a forest environment). In particular, the aim was to explore how essential goods and service characteristics can be affected by different types of stakeholders such as suppliers, customers, the community, the State, neighbours, land-owners, members of various pressure groups, etc. A case study approach was taken that included interviews with various stakeholders, upstream and downstream the supply chain. We used direct content analysis as a qualitative analytical approach to interpret meaning from the content of text data and, hence, to adhere to the naturalistic paradigm. A set of operational definitions (codes) were constructed to form the basis for our interviews. The codes, which were defined before and during data analysis, were derived from theory or relevant research findings. Empirical data were gathered in interviews with representatives for the stakeholders in the particular supply chain. The customer is the organisation that owns the wind turbines and sells electrical energy to customers. The supplier is the producer of wind turbines for the global market. The sub-supplier provides goods and services to manufacturers of wind turbines. Eight respondents were interviewed.

Main results and contributions

This paper contributes to the supply chain quality management literature by presenting answers to the following three questions.

The first research question concerns the relationship between stakeholders' requirements, wants, and expectations as far as quality performance in the wind turbine supply chain. As most manufacturers of wind turbines are LE, and almost all suppliers and customers are small, there is an imbalance in the supply chain. The customer, in this case, tried to minimise costs and to increase its ROI. In order to do this, it cut costs by vertical integration in various ways: performing some of the suppliers' work in assembly, transportation, and other services such as the use of cranes.

The second research question, which relates to the stakeholders and their influence on quality and supply chain performance, deals with how the total supply chain is described. We found that the purchasing phase was controlled by a contract between the customer and the supplier. The supplier sells the wind turbine and other related services (e.g., transportation and services). However, due to issues of cost and on-time delivery, the customer may perform some of the wind turbine services. There are several different stakeholders that may influence customer success or failure (e.g., secondary stakeholders that oppose wind power exploration, individuals who have media power, or even the media in general). These secondary stakeholders can influence the actions of the primary stakeholders (e.g., investment firms, banks, and governmental entities).

The third research question deals with the product characteristics that stakeholders find relevant and that therefore have to be measured, controlled, and improved. Finding reliable and general methods to calculate wind speed was seen as essential. The lead-time in the pre-production phase of wind turbine manufacture was seen as one of the most important issues since it affects the delivery time to the customer, which is a key stakeholder interest.

4.8 Connection among the seven papers

Paper 1: Supply chain performance – A meta-analysis
This paper reviews the identified articles and tries to establish the types of performance measures presented in theory. The paper mainly focuses on five measures: delivery, quality, cost, price, and flexibility. Paper 1 has a strong connection to Papers 3, 4, 5, 6, and 7 because of its focus on supply chain performance measures.

Paper 2: The use of processes and methods in NPD – A survey of Swedish industry
This paper contributes to the awareness and knowledge of the importance of collaboration in the different functions in the integrated supply chain in an organisation when working with New Product Development (NPD). A documented and familiar NPD process helps all functions to coordinate and participate in activities in a cross-functional way in the internal supply chain. All functions know when and how they are expected to contribute to the NPD process. The formal process, which can also be seen as a way of controlling and measuring the results, offers senior management an opportunity to evaluate and compare projects. Paper 2, which increases our knowledge of how NPD is managed in the internal supply chain, connects to Paper 1 because of the extent of the mutual co-operation within the SC that can lead to improved quality. Paper 2 connects to Papers 3 and 4 where the discussion is about innovative products and types of SC (i.e., the achieved mass customisation by postponing product differentiation until final assembly by adding innovative components to existing products). This type of SC can be termed innovative SC.

Paper 3: Measuring supply chain performance upstream and downstream the supply chain – two case studies form Swedish manufacturers of heavy vehicles
This paper addresses how two manufacturers of heavy vehicles evaluate their supply chains using performance measures and metrics. The empirical evidence consists of seven in-depth interviews with managers at the manufacturers. Paper 3 connects to the supply chain performance measures and metrics in Papers 1, 5, 6, and 7, to the type of products in Paper 2, and to the types of supply chain in Paper 6.

Paper 4: Product development in SMEs: a literature review
This paper connects to Paper 1. The conclusion is that not much is written about the performance of PD and supply chain dependencies in PD. Paper 4 also connects to Paper 2 (product development) and to Paper 5 (flow of goods and information). This paper addresses the interaction between these flows.

Paper 5: Effective information flow in the internal supply chain
This paper was a direct initiative that emerged from Paper 1. It was important to follow an internal integrated supply chain in order to establish the relevance of the theory. Therefore, Paper 5, which is a study of two large manufacturers consisting of eight cases and 31 respondents, describes a great deal of experience and illustrates the supply chain theory described in Papers 1 and 3. This paper also has a connection to Paper 4 (the flow and interaction of goods and information).

Paper 6: Measuring supply chain performance – A framework for prioritizing measures
This paper presents a framework that indicates which performance measure and metrics should be prioritized (quality, delivery, cost, price, and flexibility) and which type of supply chain should be prioritized (efficient, quick, agile, market responsive, lean, or hybrid). Papers 1, 2, 3, and 5 contributed to this framework for prioritizing supply chain performance measures due to the products manufactured and the types of SC.

Paper 7: Supply chain quality management in wind turbine industry – A case study
The paper examines the relationships among stakeholders, the supply chain, the quality of performance, and aspects of quality assurance in the supply chain: manufacturing, installation, and service. The empirical evidence consists of nine in-depth interviews with managers from the wind turbine industry. Paper 7, which has strong connections to Papers 1, 3, 5, and 6, contributes to this thesis on supply chain quality management with respect to 1) customer focus, 2) supplier relationship, and 3) the quality of the IT system.

Figure 7 depicts the connections among the seven papers.

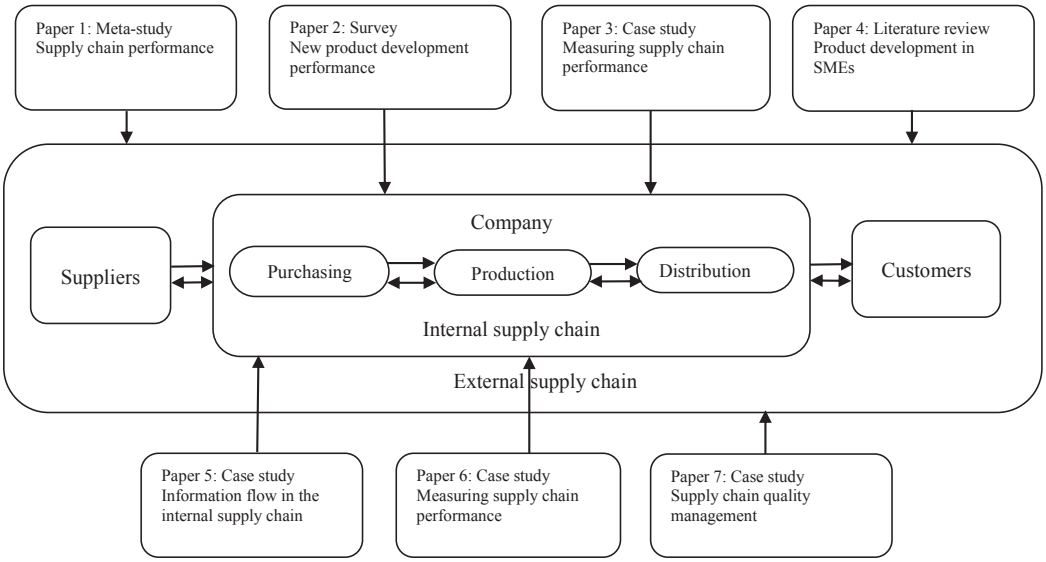


Figure 7. *The seven papers connected to internal and external parts of a supply chain. See also Kaynak and Hartley (2008).*

5. Analysis and conclusions

This chapter addresses our research question: "What improves quality performance of supply chains that include manufacturing?" The chapter analyses the results of the seven papers in the attempt to find additional conclusions through further elaboration of the issues presented in the seven papers. The chapter examine the papers' use of key dimensions, their limitations their positions, and the challenges encountered.

5.1 Study 1: Literature review – A meta-analysis study of supply chain performance

Analysis

The results from this literature study, which was a meta-analysis study (see Table 13, Type 3), indicates that the most commonly presented supply chain performance measures can be viewed as *one-sided, integrated measures* (i.e., measures that depict performance across organisational boundaries and measure supply chain performance across supplier or customer boundaries). Delivery and quality performance measures are the most important measures. The least used measure is the total supply chain measure (i.e., a measure that depicts performance across organisational boundaries and measures the performance of the complete supply chain, including links to suppliers and customers) (see Table 13, Type 4).

Table 13: *Journal articles classified according to performance measures.*

	Performance measures considered in articles					
Measures	**Delivery**	**Quality**	**Cost**	**Price**	**Flexibility**	∑
Type 1	-	-	-	-	-	0
Type 2	07, 22	04, 07, 22, 24	04, 07, 22, 24	22	07, 22	4
Type 3	01, 02, 03, 04, 05, 06, 10, 12, 15, 18, 19, 21, 25	03, 06, 11, 12, 14, 15, 17, 19, 20, 21, 23	01, 02 12, 14, 21	03, 06	03, 18	17
Type 4	08, 13, 16	08, 09, 13	08, 09	13	-	4
∑	18	17	10	4	4	25

It was not possible to compute an effect size value in the examinations of statistical results based on the analysed articles. The reason was that most articles use different research designs and different statistical forms.

Conclusions

The purpose of this study was to examine what we know about the performance of supply chains, taking a meta-analysis approach. The focus of the study was to review the identified articles and to describe the types of performance measures based on theory. The main conclusions are the following:

- The most commonly presented supply chain performance measures can be categorised as one-sided, integrated measures (i.e., indicators of performance across organisational boundaries).
- Delivery and quality performance measures are the most influential measures in the category of one-sided, integrated measures.
- The least presented category of measures is the category of total supply chain measures.
- Most of the articles use different research designs and appear in different statistical forms

(scales). Therefore, it was not possible to calculate an effect size. Of the 25 articles, 14 articles did not have a statistical form (see the Appendix, Paper 1).

- We found there were more strategic measures (i.e., quality, lead-time, and cost presented than operations metrics such as defect-free deliveries and number of complaints.

5.2 Study 2: A survey - The use of processes and methods in NPD

Analysis

This study contributes to the awareness and knowledge of the importance of collaboration among the different functions in the integrated supply chain in an organisation. Cross-functional teams are more commonly used as a process by the best practice firms. See Figure 8.

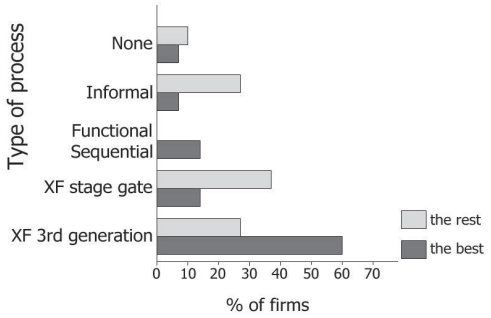


Figure 8. *NPD processes: The best versus the rest. The categories "None" and "Informal" indicate no formal processes. XF=Cross-functional teams. Chi-square=11.0, p<.05*

The formal NPD process is more commonly used by the best practice firms. See Table 14.

Table 14: *The use of a formal NPD process related to the existence of a documented strategy for different aspects of NPD.*

	*Strategy for product line***	*Strategy for outsourcing innovation*	*Strategy for product platforms*	*Strategy for continuous improvements**
Formal NPD-process	*94%*	*28%*	*78%*	*87%*
No formal NPD process	*23%*	*31%*	*62%*	*53%*

*** Anova test p<0.05, * Anova test p<0.12*

The use of an NPD Department with permanent staff members is more common at the best practice firms. A single function with sole responsibility for the NPD process is less widespread at the best practice firms. See Table 15.

Conclusions

The goal of this study was two-fold: 1) to determine the current status of NPD practice at Swedish firms, and 2) to compare the results with results from the 1995 PDMA study (Griffin, 1997). The main conclusions are the following:

- The use of cross-functional teams in the internal supply chain is more common at the firms in the best practice category.

- The use of formal NPD processes is more common at the best practice firms.
- An NPD Department with permanent staff members is more common at the best practice firms.
- A single function with sole responsibility for the NPD process is less common at the best practice firms.

Table 15: *NPD Organisation.*

*Organisational approaches **to** NPD*	*The best*			*The rest*		
	Yes	*No*	*Total*	*Yes*	*No*	*Total*
*New product department with permanent staff members **	*87%*	*13%*	*100%*	*57%*	*43%*	*100%*
*NPD projects are outsourced to external actors ***	*33%*	*67%*	*100%*	*0%*	*100%*	*100%*
A new product committee oversees all development efforts.	*20%*	*80%*	*100%*	*40%*	*60%*	*100%*
Each business unit's general manager directs their own NPD efforts.	*7%*	*93%*	*100%*	*20%*	*80%*	*100%*
A process-owner is responsible for spreading the process to the entire firm.	*13%*	*87%*	*100%*	*37%*	*63%*	*100%*
*A single function is responsible for NPD **	*33%*	*67%*	*100%*	*80%*	*20%*	*100%*

*** Anova test p<.01, * Anova test p<.05*

5.3 Study 3: A case study – Supply Chain Performance

Analysis

The characteristics of the heavy vehicle supply chain

The supply chain of the two heavy vehicle manufacturers (Kalmar Industries and Dynapac) can be described as a hybrid supply chain (Huang et al., 2002) (i.e., cost minimisation, mass customisation, and adaptability for future changes). However, most respondents described an ambition to work towards a lean supply chain (LSC). The respondents agreed that the LSC is right for the heavy vehicle industry.

The areas requiring skills for the two manufacturers are two-fold: products and service. They provide a service that is based on several years of 'know how' (e.g., core competences in lifting heavy goods, building roads, etc.). This contrasts with the automotive industry in which the core competences are engine design and development, although engines of varying horsepower may be produced for the same model in order to meet customer requirements. These manufacturers have a significant difference as far as their sources for components and articles. All respondents were clear about the position of the supply chain (upstream or downstream) in which their organisation operates. Both manufacturers see themselves as Original Equipment Manufacturers (OEM) that work closely with the end customer.

Both manufacturers interact with their suppliers to a limited extent. Kalmar Industries has a relatively structured form of interaction with its suppliers whereas Dynapac has more *ad hoc* interaction with its suppliers. At present, because Kalmar Industries does not have the resources to interact to a greater degree with its suppliers, the company interacts only with its 1st tier suppliers. Dynapac has no systematic, on-going projects with suppliers although it has a number of small projects with expected outcomes related to shorter supplier lead-times, in-house delivery performance for customers, and average lead-times.

Performance measures and metrics
Both manufacturers measure the performance in their organisations and across their supply chains. They use measures for internal functions, the internal supply chain, suppliers' performance, and customer performance (i.e., with 1st tier suppliers to hear the customer's voice). However, they do not fully capture the total supply chain performance (i.e., measures over organisational boundaries such as from 3rd tier suppliers to end customer).

Functional performance measures in the internal supply chain – Type 1
Kalmar Industries' Purchasing Department measures price development (%), payment (days), number of suppliers, number of articles, volume flexibility (% per year for flexibility), stock turnover (times per year), and stock value in SEK. The production at Site 1 is measured internally using the following measures and metrics: lead-time, productivity (hours, time wasted, time waiting), quality (PPM, defects per manufactured item), and slack in production plan. The production at Site 2 is measured in direct labour (i.e., % of minutes registers, pre-calculated time divided by used time, the target is 1). According to the Production Manager (Site 2), direct labour should be over 80% (=direct time/appearance time), total productivity and quality (PPM, defects per manufactured item).

Dynapac's Purchasing Department uses the following measures: the purchasing price per unit (changes), which is measured every month, the number of incomplete orders, how much is bought from low salary countries, how many articles/parts can be ordered through call off (30-50%), and stock value. The Production Manager at Dynapac points out that the most important measures for both workers and owners are the following: cost (work-time and machine) productivity (money), and how often a worker is present at work (present time/machine).

Internal Integrated measures – Type 2
Kalmar Industries measures the lead-time (weeks) and cost (SEK) from order to delivery to end customer. The company also measures inventory turnover (times per year) and quality (PPM). Dynapac measures internal delivery performance (i.e., "how close they are to the production plan", the customer receives information once a week). On a daily basis, Dynapac measures the following: lead-time and inventory turnover (times per year), line stop (time), quality (PPM), the number of incomplete orders, total cost (order to delivery), and productivity.

One-sided, integrated measures – Type 3
Kalmar Industries uses the following external measures: delivery performance of suppliers, quality of suppliers (PPM), and lead-time of suppliers (weeks). The company also measures when it receives the product from the suppliers (i.e., the right day, too late in days, too early in days), cost (SEK), lead-time average, and claims. The company maintains statistics on how much is purchased from low salary countries and how many parts can be ordered through call-off (30-50%). The company also measures the number of payment days from suppliers (at least once a month). Many of these measures are presented to top management.

Dynapac uses almost identical performance measures. The company measures suppliers in terms of quality (parts per million defects, PPM), claims (number and cost), and delivery precision (measured by material planner). Dynapac's customers are interested in the following: the right quality (i.e., the number of zero defects in machines and the turnover), bad costing, and claims from the market. Dynapac also measures several aspects of the delivery performance to customers.

Every week the company measures the performance of the sell companies, distributors, and their workshops, although this procedure varies. The company also measures the lead-time to customer (weeks). Dynapac works with the concept of modular thinking.

Total chain measures - measures across organisational boundaries – Type 4
Total supply chain measures depict performance across organisational boundaries (i.e., suppliers, the organisation, and customers). Both companies measure their supply chain performance using Key Performance Indicators (KPI), which are indicators of how well they manage delivery to the market. These KPI are communicated to top managers who can then interpret and use the data to take necessary action.

Typical measures used by Kalmar Industries are delivery reliability, total lead-time, and real cost from supplier order to end customer (sell company). These measures exist in certain supply chains (i.e., parts that are important because there are few suppliers, critical components/parts, etc.). Kalmar Industries uses delivery reliability as one measure although it is divided into several parts (i.e., suppliers, customers, internal, and the site delivery reliability to the market). Other KPI measure quality, warranty % of total turnover, direct cost reduction, productivity, (hours for respective groups), product cost (index), material price (index), quality (warranty against product lines in SEK), stock value (SEK), lead-time, cost, and quality (PPM). Kalmar Industries keeps a list of its 20 worst 1st tier suppliers, and also has an open day with their 1st tier suppliers.

Dynapac states that lead-time is extremely important because almost everything has to do with the time factor. The company measures the "total lead-time" from point of order to the time when the machine is booked and ready for delivery, which could be classified as a total supply chain measure. Dynapac has identified some KPS for their overall business: Quality, Delivery, and Productivity (QLP). However, these KPI are not applicable for all functions at Dynapac.

Performance that wins orders
Both Kalmar Industries and Dynapac have very good reputations and long histories. Dynapac, which was founded in 1934, focuses on supplying the best machine performance for the road industry and for the civil construction industry. Dynapac is a full-line, global supplier. Kalmar Industries, which has a long history dating to the end of the 1940s, has delivered more than 65 000 machines to over 140 countries. Both LEs win orders as a result of their good reputation and history and their focus on quality, delivery, and cost. One can say that both companies are in the premium industry segment for their products. According to the respondents, quality is the most important measure.

Although quality (metric: quality conformance, the degree to which a product is manufactured to the agreed specification) is the most important measure, one respondent stated: *"Quality is important but also service after the first 50 hours of use"* (metric: quality serviceability, the ease of servicing (planned or breakdown) to include the speed and provision of after sales service). The measure of delivery (metric: delivery reliability), the ability to deliver consistently on the agreed due date, is rated in second place by the respondents. One respondent said that all measures are equally important because they are connected to each other. Table 16 presents the different supply chain performance measures that Kalmar Industries and Dynapac use in different measurement situations.

Table 16: *Supply chain performance measures at two heavy vehicle manufacturers.*

Measurement situation	Performance measure	Sub measure	metric
Type 1	Quality	Quality conformance	PPM
Functional measures	Cost	Productivity	Man hour/machine
Type 2	Delivery	Lead-time	Days
Internal supply chain measures	Cost	Direct labour cost	SEK/machine
Type 3	**Supplier**	**Supplier**	**Supplier**
One sided integrated measures i.e. supplier or customer	Quality	Quality conformance	PPM
	Delivery	Reliability	%
	Price	Price/purchased item	SEK/item
	Customer	**Customer**	**Customer**
	Delivery	Reliability	%
	Quality	Quality conformance	PPM
	Service after delivery	Time to establish service for customer	Hours
Type 4	Total cost	-	SEK
Total chain measures	Total lead-time	-	Weeks

Conclusions

The aims of this study were three-fold: 1) to present the supply chain performance measures and metrics used by two international, heavy vehicle manufacturers; 2) to describe how the types of supply chain performance measures that such manufacturers use should be evaluated depending on the supply chain position; and 3) to present measures, sub-measures, and metrics that such manufacturers can use to track performance in their supply chain. The main conclusions are the following:

- Both manufacturers have the same type of hybrid supply chain. They try to achieve mass customisation by postponing product differentiation until final assembly and by adding innovative components to existing products.
- In selecting suppliers, both manufacturers focus on low cost, high quality building capacity for delivery (speed), and flexibility (production).
- Both manufacturers focus on shorter lead-times but not at the expense of increased cost.
- Quality (product quality) and delivery (on-time) are the most important performance measures.
- Both manufacturers measure delivery, quality, reliability, cost, and lead-time.
- Neither manufacturer measures total supply chain performance.
- For one manufacturer, it is very important to provide fast service to customers after 50 hours of use.

5.4 Study 4: A literature review - Product Development in SMEs

Analysis

The articles in this literature review were organised in three main areas of research: Management, Operations, and Performance. The articles' analytical approach is dominated by explorative and descriptive approaches, but there are also articles that take an explanatory purpose (approximately one quarter of all the articles). Most papers are empirical and take a quantitative approach. The high proportion of articles that explore and describe this research area compared with the articles meant to explain and validate this research area indicates that the research is still rather immature.

Many articles deal the firm's relation to other actors in the PD process. Articles in this category

focus on the organisation's degree of dependence on earlier stages in the supply chain. These articles typically argue that all organisations to some extent depend on the earlier stages in the supply chain. These articles address the flow of goods and information, and the interaction between these flows (Christopher, 1998; Handfield and Nichols, 1999). An example is Stroeken's (2000) analysis of the introduction of IT in SMEs and its impact on process innovation (internal and external), followed by product innovation in the sense of more diverse, cheap, and customer-specific products. Supply chain integration is the central concept in the article.

The number of articles on supply chain dependence relations issues is rather low. Only 9 of the 149 papers have this focus. The number of articles on performance-related issues is also rather low. Only 11 of the 149 papers have this focus. If this field of research is to deliver results of high importance for the development of sustainable new products, and to contribute to economic growth and societal welfare, there should be an increased focus on performance. See Table 17.

Table 17: *A summary of the research approaches of the 149 articles. An article may be 'multi-classified' (e.g., as both management and operations)*

	Analytical approach			*Methodological approach*					
Covered topics	*Explorative*	*Descriptive*	*Explanatory*	*Not applic.*	*Conceptual*	*Empirical*	*Empirical qualitative*	*Empirical Quantitative*	*No. of articles*
Management	*28*	*37*	*26*	*6*	*15*	*82*	*32*	*50*	*97*
Leadership and governance	23	30	18	2	10	63	23	40	
Information and business environment	8	7	2	2	4	15	5	10	
Finance of PD	2	5	9	3	6	13	0	13	
Operations	*32*	*34*	*25*	*2*	*7*	*86*	*31*	*49*	*93*
Method and techniques	14	15	1	1	1	30	22	8	
Capability and competence	18	19	24	1	6	56	13	43	
Chain dependence	4	2	3	0	1	8	2	6	9
Performance	*4*	*3*	*4*	*0*	*0*	*11*	*1*	*10*	*11*

Conclusions

The purpose of this paper was three-fold. First, to explore the area of PD in SMEs by analysing the literature. Second, to discuss the development in this research field in terms of maturity. Third, to suggest future research themes. The main conclusions are the following:

- Much of the research related to PD in SMEs is characterised by heterogeneity and the lack of cumulative knowledge creation. Our interpretation is that the field is still rather immature in comparison to many other research fields.
- The number of articles on supply chain dependence (i.e., the supply chain relation) issues was low. Only 9 of the 149 articles have this focus.
- The number of articles on performance-related issues was low. Only 11 of the 149 articles have this focus.
- The development of a higher degree of consensus and an increased focus on performance and supply chain dependence relations issues are important future research challenges.

5.5 Study 5: A case study – Flows in the Internal Supply Chain

Analysis

This study illustrates how to map and describe information flows and physical material flows in an integrated supply chain. The study presents a *process-oriented mapping tool* (see Figure 9) that can be used to easily map and describe information flows and physical material flows, from order to delivery. Many methods frequently used in the industry for mapping information flows are theoretically based. This assumes a deductive approach, as the model already exists before the mapping process begins. Our methodology offers an inductive approach, which is based on interviews and which has been used to produce a model in line with the empirical findings.

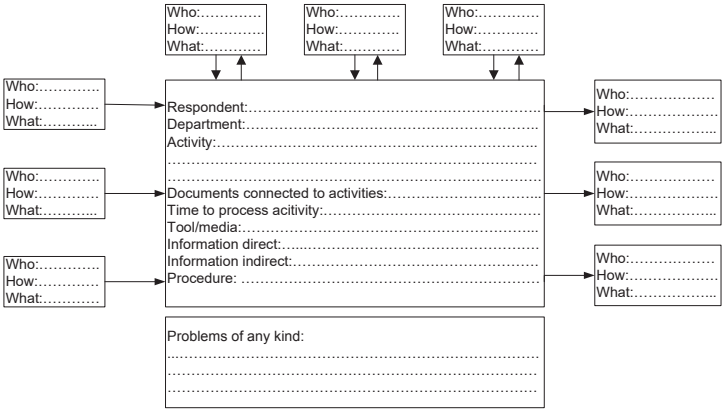


Figure 9. *The research protocol (source: Chibba and Rundquist, 2009).*

The two firms have similar information flows – the information flow is more voluminous at the beginning of the internal supply chain. See Table 18. In the case presented (A-1), we found the respondents were more "sending-intensive" at the beginning of the flow than at the end of the flow. Sending-intensive means the firms tended to send information to PRMS (an ERP system) rather than to load information from PRMS. The respondents at the end of the flow were more "loading-intensive" than at the beginning of the flow. The two firms are highly dependent on both computerised and orally communicated information.

A Director of Planning stated: *"Production did not proceed as planned. No changes are made after an order has been forwarded to production — it is better to proceed instead of creating uncertainty in the internal supply chain. This problem could have been avoided if the information had reached the head planner before a certain date. It was the lack of communication between customer and sales that created the initial problem".*

Table 18: *Description of the information flow. Arrow no. refers to the numbers in Figure 10.*

Arrow no.	Resp. no.	Respondent action – receiving or loading (what and how)	Respondent action – sending (what and how)
1	1	Receives order from customer by phone.	
2	2	Receives order from internal sales by phone.	
3	2		Sends order confirmation to customer by mail.
4	2		Sends information [A] to PRMS.
5	3	Loads information [A] from PRMS.	
6	3		Sends information [B] to PRMS.
7	4 and 5	Loads information [B] from PRMS.	
8	5		Sends information [C] to PRMS.
9	3	Loads information [C] from PRMS.	
10	3		Sends information [D] to PRMS.
11	4 and 5		Sends order to external suppliers by fax/EDI.
12	4		Sends information [E] to PRMS.
13	6	Loads information [D] from PRMS.	
14	6		Sends information [F] to respondents7, 8, 9 and 10 verbally by phone.
15	11	Loads information [E] from PRMS.	
16	11	Receives oral information [G] from respondent no. 6.	
17	12 and 13	Loads information [E] from PRMS.	
18	11		Sends information [H] to PRMS.
19	14	Receives information [J] from respondent nos. 7, 8, 9 and 10 in hard copy together with physical goods.	
20	14	Loads information [K] from PRMS.	
21	6	Loads information [H] from PRMS.	
22	15	Receives information [L] from respondent no. 14 together with goods.	
23	15	Loads information [K] from PRMS.	
24	16	Receives information [M] from respondent no. 15 together with goods.	
25	16	Loads information [N] from PRMS.	
26	2		Sends information [O] to PRMS.

We mapped the flow of information and physical materials from receiving an order to the point of delivery (i.e., Case A-1). The boxes depict a process. The arrows, which indicate information or physical material, are shown in Figure 10. The methodology presented above was used to map all cases.

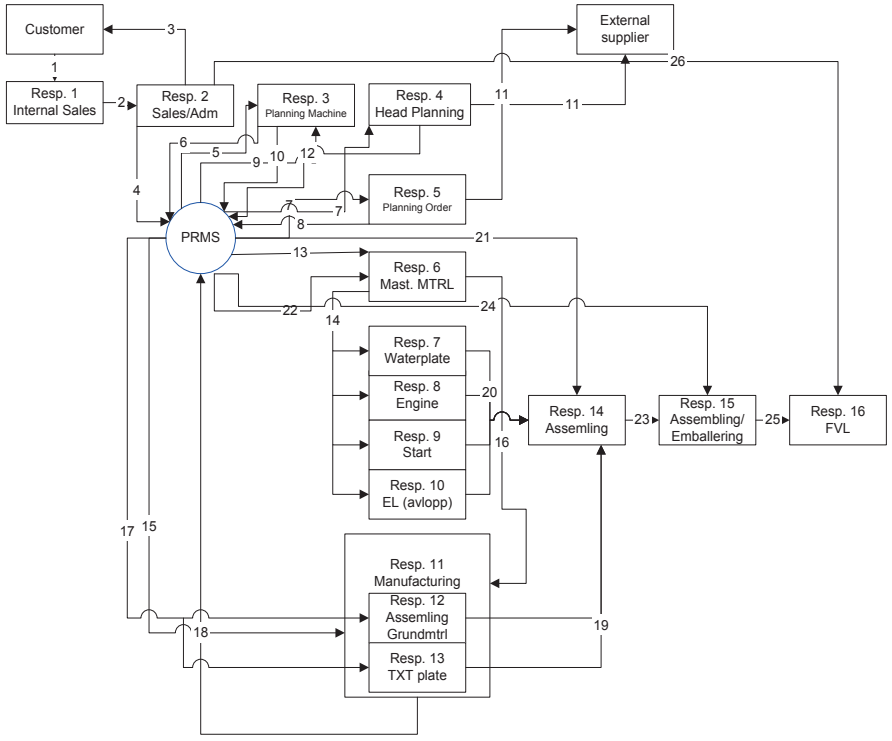


Figure 10. *Case A-1 the map of the information and physical material flow (source: Chibba and Rundquist, 2009).*

Conclusions

One purpose of this study was to develop and test techniques for mapping information flows in an internal supply chain (i.e., information flows that support the physical material flows). A second purpose was to identify factors that could improve and rationalize information flows and create a better flow for the organisation. The main conclusions are the following:

- The piloted research protocol makes it possible to map the information flow from customer to delivery of product.
- It is better to take an inductive approach when mapping information flows — that is, to follow the real flow, from source to estuary, rather than to look at the formal documentation.
- The following areas (i.e., disturbances) could be improved and rationalized to create better information flows and physical flows in the integrated supply chain:

1. Procedures for handling changes in customer orders.
2. Procedures for collecting information in the internal supply chain such as information about changed delivery times, changes in stock, and missing machines.
3. Procedures for handling information about delays in internal production or erroneous delivery of material(s).

5.6 Study 6: A case study – Framework for prioritizing supply chain performance measures

Analysis

In this study supply chain Type (1) (i.e., efficient, market responsive, agile, quick, lean, hybrid and leagile supply chain, is supported by theory). See Table 19. The type of products manufactured (defined by Fischer, 1997) -- functional, innovative, or hybrid -- indicates, according to Cigolini et al. (2004) and Huang et al. (2002), the phase in the product life cycle where the product can be classified (i.e., introduction, growth, maturity, or decline). The product life cycle phase in turn indicates the type of supply chain (Aitken et al., 2003; Christopher and Towill, 2000; Cigolini et al., 2004; Fisher, 1997; Huang et al., 2002). The number of supply chain types in Table 19 can be limited to six because the supply chain type has similar characteristics (i.e., efficient, quick, agile (market responsive), lean, hybrid, and leagile supply chains).

Table 19: *The type of supply chain and its characteristics, (Type 1).*

Type of supply chain	Author	Characteristics
Efficient supply chain (ESC)	Fisher (1997)	An efficient supply chain, ESC, brings product to the market that can be broadly considered as *commodities* and are often sold in high volumes (e.g. groceries, newspapers). Because of the stability of product flows, these organisations can invest in large and capital-intensive facilities, and improvement initiatives are focused on operations rather than product innovation.
Market responsive supply chain	Fisher (1997)	Market responsive supply chains (RSC) are linked to *innovative products*. Market Responsive supply chains (RSC) have similar characteristics to agile supply chains (Selldin and Olhager, 2007).
Agile supply chain	Christopher and Towill (2000)	*Innovative products* focus on capturing new markets and are designed to be acceptable to changing customer demands. (Huang et al., 2002) argue that this type of product usually has uncertain demand and its design may be unstable; such products are in the introduction or growth stages of the product life cycle. Huang, et al. claim the paradigm of which was presented by (Christopher and Towill, 2000). According to Naylor et al. (1999), agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace.
Quick supply chain	Li et al. (2014)	A quick supply chain, QSC, (e.g. fashion apparel, white products) can be defined as *"products whose demand is difficult to forecast"*. These types of organisations invest in manufacturing systems with a high variable vs. fixed costs ratio, due to the fact that manufacturing flexibility is highly valuable.
Lean supply chain	Naylor et al. (1999)	A lean supply chain, LSC, (e.g., *automobile*) has intermediate characteristics: firms do not mainly compete on product price or novelty, but simultaneously on price, novelty, quality, and customer service. A LSC employs continuous improvement processes to focus on the elimination of waste or non-value stops across the chain and employs both lean production and time compression in parallel in order to be economical, flexible and responsive.
Hybrid supply chain	Huang et al. (2002)	Huang et al. (2002) argue that hybrid products consist of either *different combinations of standard components, or a mix of standard and innovative components*. They suggest an hybrid supply chain, -- HSC.
Leagile supply chain	Naylor et al. (1999)	(Naylor et al., 1999) also presented a supply chain that is a *combination of* supply chain is described by (Christoher and Towill, 2000) as both lean and agile – that is, agile enough to respond to what is actually selling (market driven) with availability as the market winner.

The supply chain performance measure Type (2) (see Table 20), is also supported to some degree by theory (e.g., De Toni et al. (1994), Gadde and Håkansson (2001), Hayes and Wheelwright (1984), Lambert and Pohlen (2001), Pagell and Krause (2002), Saad and Patel (2006), and Stewart (1995). However, the three-level performance classification seems new: supply chain performance measures, sub-measures, and metrics are contributions to theory.

Table 20: *Example of supply chain performance measures and its metrics, (Type 2).*

Supply Chain Performance

Measure	Example of sub measures	Example of metrics
Quality	The degree to which a product is manufactured to the agreed specification	% of returns
Delivery	The ability to consistently deliver on the agreed due date	% of on-time delivery
Flexibility	The ability to effectively produce a wide variety of different products	X pieces of variances
Cost/price	The ability to produce products at a low cost. The ability to offer a lower product price than direct competitors.	X SEK

The scope of the measurement situation Type (3) is firmly grounded in theory. See for example, Stewart (1995) and the SCOR (Supply Chain Operations Reference) model that was further developed by the researcher. See Paper 2. The measurement scope is presented for Type 1 to Type 4, which is, to the best of our knowledge, a contribution to theory. See Figure 11.

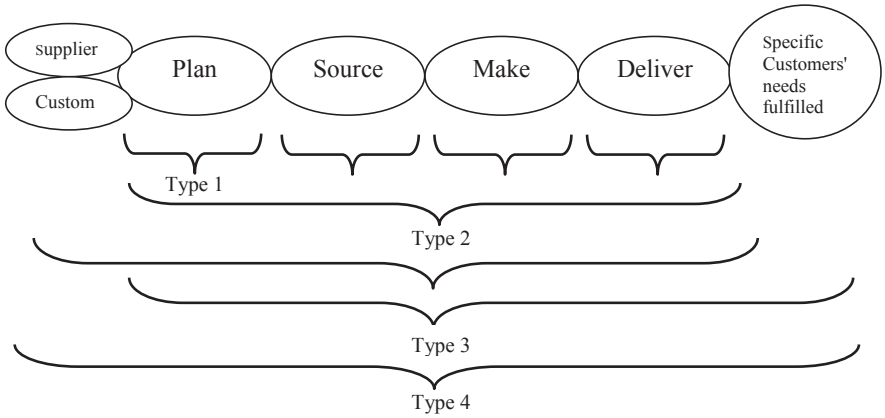


Figure 11. *Four different types of measures of supply chain performance, (Type 3).*

Conclusions

The aim of this study was to increase our knowledge on how organisations develop and improve their supply chains, both upstream and downstream. The main conclusions are the following:

- A framework for prioritizing supply chain performance measures due to:
    1) Type of supply chain: efficient, quick, agile, lean, hybrid, or leagile.
    2) Type of supply chain performance measure: quality, delivery, cost, or flexibility.
    3) The scope of measurement in the supply chain: Functional measures, internal integrated measures, one-sided, integrated measures, or total supply chain measures. The framework presented has its base in the literature (i.e., well-known theory complemented by empirical studies).

Figure 12 depicts the framework, which includes Types 1-3 from above.

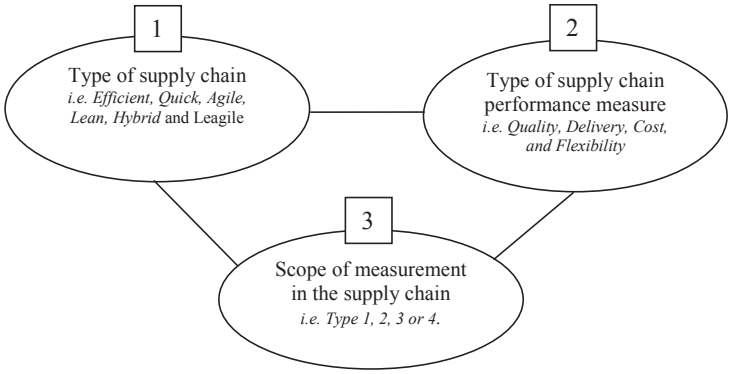


Figure 12. *Framework for prioritizing supply chain performance measures.*

5.7 Study 7: A case study – Supply Chain Quality Management

Analysis

This study generally aimed to acquire a deeper understanding of how actors in the wind turbine industry measure performance in their supply chains. The three specific aims of the study are in italicized print:

> *The first aim of the study was to examine the relationship (degree of importance) between stakeholders' requirements, wants, and expectations related to quality performance in the wind turbine supply chain.*

As most manufacturers of wind turbines are large enterprises and almost all other suppliers and customers are small, there is an imbalance in the supply chain. The customer in this case tried to minimise costs and to increase its ROI. To that end, the customer reduced costs using vertical integration (i.e., by performing some of the suppliers' work such as assembly, transportation, and other services including the use of cranes). The supplier and its sub-suppliers delivered the wind turbines including services, if ordered, to the customer. However, the customer decided to go downstream in the supply chain by using vertical integration. The customer's needs, wants, and expectations were new to the supplier compared to those of its other customers. The customer wanted, for example, more electronic systems for handling the service documentation, accessible data generated from the wind park, lower prices for service, and faster access to spare parts.

Using supply chain performance metrics, some improvements that the supplier could contribute were the following: on-time delivery of spare parts, decreased delivery lead-times, lower service costs, and greater flexibility as far as customer access to service data generated by the wind turbines.

> *The second aim of the study was to determine the influence different stakeholders' interests have on quality and supply chain performance (i.e., delivery, quality of product, cost, and flexibility) related to the total supply chain (i.e., purchasing, manufacturing, installation, and service of wind turbines in a forest environment).*

The stakeholders' influence on quality and supply chain performance related to the total supply chain may be described as follows. The purchasing phase could be controlled by a contract between the customer and the supplier. The supplier sells the wind turbine and other related services (e.g., transportation and services). However, owing to issues of cost and on-time delivery, the customer may perform some wind turbine services. There are several different stakeholders that may influence customer success (i.e., secondary stakeholders that oppose wind power exploration, individuals who have media power, or even the media in general). These stakeholders can cause the primary stakeholders, such as investment firms, banks, and governmental entities, to take action. See Figure 13.

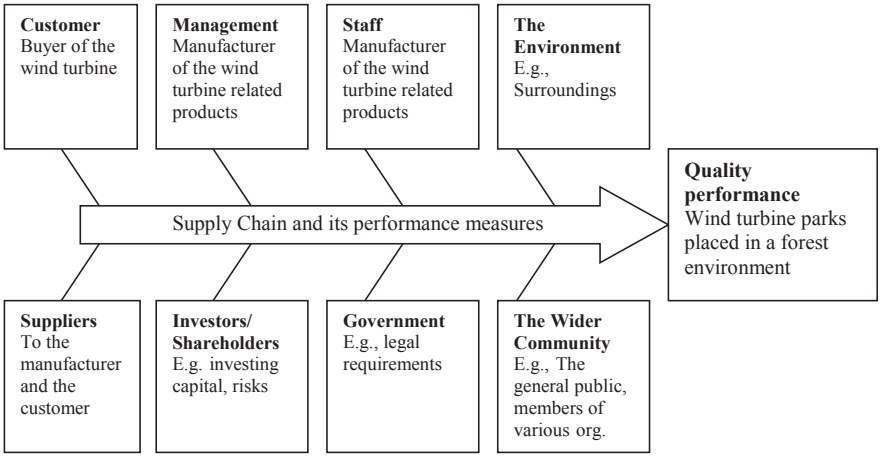


Figure 13. *Some relationships between stakeholders within a supply chain, based on the stakeholder model of the business enterprise by Foley (2001).*

> *The third aim of the study was to determine which product characteristics stakeholders find relevant and that therefore must be measured, controlled, and improved.*

In our study the customer had a clear understanding of how it could improve its processes. Finding reliable and general methods to calculate wind speed was essential. At the time of the study, the customer used several different calculation models to predict wind speed. The supplier also had a clear understanding of how to improve its processes. The lead-time from a manufactured wind turbine to production was one of the most important issues to address since it affects the delivery time to the customer (i.e., a key stakeholder interest).

The supplier did not fully control the products received from the sub-suppliers (e.g., transportation, installation, and service). The customer, who did not always work with the supplier, often worked directly with the sub-suppliers. These sub-suppliers sometimes have a difficult working environment, which often results in high staff turnover and high demands for effective, pre-site training of new personnel. This training was not always handled properly, which led to irregularities.

Conclusions

The main purpose of this study was to examine relationships among the different stakeholders, the supply chain, and quality performance. Moreover, the study examined the quality assurance in the supply chain (i.e., manufacturing, installation, and service of wind turbines in a forest environment). The main conclusions are the following:

- The organisation tried to minimise costs and increase ROI. Therefore, costs were reduced using vertical integration (i.e., performing some activities previously performed by suppliers; these activities included assembly, transportation, and other services such as the use of cranes).
- By using supply chain performance metrics, the supplier could make some improvements such as the following: delivery improvements (on-time delivery of spare parts, reduced delivery lead-times) cost reductions (reduced service costs), and increased flexibility (greater customer access to service data from the operating wind turbines).
- Because of cost issues and the requirements for on-time delivery, the customer may perform some wind turbine services. There are several different stakeholders that may influence customer success or failure (i.e., secondary stakeholders that oppose wind power exploration in general, individuals who have media power, or even the media in general). These stakeholders may cause primary stakeholders, such as investment firms, banks, and governmental entities, to take action.
- Finding reliable and general methods to calculate wind speed was essential.
- The lead-time from a manufactured wind turbine to production was one of the most important issues since it affects the delivery time to the customer (i.e., a central stakeholder interest).
- Sub-suppliers often have a difficult work environment, which sometimes leads to high staff turnover and irregularities.

5.8 Aggregated conclusion

Based on the seven studies of this thesis, a number of more general conclusions may be drawn that relate to our main research question: *What improves quality performance of supply chains that include manufacturing?* From this study of the quality performance of the supply chain at manufacturers, the following conclusions are relevant:

- The most widely used supply chain performance measures at the process level are quality (product quality) and delivery (on-time) although not at the expense of increased cost.
- The most common supply chain measures are one-sided measures that depict performance over organisational boundaries.
- It is relatively uncommon to measure total supply chain performance that includes 1st, 2nd, and 3rd tier suppliers.
- Cross-functional teams in the integrated supply chain are most appropriate when working with product development.
- Decreasing lead-times is important for making improvements in the performance of the supply chain but not at the expense of increased cost.
- The number of articles on supply chain dependence relations issues in the context of product development is low; the number of articles on performance-related issues is also rather low.
- It is of value to have an NPD Department with permanent staff members who share the responsibility for the NPD process in the supply chain.

- To generate a better flow in the supply chain, procedures are needed to manage customer changes and information communications about delays of materials/wrong materials.
- Sub-suppliers in the supply chain of manufacturers can reduce their costs by vertical integration (i.e., by performing some the work that has traditionally been assigned to the suppliers).
- Suppliers should be selected based on low cost, high quality, delivery speed, and flexibility in production.
- SCM performance measures should be used to track and improve the suppliers: quality, delivery, cost, and flexibility.
- A process-oriented mapping tool can be used to facilitate description of information flows and physical material flows and also to identify disturbances, which could be improved and rationalized to create a better flow in the integrated supply chain.

The supply chain quality performance improvement model for manufacturers in Figure 14 is supported by findings from the studies as well as by theory in the relevant research field.

1. **Process level in the integrated supply chain**
   a. Focus on the quality and delivery performance of each process in the organisation but not at the expense of increased cost (Studies 1, 3, 6, and 7).

2. **Internal integrated supply chain**
   a. Focus on quality (conformance), delivery performance (on-time), and cutting costs in the internal supply chain (Studies 3, 6, and 7).
   b. Use a process-oriented mapping tool to facilitate description of information flows and physical material flows, which could be improved and rationalized to create a better flow in the integrated supply chain (Study 5).
   c. Use cross-functional teams in the internal supply chain when working with NPD (Study 2).
   d. Employ permanent staff members in the NPD Department who share the responsibility for the NPD process in the internal supply chain (Study 2).

3. **Upstream or downstream in the supply chain**
   a. Create procedures to manage customer order changes efficiently and effectively, leading to a reduction in uncertainty (Study 5).
   b. If necessary, cut costs by vertical integration (Study 7).
   c. Choose suppliers based on measures of cost, quality, delivery speed, and flexibility of production (Studies 1, 3, and 6).
   d. Use SCM performance measures to aid supplier's improvement: quality (product quality), delivery (on-time delivery), cost, and flexibility (production) (Studies 3, 6, and 7).
   e. Shorten lead-times but not at the expense of increased cost (Studies 3 and 6).

4. **Total supply chain**
   a. Use total supply chain measures (e.g., total lead-time, total costs as the means to create, control, and improve a better flow in the supply chain) (Studies 1, 3, 6, and 7).

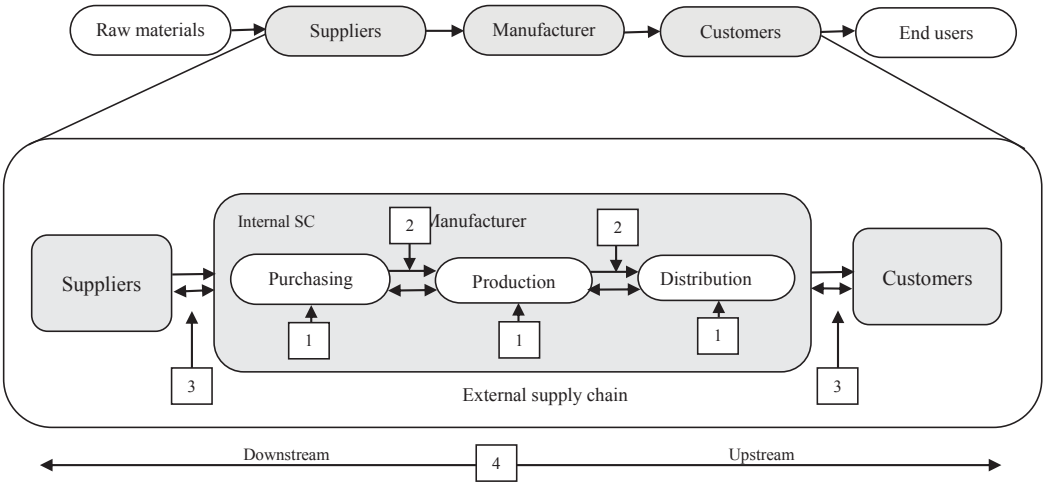


Figure 14. *The supply chain (SC) quality performance improvement model for manufacturers. The numbers represent the situations in which the studies are performed. Based on Kaynak and Hartley (2008).*

6. Discussion

This chapter begins with a discussion on the thesis findings and continues with theoretical and practical implications. The chapter concludes with a view forward and suggests future research areas.

6.1 A discussion about the findings and alternative approaches

Additional discussion of the findings is merited. Use of the right type of performance measure in a manufacturing supply chain is important because it is essential to focus on the right type of action that can improve supply chain performance. The most widely used supply chain performance measures are quality and delivery but not at the expense of increased cost. This implies that the manufacturers described in this thesis value high quality and fast delivery but they are unwilling to pay for it. Rather, they take product quality and on-time delivery for granted. This finding is similar to the results in a study by Piotrowicz and Cuthbertson (2015) who conclude that the most important metrics are on-time delivery, customer satisfaction, total costs, and transportation cost. Gunasekaran et al. (2004) observe that the quality of delivered goods and on-time delivery are highly important in relation to the perceived customer value. Our research shows that the production metric of cost per operating hour is also highly important.

The most commonly used supply chain measures are the one-sided measures that depict performance over organisational boundaries. It is not so surprising that an organisation measures its supplier performance because it is easy to track performance of suppliers and to take the necessary actions if they do not deliver as agreed. From the customer perspective, it is relatively easy to collect and track performance (e.g., returns, guaranteed responsibility, and delivery performance). However, it is relatively uncommon to measure total supply chain performance (e.g., 3rd tier supplier to end customer). The reason may be that, as the managers in this research point out, manufacturing organisations do not have the resources to interact to a greater degree with other suppliers upstream in the supply chain. They can only interact with 1st tier suppliers. This result is similar to Sila et al.'s (2006) finding. Although companies consider quality an important factor in their dealings with suppliers, they actually do not allocate enough resources to develop or strengthen this factor. They choose suppliers based on low cost, high quality, on-time delivery, and flexibility (production). Decreasing lead-times is also important when trying to improve performance in the supply chain. That is a major goal with direct financial implications.

Cross-functional teams are often appropriate when working with product development in the integrated supply chain. This finding is also not surprising. For example, the standard ISO/TS 16949:2009 (quality management standard relevant for manufacturers of car components) states that design and development should be conducted in a cross-functional way. This means involving different persons from different functions in the design and development, production, quality, planning, purchasing, and other relevant functions (Clause 7.3.1.1 ISO/TS 16949:2009).

As far as product development, the number of articles on chain dependence relations issues is low as is the number of articles on performance-related issues. The explanation is probably that NPD theory and SCM theory do not have a significant or natural connection in the way that QM and SCM do. However, collaboration with NPD and SC with different actors seems to be important, although probably not from a SC perspective.

To create a better flow in the SC, procedures are needed for managing changes and communicating information about delays of materials/wrong materials. Clearly, changes in an

order after the order is sent to production pose risks that must be considered. There are several reasons: 1) the information about the change needs to reach production as quickly as possible; 2) the ERP system needs to be updated with the changes; and 3) an early dialogue with the customer is needed to prevent misunderstandings. Moreover, process-oriented mapping tools are needed to facilitate the description of the information flow and the physical material flows in order to identify disturbances.

Companies can reduce their costs by vertical integration (i.e., by performing some work that has traditionally been assigned to the suppliers). One of the earliest, largest, and most famous examples of vertical integration occurred at the Carnegie Steel Company (Jacobs, 2000). The company controlled not only the steel mill but also the coal mines, the ships and railroads, the coke ovens, etc. However, a change of this magnitude would surely require the support of boards of directors due to the complexity and the risk.

SCM performance metrics can be used to improve supplier performance. These metrics, which relate to product quality, delivery performance, cost reduction, and flexibility in production, measure the activities that help the supplier to improve the performance in the SC. The research literature identifies numerous examples of what to measure but less on how, when, and where to measure. Section 6.3 presents implications for practice related to this problem. For manufacturers in a mature market, price is always a competition factor because customers nowadays take product quality and delivery performance for granted. However, if the product is innovative, the price may not be the most important competition factor. Instead, fast delivery may be more important.

Not least, it seems important to create a good work environment, especially when working in a tough work environment such as wind turbine installation in a forest. It is essential to minimise high staff turnover and to reduce irregularities.

In sum: To improve the quality performance in the supply chain a manufacturer could implement the following:

Directly improve performance by:

- Creating procedures to manage changes from customers, instead of creating uncertainty.
- Reducing cost by vertical integration (i.e., performing some of the suppliers' work with recognition of the risks).
- Using SCM performance measures such as quality and delivery but not at the expense of increased cost.
- Selecting suppliers based on low cost, high quality, fast delivery, and flexibility in production.
- Using cross-functional teams in the internal SC when working with NPD.

Indirectly improve performance by:

- Using total supply chain measures to create, control, and improve flows.
- Using SCM performance measures to help suppliers improve their quality, delivery, cost, and flexibility.
- Using a process-oriented mapping tool to facilitate description of information flows and physical material flows and also to identify disturbances that could be improved and rationalized to create a better flow in the integrated supply chain.

This thesis is based on seven case studies of seven companies in which the qualitative research approach was mainly used. Forty-seven interviews at the companies were conducted. Alternatively, the quantitative research method could have been taken, and a larger sample of companies could have been studied. Such an approach could have increased the possibility of generalising the findings to other companies and other situations. However, the qualitative research method was chosen because it seemed the most efficient way to gather detailed knowledge about the phenomena studied.

Another alternative approach could be to broaden the research focus by including supply chains at non-manufacturers. However, this approach was not taken in this research because the manufacturers use their own resources to measure and monitor the performance of the supply chain. We recommend, nevertheless, that this is a possible avenue for future research. The measures and metrics addressed in this thesis may also be expanded by the inclusion of more types of performance measures and metrics connected to sustainability or measures or metrics that present the performance of the information flow in the supply chain. In that research, performance measures and metrics should be considered.

The choice of the selected measures and metrics in these studies was influenced by the need for measures and metrics that shed light over the total supply chain including suppliers, the organisation, and its customers. Moreover, this thesis focuses on LE manufacturers. I could equally have chosen other types of manufacturers. However, irrespective of the respondents, it is essential to describe how and why they were selected; this is to some extent described in the seven papers in the Appendix.

6.2 Theoretical implications

In addition to the contribution to knowledge described in the seven papers (see the Appendix) in this thesis, the aggregated conclusions should also be seen as a contribution to knowledge (i.e., the supply chain quality management improvement model) in the context of measuring performance in supply chains that include manufacturing as depicted in Figure 14. The theoretical model presented by Kaynak and Hartley (2008), which describes the internal and external supply chain, is developed and includes improvement suggestions for manufacturers. The expanded model has support from the seven studies as well as from other research. The supply chain quality management improvement model should be seen as a model that needs to be set by the specific organisation that adopts the model. Section 6.3 develops the model following a suggested KPI matrix.

Another contribution to knowledge from this thesis is its focus on performance measures at a higher level (e.g., strategic or tactical). Quality, flexibility, and delivery are well represented in the research literature while performance metrics at a detailed level (e.g., operational, including defects and bad quality) are less well represented. Results from these seven studies indicate that practitioners need relevant detailed performance metrics and not just performance measures that are at a higher level. See Table 21.

Table 21: *The contribution to knowledge in terms of SC performance measures and metrics, and in the context of manufacturers.*

	Performance of supply chains	
	Measures e.g., quality, delivery	**Metrics** e.g., % of defects, cost of poor quality, on-time delivery, total lead-time
Research literature	Well presented	Less presented
In practice	Exist	More needed

6.3 Implications for practice

Today, top managers need control over financial figures as well as other performance measures such as delivery, quality, and flexibility. This information helps them deal with the changing market on a timely basis. For manufacturers, selecting the right measures and metrics is a complex task. They could use the proposed supply chain quality performance improvement model in this thesis to reflect on, choose, and construct KPI that measure the performance in the total supply chain as defined by the organisation. Table 22 presents a suggested KPI Matrix. This KPI Matrix is derived from the seven studies described in this thesis and on relevant theory related to the manufacturing supply chain. However, the KPI Matrix, which can be modified, may also be used to measure performance of service businesses. A description of how to use the KPI matrix is presented next.

The first column is a typical manufacturing supply chain with its various parts (see Quang et al., 2016). This column is typical for a manufacturing supply chain. The column presents the different actors in its internal supply chain: purchasing, production and distribution, and its customers and suppliers.

The second column presents the supply chain quality performance measurement situation. This column points to the types of measurement situations in the supply chain (see Chibba and Rundquist, 2009). The column calls attention to the measures that depict the various actors' performance in the SC.

The third column, which presents the KPI such as supplier, related results, financial ratios, R&D, Productivity ratios, Operational/quality results, human resources, customer-related results and structural measures, and market share data (see Foster, 2013) and the studies conducted. Manufacturers could use these factors to discuss and add KPI that are relevant and specific to the organisation (e.g., downtime reduction in equipment turning, milling, sanding, grinding, sawing, cutting, shearing, drilling, making holes, punching, folding, and bending).

The fourth column describes the KPI (i.e., the performance metrics) (see Chibba, 2007b) with support from the seven studies of the thesis. This column is the most important because it presents the relevant metrics for a supply chain. This KPI Matrix presents general metrics that are

appropriate for a manufacturing supply chain. However, the metrics can differ depending on the product manufactured, whether it is an innovative, functional, or hybrid product.

The fifth column presents the units used for the metrics. These units are often a number, a division, time, or percentage. It is important to use the right type of unit for the right metric.

The sixth column describes the frequency of measuring the KPI (e.g., monthly, yearly etc.). The organisation needs to decide how often to use a measure.

The seventh column describes the target for next year. An organisation should decide on its annual target for the specific KPI.

The eighth column presents the actual outcome of the KPI.

The KPI Matrix can be used as a tool to monitor and track performance indicators (a requirement of ISO 9001:2015) in the supply chain. The KPI Matrix should be evaluated least once a year to check the relevance of the KPI. The KPI should be seen as control and monitoring targets that can be adjusted or replaced if there is a change in business (e.g., when the organisation enters a new market, changes its product lines, etc.).

Table 22: *The KPI Matrix – supply chain quality performance for manufacturers*

1. Part of the SC based on Quang et al. (2016) and SCOR. Framework (2012)	2. Supply chain quality performance measurement situation, Chibba and Rundquist, (2009)		3. Key business factors based on Foster, (2013) with support from the studies performed	4. KPI based on Chibba, (2007b) with support from studied performed	5. Unit	6. Frequency	7. Target 2017/2018	8. Actual 2017/2018
Suppliers	Total chain measure	Type 3: One-sided measure	Supplier-related results	Supplier OTD	%	Monthly		
				Supplier Quality Rate	%	Monthly		
				Price/purchased item	kSEK	Monthly		
Your organisation (Plan)		Type 2: Internal integrated measure	Financial ratios	EBIT (IFRS)	kSEK	Monthly		
				EBIT-Margin	%	Monthly		
				CAPEX	KSEK	Quarterly		
				Uninsured receivables	Number	Monthly		
Purchasing (Source)				Uninsured receivables	KSEK	Monthly		
				TCO / IT-workplace	kSEK/IT WP	Yearly		
		Type 1: Functional measure	R&D, Research and Development	New Products /Processes	SEK/BY	Yearly		
				New Product/Processes	Number	Yearly		
			HR, Human Resources	Health Rate, Attendance Rate	%	Monthly		
				Fluctuation rate	%	Monthly		
				Training time per FTE	Hours/FTE	Monthly		
Production (Make)		Type 2: Internal integrated measure	Productivity ratios	Man hour/machine	hours	Monthly		
			Operating / Quality results	OEE	%	Monthly		
				Net value added per Employee adjusted by temporary staff	kSEK/FTE	Monthly		
				Capacity load	%	Monthly		
				Breakdown rate	%	Monthly		
				Claims	Number	Monthly		
				Claims Acceptance	%	Quarterly		
				External PPM-rate	PPM	Monthly		
				Actual Rate: Actual vs Planned	%	Quarterly		
				Bad Quality Cost	SEK	Monthly		
				Continuous improvement projects	Number	Quarterly		
				Lead-time	Days	Monthly		
Distribution (Deliver)		Type 3: One-sided measure	Customer-related results	Customer OTD	%	Monthly		
				New Customers	Number	Yearly		
				New Customers	kSEK/BY	Yearly		
				Lost Customer	Number	Yearly		
				Lost Customer	kSEK/BY	Yearly		
				Service after delivery	Hours/days	Monthly		
Customers (Return)		Type 3: One-sided measure	Customer-related results	Quality conformance /Complaint/Warranty	kSEK/BY	Monthly		
SCOR (Enable)		Type 4: Total Chain measure	Customer-related results	Total lead-time	Weeks	Monthly		
				Total cost	kSEK	Monthly		
			Market share data	Market share	%	Yearly		

6.4 Future research

Studying management issues is a complex task and involves several choices for the researcher including methodological choices. In this thesis, a supply chain performance improvement model is presented that is supported by previous theories and empirical evidence from the seven studies. The results should be seen as a small but significant contribution to knowledge in the field of measuring performance in manufacturing supply chains. There are several questions and issues that should be addressed in order to further develop our examination of "supply chain quality performance". Therefore, it is relevant to suggest directions for future studies in this area. Five suggestions follow:

1) In the new edition of ISO 9001 (year 2015), the requirement for performance measurement is presented as: *"The organisation shall determine the processes needed for the quality management system and their application throughout the organisation, and shall:…c) determine and apply the criteria and methods (including monitoring, measurements and related performance indictors) needed to ensure operation and control of these processes".* Therefore, it would be interesting to study how organisations that include manufacturing use performance indicators, as the standard requires. Moreover, it would be interesting to study how these performance indicators really indicate performance of the internal SC and if they contribute to the improvement of the total SC.

2) The performance measures and metrics presented in this thesis are those usually employed by manufacturers to select their suppliers (i.e., quality, delivery, cost, and flexibility). Other types of measures and metrics can be researched that focus more on sustainable development (e.g., DFE (Design For Environment), the PLC (Product Life Cycle) and carbon footprint). Still other measures or metrics of interest are those that present the performance of the information flow in the supply chain (e.g., information exchange, and availability). In addition, qualitative performance measures should be considered (e.g., trust and proximity).

3) A study of the various metrics (KPI) used by manufacturers with different types of products (i.e., mature, innovative, or functional) in different phases in the PLC (Product Life cycle) would be of value. The aim of this research could be to capture standardized measures suitable for sharing by organisations.

4) The role of information sharing in supply chains could be further explored. Information can be seen as the glue that combines the other two flows (i.e., physical material flow and financial flow). Therefore, the role of information sharing between the supply chain partners is a relevant area of study with a focus on performance.

5) The influence of the position in the supply chain (i.e. upstream or downstream) on the choice of performance measure to monitor is worth studying. For example, downstream suppliers are more focused on measuring cost and quality (conformance), while upstream suppliers focus more on delivery (delivery reliability) lead-time, and flexibility (flexibility of production).

References

Abolemaged, M.G. (2010). Six Sigma quality: a structured review and implications for future research. *International Journal of Quality & Reliability Management*, 27(3): 269-318.

Adam Jr., E.E., Corbett, L.M., Flores, B.E., Harrison, N.J., Lee, T.S., Rho, B.H., Ribera, J., Samson, D. and Westbrook, R. (1997). An international study of quality improvement approach and firm performance, *International Journal of Operations and Production Management*, 17(9): 842–873.

Adams, C. and Neely, A. (2000). The performance prism to boost M&A success. *Measuring Business Excellence*, 4(3): 19-23.

Agus, A. and Mohd, S.H. (2012). Lean production supply chain management as driver towards enhancing product quality and business performance. *International Journal of Quality & Reliability Management*, 29(1): 92-212.

Ahire S.L. and Dreyfus, P. (2000). The impact of design management and process management on quality: an empirical examination. *Journal of Operations Management,* 18: 549-575.

Ahire, S.L. and O'Shaughennesy, K.C. (1998). The role of top management commitment in quality management: an empirical analysis of the auto parts industry. *International Journal of Quality Science*, 3(1): 5-37.

Aitken, J., Childerhouse, P. et al. (2003). The impact of product life cycle on supply chain strategy. *International Journal of Production Economics,* 85: 127-140.

Akamp, M. and Müller, M. (2013). Supplier management in developing countries. *Journal of Cleaner Production*, 56: 54-62.

Alderson, W. (1965). *Dynamic Marketing Behaviour: A Functionalist Theory of Marketing*. Homewood, IL: Richard D. Irwin, Inc.

Alvesson, M. and Svenningsson, S. (2008). *Förändringsarbete i organisationer*, Liber.

Anderson, J.C., Rungtusanatham, M., Schroeder, R.G. and Devaraj, S. (1995). A path analytic model of a theory of quality management underlying the Deming management method: preliminary empirical findings, *Decision Sciences*, 26(5): 637-658.

Andreasson, K., Chibba, A. and Larsson, J. (1995). *The Basics of Quality Assurance*. QMI Publications, ISBN 91-88864-04-9.

Awan, M.U., Raouf, A., Ahmad, N. and Sparks, L. (2009). Total quality management in developing countries: a case of pharmaceutical wholesale distribution in Pakistan. *International Journal of Pharmaceutical and Healthcare Marketing*, 3(4): 363-380.

Banbury, J. G. (1975). Distribution – The final link in the electricity-supply chain. *Electronics and Power Journal of the Institution of Electrical Engineers,* 21(13): 773-775.

Beamon, M. B. (1999). Measuring supply chain performance. *International Journal of Operations and Production Management*, 19(3): 275-292.

Behn, R.D. (2013). "Why measure performance? Different purposes require different measures". *Public Administration Review*, 63(5): 586-606.

Bergman, B. and Klefsjö, B. (2012). *Kvalitet från behov till användning*. Femte upplagan. Lund: Studentlitteratur.

Bergqvist, B., Foley, K., Garvare, R. et al. (2008). *The Theories and Practices of Organization Excellence: New Perspectives*. Sydney: SAI Global, 501-538.

Bhatt, G.D. (2000). Information dynamics, learning and knowledge creation in organizations. *The Learning Organization* 7(2): 89-98.

Blanchard, D. (2010). *Supply Chain Management Best Practices*. 2nd. Edition, John Wiley & Sons, ISBN: 9780470531884.

Bourne, M., Mills, J., Wilcox, M., Neely, A. and Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations & Production Management*, 20(7): 754-771.

Boyer, K.K., Frohlich, M. and Hult, G.T.M. (2005). *Extending the Supply Chain.* New York: AMACOM,

Brewer, P.C. and Speh, T.W. (2001). Adapting the balanced scorecard to supply chain management. *Supply Chain Management Review*, 5(2): 48-56.

Cai. J., Liu, X. D., Xiao, Z. H. et al. (2009). Improving supply chain performance management: A systematic approach to analyzing iterative KPI accomplishment. *Decision Support Systems*, 46(2): 512-521.

Carlton, D.W and Perloff, J.M. (2005). *Modern Industrial Organization*. United States of America.

Casadesús, M. and De Castro, R. (2005). How improving quality improves supply chain management: empirical study. *Total Quality Management*, 17: 345-357.

Chibba, A. (2007a). *Measuring supply chain performance measures – prioritizing performance measures*. Licentiate thesis. Luleå University of Technology, Luleå.

Chibba, A. (2007b). *Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers*. Conference proceedings, 14th International Annual EUROMA conference in Ankara, Turkey.

Chibba, A. and Hörte, S. (2003a). *Supply Chain Performance – A Meta-analysis*. Conference proceedings, 10th EUROMA conference in Como, Italy.

Chibba, A. and Hörte, S.Å. (2003b). *Information and physical material flows in supply chains – A survey of calculation methods and models*. Centre for Information Logistics in Ljungby, Sweden.

Chibba, A. and Rundquist, J. (2009). Effective information flow in the internal supply chain: Results from a snowball method to map information flows. *Journal of Information & Knowledge Management*, 8(4): 331-343.

Chin, O., Liu, F., Hung, Y., and Yen, D. (2010). A structural model of supply chain management on firm performance. *International Journal of Operations & Production Management*, 30(5): 526-545.

Choi, T.Y. and Eboch, K. (1998). The TQM paradox: relations among TQM practices, plant performance, and customer satisfaction. *Journal of Operations Management*, 17(1): 59-75.

Christopher, M. (1997). *Marketing Logistics*. Oxford: Butterworth-Heinemann.

Christopher, M. (1998). *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*. Harlow: Financial Times - Prentice Hall.

Christopher, M. and Towill, D.R. (2000). Supply chain migration from lean to functional to agile and customised. *Supply Chain Management: An International Journal*, 5(4): 206-213.

Christopher, M. and Towill, D. R. (2001). An integrated model for the design of agile supply chains. *International Journal of Physical Distribution and Logistics Management*, 31(4): 235-246.

Cigolini, R., Cozz, M. et al. (2004). A new framework for supply chain management. *International Journal of Operations & Production Management*, 24(1): 7-41.

Croom, S., Romano, P. et al. (2000). Supply chain management: an analytical framework for critical literature review. *European Journal of Purchasing & Supply Management*, 6(1): 67-83.

Crosby, P.B. (1979). *Quality is Free*. New York: New American Library.

Cuthbertson, R. and Piotrowicz, W. (2008). Supply chain metrics – review of supply chain best practices. *International Journal of Productivity and Performance Management*, 57(5): 389-404.

Danese, P. and Romano, P. (2011). Relationship between downstream integration, performance measurement systems and supply network efficiency. *International Journal of Production Research,* 50(7): 2002-2013.

De Toni, A., Nassimbeni , G. et al. (1994). Service dimensions in the buyer-supplier relationship:

A case study. *International Journal of Physical Distribution & Logistics Management*, 24(8): 4-14.

Ding, M.J., Jie. F., Parton, K.A. and Matanda, M.J. (2014). Relationships between quality of information sharing and supply chain food quality in the Australian beef processing industry. *The International Journal of Logistics Management*, 25(1): 85-108.

Eisenhardt, K.M. (1989). Building theories from case study research. *Academy of Management Review,* 14(4): 532-550.

Ellinger, A.E. (2000). Improving marketing/logistics cross-functional collaboration in the supply chain. *Industrial Marketing Management*, 29: 85-96.

Evans, P. and Wurster. T. S.(2000). *Blown to Bits*. Boston: Harvard Business School Press.

Feller, A., Shunk, D. and Callarman, T. (2006). *Value Chains Vs. Supply Chains*. BP Trends.

Fisher, M. L. (1997). What is the right supply chain for your product? *Harvard Business Review,* 105-116.

Flynn, B.B. and Flynn, E.J. (2005). Synergies between supply chain management and quality management: emerging implications. *International Journal of Production Research*, 43(16): 3421-36.

Flynn, B., Schroeder, R.G. and Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, 26(5): 659-91.

Foley, K. (2001). *From quality management to organization excellence: further thoughts on the contemporary business organization*. In P. Hermel (Ed.), Proceedings of the 2nd MAAOE International Conference, University of Versailles, France, 26-28 September.

Forker, L.B., Mendez, D. and Hershauer, J.C. (1997). Total quality management in the supply chain: what is its impact on performance? *International Journal of Production Research*, 35: 1681-701.

Forslund, H. and Jonsson, P. (2007). Dyadic integration of the performance management process: a delivery service case study. *International Journal of Physical Distribution & Logistics Management*, 37(7): 546-67.

Forslund, H. and Jonsson, P. (2009). Obstacles to supply chain integration of the performance management process in buyer-supplier dyads. *International Journal of Operations & Production Management,* 29(1): 77-95.

Forslund, H. and Jonsson, P. (2010). Selection, implementation and use of ERP systems for supply chain performance management. *Industrial Management & Data Systems*, 110(8): 1159-1175.

Foster, S.T., Jr. (2013). *Managing Quality – Integrating the Supply Chain.* Harlow: Pearson Education Limited.

Foster, S.T., Jr. (2008). Towards and understanding of supply chain quality management. *Journal of Operations Management,* 26(4): 461-77.

Foster, S.T., Jr. and Ogden, J. (2008). On differences in how operations and supply chain managers approach quality management. *International Journal of Production Research*, 46: 6945-61.

Fotopoulos, C.V. and Psomas, E.L. (2010). The structural relationships between TQM factors and organizational performance. *The TQM Journal*, 22(5): 539-52.

Fredrick, R.D. (1998). *Competing through Supply Chain Management*. New York: Chapman and Hall.

Fynes, B. and Voss, C. (2002). The moderating effect of buyer-supplier relationships on quality practices and performance. *International Journal of Operations and Production Management*, 22(6): 583-613.

Fynes, B., Voss, C. and de Burca, S. (2005a). The moderating effect of buyer-supplier relationships on quality practices and performance. *International Journal of Operations & Production Management*, 22: 589-613.

Fynes, B., Voss, C. and de Burca, S. (2005b). The impact of supply chain relationship quality on quality performance. *International Journal of Production Economics*, 96: 339-54.

Gadde, L. E. and Håkansson, H. (2001). *Supply Network Strategies*. UK: John Wiley and Sons.

Garvin, A. D. (1988). *Managing Quality*: *The Strategic and Competitive Edge.* New York: The Free Press.

Gopal, P.R.C. and Thakkar, J. (2012). A review of supply chain performance measures and metrics: 2000-2011. *International Journal of Productivity and Performance Management*, 61(5): 518-547.

Griffin, A. (1997). PDMA research on new product development practices: Updating trends and benchmarking best practices. *Journal of Product Innovation Management*, 14: 429-458.

Grimm, C., Polyviou, M. et al. (2015). *Supply chain management research in management journals: A review of recent literature (2004-2013). International Journal of Physical Distirbution & Logistics Management,* 45(5): 404-458.

Grünbaum, N.N. (2007). Identification of ambiguity in the case study research typology: what is a unit of analysis? *Qualitative Market Research: An International Journal,* 10(1): 78-97.

Gummesson, E. (1991). *Qualitative Research in Management*. Qualitative Methods in

Management Research. London: Sage Publications.

Gunasekaran, A. and Kobu, B. (2007). Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995-2004) for research and applications. *International Journal of Production Research*, 45(12): 2819-2840.

Gunasekaran, A., Patel, C. et al. (2001). Performance measures and metrics in a supply chain environment. *International Journal of Operations & Production Management*, 21(1/2): 71-78.

Gunasekaran, A, Patel, C and McGaughey, E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, 87: 333-347.

Halldórsson, A. and Arlbjorn, S. (2001). *Musings on Supply Chain Management*. Nofoma 2001 Conference Proceedings.

Halldórsson, Á., Husan, J. et al. (2015). Complementary theories to supply chain management revisited – form borrowing theories to theorizing. *Supply Chain Management: An International Journal*, 20(6): 574-586.

Handfield, R. B. and Nichols, E. L. (1999). *Introduction to Supply Chain Management*. New Jersey: Prentice Hall.

Hart, C. (2001). *Doing a Literature Review*. London, UK: Sage.

Harrington, J.H. (1991). *Business Process Improvement - The Breakthrough Strategy for Total Quality, Productivity*, and Competitiveness. New York: McGraw-Hill, Inc.

Harrison, A. and New. C. J. (2002). The role of coherent supply chain strategy and performance management in achieving competitive advantage: an international survey. *Journal of the Operations Research Society*, 53(3): 263-271.

Hayes, R. H. and Wheelwright, S. C. (1984). *Restoring our Competitive Advantage*. New York: John Wiley.

Helms Mills, J., Dye, K., and Mills A.J. (2009). *Understanding Organizational Change*. USA and Canada: Routledge.

Hickey, G., and Kipping, C. (1996). Issues in research. A multi-stage approach to the coding of data from open-ended questions. *Nurse Researcher*, 4: 81-91.

Hill, T., Nicholson, A. and Westbrook, R. (1999). Closing the gap: a polemic on plant-based research in operations management. *International Journal of Operations & Production Management*, 19(2): 139-156.

Hollos, D., Blome, C. and Foerst, K. (2011). Does sustainable supplier co-operation affect performance? Examining implications for the triple bottom line. *International Journal of Production Research*, 50(11): 2968-2986.

Horvarth, l. (2001). Collaboration: the key to value creation in supply chain management. *Supply Chain Management: An International Journal*, 6(5): 205-207.

Houlihan, J.B. (1985). International supply chain management. *International Journal of Physical Distribution & Materials Management*, (15): 1.

Hsieh, H.F., and Shannon, S.E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, 15(9): 1277-1288.

Huang, S.H. and Uppal, M. and Shi, J. (2002). A product driven approach to manufacturing supply chain selection. *Supply Chain Management: An International Journal*, 7(4): 189-199.

Huang, S. H., Sheoran, S. K., and Wang, G. (2004). A review and analysis of supply chain operations reference (SCOR) model. *Supply Chain Management: an International Journal*, 9(1): 23-29.

Hull, B. (2002). A Structure for supply-chain information flows and its application to the Alaskan crude oil supply chain. *Logistics Information Management* 15(1): 8-23.

Inderfurth, K., Sadrieh, A. and Voigt, G. (2013). The impact of information sharing on supply chain performance under asymmetric information. *Production and Operations Management*, 22(2): 410-425.

Institute of Management and Administration. (2002). How Dell Resolved Its Quality Issue Through Supplier Partnerships, *Supplier Selection & Management Report*, 2(8): 1-3.

ISO 9001 (2015). *Quality Management System – Requirements*. ISO International Organization for Standardization, Geneva.

ISO/TS 16949 (2009). *Quality management systems – Particular requirements for the application of ISO 9001:2008 for automotive production and relevant service part organizations.* ISO International Organization for Standardization, Geneva.

Jacobs, D.G. (2003). Anatomy of a supply chain. *Transportation & Distribution*, 44(6): 60-63.

Jacobs, P. D. (2000). The United States Steel Company, 1890-1920: An Examination of Economic Cooperation and Competition. *The Sloping Halls Review*, 7.

Jacoby, B. (2009). *Guide to Supply Chain Management: How Getting it Right Boosts Corporate Performance* (The Economist Books), Bloomberg Press; 1st edition, ISBN 978-1576603451.

Janvier-James, A.M. (2012). A new introduction to supply chains and supply chain management: Definitions and theories perspective. *International Business Research*, 5(1): 194-207.

Jones, T.C and Riley, D.W. (1985). Using inventory for competitive advantage through supply chain management. *International Journal of Physical Distribution & Materials Management*,

15(5): 16-26.

Jonsson, P. and Lesshammar, M. (1999). Evaluation and improvement of manufacturing performance measurement systems – the role of OEE. *International Journal of Operations & Production Management*, 19(1): 55-78.

Juran, J.M. (1999). *Juran´s Quality Handbook*, 5th edition. New York: McGraw-Hill.

Kallet, R.H. (2004). How to write the methods section of a research paper. *Respiratory Care* 49(10): 1229-1232.

Kamran, R. and Aslam, M.M.H. (2012). Business excellence through total supply chain quality management. *Asian Journal on Quality,* 13(3): 309-324.

Kannan, V.R. and Tan, K.C. (2005). Just in time, total quality management, and supply chain performance under asymmetric information. *Production and Operations Management*, 22(2): 410-425.

Kannan, V.R., and Tan, K.C. (2007). The impact of operational quality: A supply chain view. *Supply Chain Management: An International Journal*, 12: 14-19.

Kaplan, R. S. and D. P. Norton. (1992). The balanced scorecard - Measures that drive performance. *Harvard Business Review* (January-February): 71-79.

Katiyar, R. and Barua, M.K. and Meena, P. (2015). Modelling the measures of supply chain performance in the Indian automotive industry. *Benchmarking An International Journal*, 22(4): 665-696.

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of Operations Management*, 21(4): 405-35.

Kaynak, H. and Hartley, J.L. (2008). A replication and extension of quality management into the supply chain. *Journal of Operations Management*, 26(4): 468-89.

Ketchen, D.J. and Guinipero, l. (2004). The intersection of strategic management and supply chain management. *Industrial Marketing Management*, 33(1): 51-56.

Ketchen, D.J. and Hult, G.T.M. (2006). Bridging organization theory and supply chain management: the case of best value supply chains. *Journal of Operations Management*, 25: 573-580.

Klaus, P. (2009). Logistics research: a 50 year´s march of ideas. *Logistics Research*, 1(1): 53-65.

Kotler, P., Armstrong, G., Wong, V. and Saunders, J. (2008). *Principles of Marketing*. London: Prentice Hall.

Kuei, C., Madu, C. and Lin, C. (2001). The relationship between supply chain quality

management practices and organizational performance. *International Journal of Quality & Reliability Management*, 18(8): 864-872.

Kuei, C. and Madu, C. (2001). Identifying critical success factors for supply chain quality management. *Asia Pacific Management Review*, 6(4): 409-23.

Kuei, C.H., Madu, C.N. and Lin, C. (2008). Implementing supply chain quality management. *Total Quality Management and Business Excellence*, 19(11): 1127-41.

Kuei, C., Madu, C. and Lin, C. (2010). Developing global supply chain quality management systems. *International Journal of Production Research*, 49(15): 4457-81.

Kumar, S., Clements, A.C. and Keller, E.W. (2014). Supplier management in manufacturing environment: a strategically focussed performance scorecard. *International Journal of Productivity and Performance Management*, 63(1): 127-138.

Lambert, D.M. and Cooper, M.C. (2000). Issues in supply chain management. *Industrial Marketing Management*, 29: 65-83.

Lambert, D.M. and Pohlen, T.L. (2001). Supply chain metrics. *The International Journal of Logistics Management*, 12(1): 1-19.

Larson, P.D. and Halldórsson, A. (2004). Logistics versus supply chain management: an international survey. *International Journal of Logistics: Research and Application*, 7(1): 17-31.

Lee, T.W. (1999). *Using Qualitative Methods in Organizational Research*. London: Sage.

Lee, B., Collier, P.M. and Cullen, J. (2007). Reflections on the use of case studies in the accounting, management and organizational disciplines. *Qualitative Research in Organizations and Management: An International Journal*, 2(3): 169-178.

Levy, P., Bessant, J., Sarg, B. and Lamming, R. (1995). Developing integration through total quality supply chain management. *Integrated Manufacturing Systems,* 6(3): 4-13.

Lipsey, M. W. and Wilson D.B. (2001). *Practical Meta-Analysis*. Thousand Oaks, CA: Sage Publications, Inc.

Lueg, C. (2001). Information, knowledge, and networked minds. *Journal of Knowledge Management*, 5(2): 151-159.

Li, S., Ragu-Nathan, B., Ragu-Nathan, T.S. and Rao, S.S. (2006). The impact of supply chain management practices on competitive advantage and organizational performance. *Omega*, 34(2) 107-24.

Li, Y., Zhao, X., Shi, D. and Li, X. (2014). Governance of sustainable supply chains in the fast fashion industry. *European Management Journal*, 32(5): 823-836.

Lin, C. and Chai, K. (2012). Exploration of the key evolutionary operational improvement activities. *Industrial Management & Data Systems*, 112(7): 1123-1141.

Lin, C., Chow, W.S., Madu, C.N., Kuei, C.H. and Yu, P.P. (2005). A structural model of supply chain quality management and performance. *International Journal of Production Economics*, 118: 367-74.

Lo, C.K. Yeung, A.C.L. and Cheng, T.C.E. (2009). ISO 9000 and supply chain efficiency: empirical evidence on inventory and account receivable days. *International Journal of Production Economics*, 118: 367-74.

Lo, C.K., Yeung, A.H.W. and Yeung, A.C.L. (2007). How supply chain quality management improves and organisation´s quality performance: a study of Chinese manufacturing firms. *International Journal of Production Research*, 45: 2219-43.

Madu, C.N. (1998). An empirical assessment of quality, research considerations. *International Journal of Quality Science*, 3(4): 348-355.

Mason-Jones, R. and Towill, R. D. (1998). Time compression in the supply chain: information management is the vital ingredient. *Logistics Information Management*, 11(2): 93-104.

Matson, S.-A. (2004). *Logistikens termer och begrepp*. Stockholm, Sweden: PLAN, Föreningen för Produktionslogistik.

Mellat-Parast, M. (2013). Supply chain quality management. *International Journal of Quality & Reliability Management,* 30(5): 511-529.

Mellat-Parast, M. (2015). An institutional theory of quality outcome in strategic supply chain partnership. *International Journal of Quality and Reliability Management*, 32(1): 356-360.

Mentzer, J.T. et al. (2001). Defining supply chain management. *Journal of Business Logistics*, 22(2): 1-25.

Meredith, J. (1998). Building operations management theory through case and field research. *Journal of Operations Management*, 16: 441-54.

Merriam, S. B. (1988). *Case Study Research in Education: A Qualitative Approach*. San Francisco: Jossey Bass.

Mohrman, S.A., Tenkasi, R.V., Lawler, E.E. and Ledford, G.E. (1995). Total quality management: practice and outcomes in the largest US firms. *Employee Relations*, 17(3): 26-41.

Mokhatar, S.S.M. (2013). The effects of customer focus on new product performance. *Business Strategy Series*, 14(2/3): 67-71.

Moore, J.F. (1993). The evolution of Wal-Mart: Savvy expansion and leadership. *Harvard Business Review*, 71(3): 82-84.

Mukerjee, K. (2013). Customer-oriented organizations: a framework for innovation. *Journal of Business Strategy*, 34(3): 49-56.

Nair, A. (2006). Meta-analysis of the relationship between quality management practices and firm performance – implications for quality management theory development. *Journal of Operations Management*, 24(6): 948-75.

Najmi, M., Etebari, M. and Emami, S. (2012). A framework to review Performance Prism. *International Journal of Operations & Production Management*, 32(10): 1124-1146.

Naylor, R., Naimi, M. M. et al. (1999). Leagility: Integrating the lean and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics*, 62: 107-118.

Novak, R.A. and Simco, S.W. (1991). The industrial procurement process: a supply chain perspective. *Journal of Business Logistics*, 12(1): 145-167.

O' Brien, J. A. (1999). *Management Information Systems*, McGraw-Hill.

Oliver, R.K. and Webber, M. D. (1982). Supply-chain management: logistics catches up with strategy. In M. Christopher (Ed.), *Logistics: The Strategic Issues*: London: Chapman & Hall, pp. 63-75.

Opengart, R. (2015). Supply chain management and learning organization: a merging of literatures. *International Journal of Commerce and Management*, 25(2): 183-195.

Ou, C.S., Liu, F.C., Hung, Y.C. and Yen, D.C. (2010). A structural model of supply chain management on firm performance. *International Journal of Operations & Production Management*, 30(5): 526-45.

Page, A. L. (1993). Assessing new product development practices and performances: Establishing crucial norms. *Journal of Product Innovation Management*, 10: 273-290.

Pagell, M. and Krause, D. (2002). Strategic consensus in the supply chain: Exploring the manufacturing purchasing link. *International Journal of Production Research*, 40(13): 3075-3092.

Paterson, B. L., Thorne S.E. et al. (2001). *Meta-study of Qualitative Health Research*. Thousand Oaks, CA: Sage Publications Ltd.

Phusavat, K., Anussornnitisarn, P., Helo, P. and Dwight, R. (2009). Performance measurement: roles and challenges. *Industrial Management & Data Systems*, 109(5): 646-61.

Piotrowicz, W. and Cuthbertson, R. (2015). Performance measurement and metrics in supply chains: an exploratory study. *International Journal of Productivity and Performance Management*. 64(8): 1068-1091.

Potter,W. J., and Levine-Donnerstein, D. (1999). Rethinking validity and reliability in content analysis. *Journal of Applied Communication Research*, 27: 258-284.

Powell, T.C. (1995). Total quality management as competitive advantage: a review and empirical study. *Strategic Management Journal*, 16(1): 15-37.

Prado-Prado, J.C. (2009). Continuous improvement in the supply chain. *Total Quality Management & Business Excellence*, 20(3): 301-9.

Prajogo, D.I. and Sohal, A.S. (2006). The relationship between organization strategy, total quality management (TQM), and organization performance – the mediating role of TQM. *European Journal of Operational Research*, 168(1): 35-50.

Quang, T. H., Sampaio, P. et al. (2016). An extensive structural model of supply chain quality management and firm performance. *International Journal of Quality and Reliability Management*, 33(4): 444-464.

Quinn, J. P., Anderson, P. et al. (1996). Managing professional intellect: making the most of the best. *Harvard Business Review*, 74(2): 71-80.

Rashid , K. and Aslam, H. M.M. (2012). Business excellence through total supply chain quality management. *Asian Journal of Quality*, 13(3): 309-324.

Robinson, C.J. and Malhotra, M.K. (2005). Defining the concept of supply chain quality management and its relevance to academic and industrial practice. *International Journal of Production Economics*, 96(3): 315-37.

Robson, I. (2004). From process measurement to performance improvement. *Business Process Management Journal,* 10(5): 510-521.

Romano, P. and Vinelli, A. (2001). Quality management in supply chain perspective, strategies and operative choices in a textile-apparel network. *International Journal of Operations & Production Management*, 21: 134-9.

Roth, A.V., Tsay, A.A., Pullman, M.E. and Gary, J.V. (2008). Unravelling the food supply chain: strategic insights from China and the 2007 recalls. *Journal of Supply Chain Management*, 44(1): 22-39.

Ruggles, R. L. (1997). *Knowledge Management Tools*. Newton, MA: Butterworth-Heinemann.

Rungtusanatham, M., Salvador, F., Forza, C. and Choi. T.Y. (2003). Supply chain linkages and operational performance: A resource-based view perspective. *International Journal of Operations & Production Management*, 23(9): 1084-1099

Saad, M. and Patel, B. (2006). An investigation of supply chain performance measurement in the Indian automotive sector. *Benchmarking: An International Journal*, 13(1/2): 36-53.

Samson, D. and Terziovski, M. (1999). The relationship between total quality management practices and operational performance. *Journal of Operations Management*, 17(4): 393-409.

Sánchez-Rodriquez, C. and Martinez-Lorente, Á. (2004). Quality management practices in the purchasing function: an empirical study. *International Journal of Operations & Production Management*, 24: 666-87.

Sandholm, L. (2000). *Total Quality Management*. Lund: Studentlitteratur.

Saraph, J.V., Benson, P. G. and Shroeder, R.G. (1989). An instrument for measuring the critical factors of quality management. *Decision Sciences*, 20: 810-829.

Selldin, E., and Olhager, J. (2007). Linking products with supply chains: Testing Fisher's model. *Supply Chain Management: An International Journa*l, 12(1): 42-51.

Schulman, P.R. (1993). The analysis of high reliability organisations: a comparative framework. In K. H. Robets (Ed.), *New Challenges to Understanding Organisations*, Macmillan, New York, NY.

Schwab, D.P. (2005). *Research Methods for Organizational Studies*, 2nd ed. Mahwah: Lawrence Erlbaum Associates.

Sila, I. and Ebrahimpour, M. (2002). An investigation into the total quality management survey based research published between 1989 and 2000: a literature review. *International Journal of Quality and Reliability Management*, 19(7): 903-71.

Sila, I. and Ebrahimpour, M. (2005). Critical linkages among TQM factors and business results. *International Journal of Operations & Production Management*, 25(11): 1123-1155.

Sila, I., Ebrahimpour, M. et al. (2006). Quality in supply chains: an empirical analysis. *Supply Chain Management - An International Journal*, 11(6): 491-502.

Simon, A. and Sohal, A. (1996). Generative and case study research in quality management – Part I: theoretical considerations. *International Journal of Quality & Reliability Management*, 13(1): 32-42

Singh, J. (1996). The importance of information flow within the supply chain. *Logistics Information Management*, 9(4): 28-30.

Singh, P. and Power, D. (2009). The nature and effectiveness of collaboration between firms, their customers and suppliers: a supply chain perspective. *Supply Chain Management: An International Journal*, 14(3): 189-200.

Slack, N., Ed. (1998). *Encyclopedic Dictionary of Operations Management*. Oxford, Blackwell Publishers Ltd.

Sroufe, R. and Curkovic, S. (2008). An examination of ISO 9000:2000 and supply chain quality assurance. *Journal of Operations Management*, 26: 503-20.

Stake, R. (1995). *The Art of Case Study Research*. Thousand Oaks, CA: Sage

Stevens, G. C. (2016). Integrating the supply chain…25 years on. *International Journal of Physical Distribution & Logistics Management*, 46(1): 19-42.

Stewart, G. (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. *Logistics Information Management*, 8(2): 38-44.

Stroeken, J.H.M. (2000). Information technology, innovation and supply chain Structure. *International Journal of Technology Management*, 20(1-2): 156–175.

Stuart, I., Mc Cutcheon, D., Handfield, R., McLachlin, R. and Samson, D. (2002). Effective case research in operations management: a process perspective. *Journal of Operations Management,* 20(5): 419-433.

Sun, H. and Ni, W. (2012). The impact of upstream supply and downstream demand integration on quality management and quality performance. *International Journal of Quality and Reliability Management*, 29(8): 872-890.

Supply Chain Operations Reference (SCOR®) model. (2010), Overview, Version 10.0, *Supply Chain Council*.

Supply Chain Operations Reference (SCOR®) model. (2013), Version 11.0, *Supply Chain Council*.

Supplier Selection & Management Report, (2002). Institute of Management and Administration (IOMA).

Svensson, G. (2002). The theoretical foundation of supply chain management: A functionalist theory of marketing. *International Journal of Physical Distribution & Logistics Management* 32(9): 734-754.

Sweeney, E., Grant, D. B. et al. (2015). The implementation of supply chain management theory in practice: an empirical investigation. *Supply Chain Management: An International Journal*, 20(1): 56-70.

Tan, K.C. (2001). A framework of supply chain management literature. *European Journal of Purchasing and Supply Management*, 7(1): 39-48.

Tan, K.C., Handfield, R.B. and Krause, D.R. (1998). Enhancing the firm's performance through quality and supply base management: and empirical study. *International Journal of Production Research*, 36: 2813-37.

Teng, S.G., Ho, S. M., Shumar, D. and Liu, P.C. (2006). Implementing FMEA in a collaborative

supply chain environment. *International Journal of Quality and Reliability Management*, 23(2/3): 179-196.

Tompkins, J. A. (2000). *No Boundaries: Moving Beyond Supply Chain*. Tompkins Press.

Tsui, E. (2000). Exploring the KM toolbox. *Knowledge Management*, 4(2): 11-14.

Vachon, S. and Klassen R. D. (2006). Extending green practices across the supply chain. *International Journal of Operations & Production Management*, 26(7): 795-821.

Vanichchinchai, A. (2014). Supply chain management, supply performance and total quality management: An organizational characteristic analysis. *International Journal of Organizational Analysis*, 22(2): 126-148.

Vanichchinchai, A. and Igel, B. (2010). The impact of total quality management on supply chain management and firm´s supply performance. *International Journal of Operations & Production Management,* 26(7): 795-821.

Voss, C. A. (1995). Operations management - from Taylor to Toyota and beyond. *British Journal of Management*, 6: 17-29.

Voss, C. A., Tsikriktsis, N. and Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management*, 22(2): 195-219.

Weckenmann, A., Akkasogul, G. et al. (2015). Quality management - history and trends. *The TQM Journal*, 27(3): 281-293.

Wong, A. and Fung, P. (1999). TQM in the construction industry in Hong Kong: a supply chain management perspective. *Total Quality Management*, 10(2): 199-208.

Wu, X., Choi, T.Y. and Rungtusanatham, M.J. (2010). Supplier – supplier relationships in byer - supplier – supplier triads: Implications for supplier performance. *Journal of Operations Management*, 28(2): 115-123.

Wu, I.-L., Chuang, C.-H. and Hsu, C.-H. (2014). Information sharing and collaborative behaviours in enabling supply chain performance: a social exchange perspective. *International Journal of Production Economics*, 148(2): 122-132.

Yeung, A.C.L. (2006). The impact of third-party logistics performance on the logistics and export performance of users: an empirical study. *Maritime Economics and Logistics*, 8:121-139.

Yeung, A.C.L. (2008). Strategic supply management, quality initiatives, and organizational performance. *Journal of Operations Management*, 26(4): 490-502.

Yeung, H.Y., Selen, W., Sum, C.C. and Huo, B.F. (2006). Linking financial performance to strategic orientation and operational priorities. *International Journal of Physical Distribution and Logistics Management*, 36(3): 210–230.

Yin, R. K. (1989). Case Study Research: Design and Methods. *Applied Social Research Series*, Vol. 5. London: Sage.

Yin, R.K. (1994). *Case Study Research: Design and Methods* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Yin, R. (2003). *Case Study Research: Design and Methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Yin, R. (2009). *Case Study Research: Design and Methods* (4th ed.). Thousand Oaks, CA: Sage Publications.

Zairi, M. (2002). Beyond TQM Implementation: the new paradigm of TQM sustainability. *Total Quality Management*, 13(8): 1125-1140.

Zhang, l., Wang, S., Li, F., Wang, H., Wang, L. and Tan, W. (2011). A few measures for ensuring supply chain quality. *International Journal of Production Research*, 49(1): 87-97.

Zu, X., and Kaynak, H. (2012). An agency theory perspective on supply chain quality management. *International Journal of Operations & Production Management,* 32(4): 423-446.

Paper 1

Chibba, A. and Hörte, S. (2003). Supply Chain Performance – A Meta-analysis. *Conference proceedings, 10th International Annual EUROMA conference* in Como, Italy.

Supply Chain Performance – A Meta analysis

Aron Chibba, Sven Åke Hörte

School of Business and Engineering, University of Halmstad, PO: BOX 823, S-301 18 Halmstad, Sweden

ABSTRACT

This article examines what we know about the performance of supply chains, utilizing a meta-analysis approach. Supply chain management is expected to have a positive impact on the performance of supply chains through e.g. quality, lower costs, delivery, lead-time, flexibility, and customer query time, but the expectations are not always met. There are research reports supporting the improvement hypothesis, but there are also studies reporting no performance increase. To shed further light on the performance increase hypothesis, a meta-analysis approach is used. Meta-analysis is a technique for analysing research findings as they are typically presented in research reports. The article analyse research reports and scientific journal articles on different types of supply chain performance. Our primary focus is five performance measures: delivery, quality, cost, price and flexibility. The meta-analysis indicates that delivery and quality are measures that are the most often presented measures in the articles. It also indicates that *One sided integrated measures* was the most used measure which depict performance across organisational boundaries and measure chain performance across supplier or customer boundaries.

Keywords: Supply Chain Performance, Physical material- and information flows, Meta-analysis

INTRODUCTION

The supply chain of a firm is often described in terms of upstream and downstream flows. Handfield & Nichols (Handfield and Nichols 1999) writes that *""supply chains are essentially a series of linked suppliers and customers; every customer is in turn a supplier to the next downstream organisation until a finished product reaches the ultimate user. ... the supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage, through to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain"*. Christopher's (Christopher 1998) definition is similar. He defines the supply chain and its management as: *"the management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole"*. Both definitions state that the supply chain includes upstream suppliers, internal functions, and downstream customers. The first definition mentions the information flow which is connected to the physical material flow, while the second introduces the important economic aspects of cost and price in the (management of) the flows (Morgan 2001).

Several recent studies indicate that the knowledge and improvements of an organisations supply chain can make considerable benefits to organisations (Mason-Jones and Towill 1998; Gunasekaran, Patel et al. 2001; Simatupang, Wright et al. 2002; Tan, Lyman et al. 2002). The streamlining of operations all along the supply chain leads to process efficiencies that translate into cost savings, better products, and improved customer service (Fadel and Narayanan 1997). Therefore, an effective management of a supply chain must consider the overall supply chain goals and the metrics to be used. These should represent a balanced approach and should be classified on a strategic, tactical and operational level, and include both financial and non-financial measures as well (Gunasekaran, Patel et al. 2001). Stewart (Stewart 1995) illustrates an integrated supply chain utilising four interrelated activities of a firm: 1) plan 2) source 3) make/assemble and 4) delivery to customer, see figure 1. To *plan* means converting sales history, marketing and product management inputs into end-item forecasts. The main objective with *sourcing* is to convert forecast changes into build plans and raw material requirements to be placed on external suppliers. To *make* or assemble, is to convert raw materials and sub-assemblies into shippable end items. *Delivery* is a link that directly deals with customers, the delivery of gods and services (Stewart 1995).

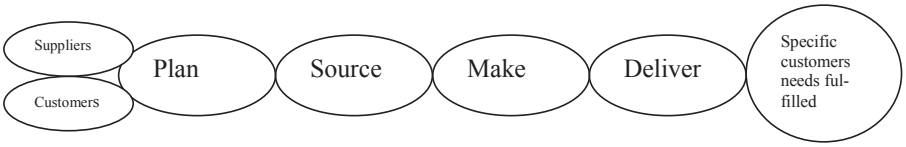


Figure 1. The integrated supply chain. Freely after Stewart, 1995

Several studies have tried to outline how to measure the efficiency of the integrated supply chain (Gunasekaran, Patel et al. 2001; Hoek van 2001; Landeghem van and Persoons 2001; Otto and Kotzab 2001). To find metrics that indicate the status of the overall supply chain performance is a key issue for management to control, manage and improve the performance of the supply chain. Petroni and Panciroli (Petroni and Panciroli 2002) argue that customers usually retain suppliers that produce the highest aggregate score on: price, quality, flexibility of production and delivery times. Some researchers claim that an efficient supply chain of high quality depend on the achievement of high-level performances in terms of cost, quality and time-to-market (De Toni and Nassimbeni, 1995; Dyer 1996).

METHODOLOGICAL APPROACH AND RESEARCH QUESTIONS

The research questions we put forward in this paper are:
What does the research literature say about different types of supply chains performance? What does research tell us about the impact of different types of SCM on the performance of supply chains? Meta-analysis is a methodological approach that could be used to answer this type of questions (see Lipsey, M. & Wilson, D. (2001) and Paterson et. al. (2001)). Meta-analysis is a technique for analyzing research findings as they are typically presented in research reports. A meta-analysis summarizes research findings in a structured way. It provides an organized way of handling information from a large number of published studies. There are two ways of conducting a meta-analysis, a quantitative approach or a qualitative approach (meta study). In a quantitative meta-analysis the key is to define an effect size statistic, i.e. index used to repre-

sent study findings, capable of representing the quantitative findings of a set of research studies in a standardised form that permits meaningful numerical comparison and analysis across the study (Lipsey and Wilson 2001). The quantitative meta-analysis is mostly used in medicine and natural science where the same research question could be statistically analysed. In a qualitative meta-study the primary goal is to develop midrange theory concentrating a substantive body of qualitative research (Paterson, Thorne et al. 2001). Paterson et al (2001) argues that qualitative meta study is an interpretive constructivist approach and that research may go beyond presented conclusions and synthesis presented in the reports. The qualitative meta study is primary used in health and social sciences.

There are differences between conducting a literature review and a meta-analysis. First, in a meta-analysis or meta study a specific research question has to be presented while a literature review is more like a effective evaluation of research or other studies from a particular standpoint to fulfil certain aims or express certain views on the nature of the topic investigated (Hart 1998). Secondly, there is a need for theoretical framework in contrast to literature where a review of earlier research and theories is more common. Finally, a meta-analysis (Lipsey and Wilson 2001) is only applicable on empirical studies with empiric data, meanwhile a literature review is applicable to almost all types of studies which presents conclusions. A meta study (Paterson, Thorne et al. 2001) requires a specific theory base and explicit research questions forming a coding form which give a deeper synthesis and understanding of a phenomenon. Doing a literature review is simply a review of earlier research and theories.

We have the aim to try to calculate an effect size statistic i.e. arithmetic means of the presented performance measures found. If the research designs and statistical form presented in the gathered articles are not configured similar, we use a more qualitative meta-study approach.

The paper is disposed in the following way, to answer the research questions. The next section presents a classification of supply chain performance measures, related to the activities and links presented in Figure 1. The following sections describe the selection process of journal articles included in the analysis. The results of the analysis are used to answer the main question of the paper, and in a concluding section, the paper discuss' some managerial implications of the results.

SUPPLY CHAIN PERFORMANCE MEASURES

The performance measures considered in this paper are delivery, quality, cost, price, and flexibility, these measures are often referred to by purchasing managers when selecting suppliers, and often used as performance measures in research in the area of supply chain management. (Krause and Pagell 2002) Krause and Pagell argue that one of the most commonly accepted methods of addressing operations strategy has been through the use of four generic competitive priorities; quality, cost, flexibility and delivery. (Hayes and Wheelwright 1984) Hayes and Wheelwrights were the first to present these priorities as the dimensions on which a company chooses to compete within a target market. Their original formulation was applicable for all functions. Krause and

Pagell argue that even though these measures may have their basis in operations it is possible to extend the generic concepts to other functions or a supply chain.

We relate the measures to the total integrated supply chain, but also to the separate activities, or functions, within the chain, as depicted in Figure 2. We define four types of performance measurement situations and give some example of measures from Krause and Pagell (2002).

1) *Functional measures* depict performance of a separate activity/function of the chain, e.g. flexibility (mix) of production – the ability to produce effectively a wide variety of different products.
2) *Internal integrated measures* depict performance across functional boundaries within the firm, e.g. quality (conformance) – the ability to manufacture a product whose operating characteristics meet established performance standards; Cost (total cost) the ability to minimize the total cost of production (labour, materials, and operating costs) – through efficient operations, process technology, and or scale economies; Delivery (speed) – the ability to minimise the time between the receipt of a customer order and final delivery.
3) *One sided integrated measures* depict performance across organisational boundaries and measure chain performance across supplier or customer boundaries, e.g. delivery (speed) – the ability to respond in a timely manner to the needs of your companies customer.
4) *Total chain measures* depict performance across organisational boundaries and measure the performance of the complete supply chain, including links to suppliers and customers, e.g. total chain costs – the ability to minimise the total cost from supplier to the end customer.

Type 1 – Functional measures

Often the first step in assessing performance is to analyse the way the order-related activities are carried out. To do this the most important issues – such as the order-entry method, order lead-time and path of order traverse – need to be considered (Gunasekaran, Patel et al. 2001). Other measures could be non-conformities, time to perform different activities within the function i.e. sub-processes. The production process in manufacturing organisations is often an activity that has a major impact on production cost, quality, speed of delivery. Therefore, the production process needs to be measured, managed and improved and suitable metrics for it should be established. These metrics could fit under three headings (Gunasekaran, Patel et al. 2001): Range of product and services, capacity utilization and effectiveness of scheduling techniques.

Type 2 – Internal integrated measures

These measures show the performance of several connected functions i.e. head-process. Metrics as cost (total cost), quality, non-conformities, delivery lead-time are appropriate to measure.

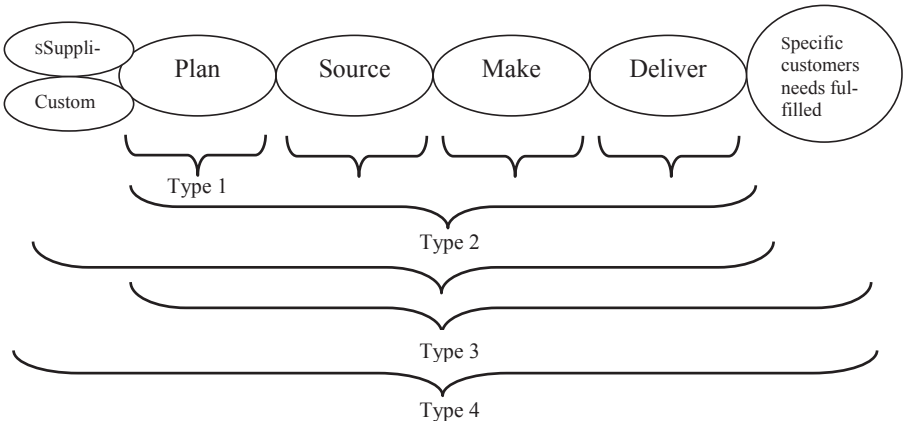


Figure 2. Four different types of measures of supply chain performance

Type 3 – One sided integrated measures: A study of US food industry reports that poor co-ordination among supply chain partners is wasting $30 billion (estimated) annually (Fisher 1997). This indicates the importance of establishing partnerships in a supply chain. The extent of partnership that exists between the buyer and supplier needs to be evaluated and improved. There are a set of criteria/parameters that needs to be considered in evaluating partnership (Gunasekaran, Patel et al. 2001). For example, the level of assistance in mutual problem solving supports the buyer-supplier partnership development. Several researchers has suggested partnership evaluation criteria in a supply chain: Level and degree of information sharing, the entity and stage at which supplier is involved (Toni, Nassimbeni et al. 1994), buyer-vendor cost saving initiatives (Thomas and Graham 1996), extent of mutual co-operation leading to improved quality (Graham, Dougherty et al. 1994), extent of mutual assistance in problem solving efforts (Maloni and Benton 1997). Other measures to consider are delivery performance, product price and flexibility of scheduling and production.

Type 4 – Total chain measures: Some researchers (Rushton and Oaxly 1991; Thomas and Graham 1996) claims that the largest cost component of logistics is transportation costs in the total chain . They claim that the trucking cost is always the highest among costs of total distribution cost. It seems therefore important to treat delivery and cost as a metric of high priority. Stewart (1995) identifies the following as the measures of delivery performance: delivery-to-request date, delivery-to-commit date, and order fill lead-time.

THE META-ANALYSIS METHOD OF SUPPLY CHAIN PERFORMANCE

The meta-analysis is based on recently published scientific journal articles presenting empirical research result on the different types of supply chains performance. Our primary focus is on five types of performance measures: delivery, quality, cost, price and flexibility. The selection of articles has been done in three steps.

Selection of articles
The first step consists of two phases. In the first phase we searched for reports and articles in different literature databases i.e. Ingenta database (SAGE publications), Emerald and AOM (Academy of Management) using a specified list of keywords as search criteria (i.e. supply chain, value chain, logistics alliances, supplier and subcontractor). The total number of articles in these three databases exceeded 14 millions. Of these met 6 452 articles (including duplicates) our search criteria. In the second phase of the selection process we searched for articles that, in addition to the above mentioned search criteria also included references to *performance or metrics or measures and empirical*. In the end, the first step provided us with 154 articles, see Table 1.

Table 1 - Results of the first step, phase1and (phase 2)

	Keywords used as search criteria					
Type of database	**Supply Chain**	**Value Chain**	**Logistics alliances**	**Supplier**	**Sub-contractor**	**Total number**
INGENTA: in title, keyword or abstract	1 293 (43)	2 302 (24)	25 (0)	1 484 (51)	51 (1)	5 155 (119)
EMERALD: in title, keyword or abstract	645 (19)	149 (1)	6 (0)	444 (13)	8 (0)	1 248 (33)
AOM: in keyword search	6 (0)	5 (0)	0 (0)	38 (2)	0 (0)	49 (2)
Total number	1 944 (62)	2 456 (25)	27 (0)	1 966 (66)	59 (1)	6 452 (154)

The second step also consists of two phases. In the first phase we removed all duplicates. This left us with 90 articles. In the second phase we scrutinized the abstracts to select those that meet the following three criteria. The abstract must indicate that the article: 1) deals with Supply Chain(s) or SCM, 2) contains empirical material i.e. survey or case studies, and 3) presents performance results i.e. metrics or measures. This step provided 49 articles.

In the third step we analysed the full article to make certain that they meet the selection criteria and especially that they presented performance results about the five areas that we were interested in: delivery, quality, price, cost or flexibility. This third step provided us with 25 articles (listed in Appendix 1), to be further analyzed.

ANALYSIS AND RESULTS

The selected articles were analysed and classified according to a set of quality criteria: 1) related to the presentation of theory i.e. how good they relate the article to theory , 2) utilized sampling technique i.e. appropriate methodology used, 3) operational performance i.e. how the work was conducted, and 4) analysis and results i.e. if the analy-

sis supports the results This criteria where classified into three levels: articles of high quality, medium quality and low quality. All papers were found to have high or medium quality.

The articles were then classified according to the four types of performance measures (see Figure 1) and if the article discussed measures related to delivery, quality, price, cost and flexibility see Table 2. In appendix 1 we present the measures discussed in each article.

Table 2 – Journal articles classified according to performance measures. (The numbers relate to the list of articles in Appendix 1.)

	Performance measures considered in articles					
Measures	**Delivery**	**Quality**	**Cost**	**Price**	**Flexibility**	∑
Type 1	-	-	-	-	-	0
Type 2	07, 22	04, 07, 22, 24	04, 07, 22, 24	22	07, 22	4
Type 3	01, 02, 03, 04, 05, 06, 10, 12, 15, 18, 19, 21, 25	03, 06, 11, 12, 14, 15, 17, 19, 20, 21, 23	01, 02 12, 14, 21	03, 06	03, 18	17
Type 4	08, 13, 16	08, 09, 13	08, 09	13	-	4
∑	18	17	10	4	4	25

Type 1- Functional measures

No article presents only functional measures on delivery, quality, cost, price and flexibility. This is not surprising, as the probability is high that the selection process should exclude such articles.

Type 2 – Internal integrated measures

Three articles discuss this type of measures. Delivery, flexibility, quality and cost are pointed out as important purchasing competitive priorities (no 07) and there are positive relationships between manufacturing planning control (MPC) and organisational performance including product quality and manufacturing cost (no 04). None of the articles discussed price as a measure. One article (no 22) indicates that higher levels of consensus within the manufacturing function and between manufacturing and general managers are associated with higher levels of performance i.e. delivery, quality, cost, price and flexibility. One article (no 24) indicates that operational quality approaches and supply base management practices, which were positively correlated to firm performance i.e. quality (product), cost (production), should be implemented concurrently to gain significant competitive advantage.

Type 3 – One sided integrated measures

Seventeen of the articles discuss measures related to the front or back links of the supply chain, often related to delivery or quality issues.

Delivery: Two of the articles stress the importance of IT and claims that IT has a positive impact on delivery performance i.e. delivery overall (no 02) and delivery speed (no 10). Three of the articles points out delivery performance as a relevant measure to consider i.e. delivery performance has a positive impact on supply chain performance

in transportation logistics (no 01) and together with price, quality and flexibility possess distinctive innovative characteristics (no 03). One article points out that the buyer's firm often assist the supplier's plant in carrying out necessary changes to improve JIT supply, i.e. well-timed deliveries (among other measures) (no 15) another article (no 21) points out that the choice of certified (ISO 9000) suppliers seems positively to affect punctuality and delivery speed. Two of the articles point out the strategic issue. Firms that buy from an international supplier only because the material or component is unavailable domestically are more sensitive for delivery that firms that employ a more strategic view of international sourcing (no 18). Strategic firms have a formal supplier assessment system to measure delivery performance in a wider extent than reactive firms (no 12). Four articles points out that delivery performance could be improved. Manufacturing planning control (MPC) (no 04) has a positive relation to organisational performance including goods delivery and supply chain interactions for purposes of managing flows and ensuring quality and may have: 1) a direct impact on time-related performances e.g. punctuality of delivery and operations speed, 2) a mediated impact on time-related performance (no 05). Involving customer in the supply chain by way of participation on product design teams and in continuous improvement programs enriches the firm's delivery service and overall performance (no 06). The biggest inroads to be made into delivery speed are firstly on the design/manufacturing interface, secondly on the subsequent "translation" of these designs to supplier requirements and lastly on the actual production floor in terms of process layout (no 25). One article indicated that there were no statistically significant correlations between end product quality and supplier's activities completed on time and end product quality and overall project delay (no 19).

Quality: Four articles point out that quality characteristics have impact on performance and selecting suppliers. Quality performance is shown to be a relevant performance measure that together with price, delivery and flexibility possess distinctive innovative characteristics (no 03). Product quality, delivery reliability and product performance has a major impact when selecting suppliers (no 06). The management philosophy Total Quality Management (TQM) has a positive impact on supply chain performance (no 11). Conformance quality, product cost, external quality-in-use and time to market support the "enabling" role of design quality. The results also indicate that quality performance alone does not explain business performance (no 14). Two articles point out the strategic issue. Strategic firms have a formal supplier assessment system to measure quality performance (among other performance metrics) in a wider extent than reactive firms (no 12) and the greater use of advanced supplier selection and monitoring practices tends to increase profitability, product quality, and supplier performance in firms following supplier partnership strategies, but has little effect on the performance in firms utilising arm-lengths transaction (no 17). Two articles point out the role of suppliers in the supply chain. The buyer's firm often assist the supplier's plant in carrying out necessary changes to improve JIT supply, adopting quality control methods, among other measures, (no 15). Between one fourth and one third of the survey participants made little or no use of supplier quality management e.g. suppliers did little to develop their own supply bases (no 20). One article (no 19) indicates that there were no statistically significant correlations between end product quality and supplier's activities completed on time and end product quality and overall project delay. One arti-

cle (no 21) points out that the presence of an initial certified supplier portfolio is generally not associated with quality performance. One article (no 23) points out that efficient implementation of quality management further up the supply chain explains variation in supplier quality performance which underlies the importance of managing quality throughout the value chain.

Cost: The six articles that described cost as a measure had all different focus. One article claims that cost as a measure for operations efficiency has a positive impact on supply chain performance in transportation logistics (no 01). While another points out that using web-based integration over the supply chain has an positive impact on reducing transaction costs (no 02). Two articles point out the strategic issue. Strategic firms have a formal supplier assessment system to measure cost performance in a wider extent than reactive firms (no 03) and firms that buys from an international supplier only because the material or component is unavailable domestically are more sensitive for costs that firms that employ a more strategic view of international sourcing (no 18). One article indicated that design quality had a significant inverse effect on product cost (no 14). One article (no 21) points out that the presence of an initial certified supplier portfolio is generally not associated with lower quality costs.

Price: Two articles discuss this type of measures. One article claims that price is a relevant performance measure that together with delivery performance, quality and flexibility possess distinctive innovative characteristics (no 03). While one article (no 6) indicates that there is no evidence that selecting suppliers based on unit price has positive impact on customer satisfaction or firm performance.

Flexibility: Three articles discuss flexibility as an important measure. One article points out that flexibility is a relevant performance measure that together with delivery performance, price, quality and possess distinctive innovative characteristics (03). The other indicates that firms that buy from an international supplier only because the material or component is unavailable domestically are more demand scheduling flexibility to a more extent that firms that employ a more strategic view of international sourcing (18). One article (no 21) points out that the choice of certified (ISO 9000) suppliers seems positively to affect volume flexibility.

Type 4 – Total chain measures
Four of the articles discuss measures related to the front or back links of the supply chain, also in this case, most related to delivery or quality issues.

Delivery: Two of the articles point out the importance of total integration. One article (no 08) indicate that the outward-facing group had the highest level of performance improvements such as on-time delivery, in compare to inward-facing, periphery-facing, supplier-facing, and customer-facing organisations. The other (no 16) points out that if managers are concerned with increasing delivery speed, they can achieve this most effectively by using CAD/CAE, continuous improvement , JIT manufacturing, JIT purchasing, set-up reduction. One article (no 13) demonstrates the differences in requirements between chains (car-manufacturer, area distributor and local distribu-

tor) in different territories. Delivery time is shown to be more important at the area distributor and very important at the local distributor.

Quality: One article (no 08) indicates that the outward-facing group had the highest level of performance improvements such as conformance quality and suppliers quality, in compare to inward-facing, periphery-facing, supplier-facing, and customer-facing organisations. One article (no 9) indicates the importance of quality metrics over the supply chain and another (no 13) demonstrates the differences in requirements between chains (car-manufacturer, area distributor and local distributor) in different territories. The quality aspect is shown to be more important for the car-manufacturer.

Cost: Two articles discuss this type of measures. One article (no 08) indicates that outward-facing organisations make better improvements when it comes to reducing costs as: average unit manufacturing cost and materials and overhead total cost, than inward-facing, periphery-facing, supplier-facing, and customer-facing organisations. The other article (no 9) indicates the importance of cost over the supply chain.

Price: One article (no 13) demonstrates that the differences in requirements between chains (car-manufacturer, area distributor and local distributor) in different territories. The price aspect is shown to be more important for the area distributor.

Flexibility: No measures were found.

CONCLUSIONS

The analysis of the articles clearly shows that the most presented performance measures can be viewed as *one sided integrated measures* i.e. measures that depicts performance across organisational boundaries and measure chain performance across supplier or customer boundaries, see figure 2. As much as seventeen of the articles discuss measures related to the front or back links of the supply chain, often related to delivery or quality performance measures. It seems that these two measures are the most important performance measure.

The least concerned measure (four articles) is type 4, *total chain measures* i.e. measures that depicts performance across organisational boundaries and measure the performance of the complete supply chain, including links to suppliers and customers. Surprisingly, the most presented measures here were delivery and quality. One might have expected cost (total cost) as to be presented in the articles.

Only three articles presents measures that could be classified as type 2, *internal integrated measures* i.e. measures that depict performance across functional boundaries within the firm. All performance measures are mentioned but quality and cost are most presented.

The result indicates, in a quantitative meta-analysis perspective, that it was hard to compute an effect size value to analyse statistical results based on the analysed articles. One reason is that most of the articles use different research design and appearing in different statistical forms, see appendix 1. Although, it is important to increase the

knowledge about the total supply chain i.e. total chain measures if supply chain performance research will have a managerial impact.

References

Christopher, M. (1998). Logistics and Supply Chain Management: Strategies for Reducing Cost and Improvning Service. Harlow, Financial Times - Prentice Hall.

Fadel, H. and S. Narayanan (1997). Telecommunications service and expense management in US businesses - An analysis of the Telecom Supply Chain and the Impact of Internet Tools, Massachusetts Institute of Technology

Fisher, M. L. (1997). "What is the Right Supply Chain for your Product?" Harvard Business Review: 105-116.

Graham, T. S., P. J. Dougherty, et al. (1994). "The long term strategic impact of purchasing partnership's." International Journal of Purchasing and Materials Management **30**(4): pp. 13-18.

Gunasekaran, A., C. Patel, et al. (2001). "Performance measures and metrics in a supply chain environment." International Jorunal of Operations & Production Management **21**(1/2): p 71-78.

Handfield, R. B. and E. L. Nichols (1999). Introduction to Supply Chian Management. New Jersey, Prentice Hall.

Hart, C. (1998). Doing a literature review, Sage Publications Ltd.

Hayes, R. H. and S. C. Wheelwright (1984). Restoring our Competitive Advantage. New York:, Wiley.

Hoek van, R. I. (2001). "The contribution of performance measurement to the expansion of third party logistics alliances in the supply chain." International Jorunal of Operations & Production Management **21**(1/2): 15-29.

Krause, D. R. and M. Pagell (2002). "Strategic consensus in the internal supply chain:exploring the manufacturing purchasing link." International Journal of Production Research **4**: pp. 3075-3092.

Landeghem van, R. and K. Persoons (2001). "Benchmarking of logistical operations based on a casual model." International Jorunal of Operations & Production Management **21**(1/2): pp. 254-266.

Lipsey, M. W. and D. B. Wilson (2001). Practical Meta-Analysis. Thousand Oaks, Sage Publications, Inc.

Maloni, M. J. and W. C. Benton (1997). "Supply chain partnerships: opportunities for operations research." European Journal of Operational Research **101**(10): pp. 1020-1033.

Mason-Jones, R. and R. D. Towill (1998). "Time compression in the supply chain: information management is the vital ingredient." Logistics Information Management **11**(2): pp. 93-104.

Morgan, C. (2001). The role of government in supply chain development: multimedia case studies. Supply chain knowledge 2001, Cranfield School of Management, UK

Otto, A. and H. Kotzab (2001). Does Supply Chain Management really pay? - Six perspectives to measure the performance of managing a supply chain. Nurnberg, Lehrstuhl fur Logistik, Friedrich-Alexander-Universiteät**:** p. 17

Paterson, B. L., S. E. Thorne, et al. (2001). Meta-study of Qualitatie Health Research. Thousand Oaks, Sage Publications Ltd.

Petroni, A. and B. Panciroli (2002). "Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry." European Journal of Purchasing & Supply Management **8**: pp. 135-149.

Rushton, A. and J. Oaxly (1991). Handbook of Logistics and Distribution Management. London, Kogan Page.

Simatupang, M. T., C. A. Wright, et al. (2002). "The knowledge of coordination for supply chain integration." Business Process Management Journal **8**(3): pp. 289-308.

Stewart, G. (1995). "Supply chain performance benchmarking study reveals keys to supply chain excellence." Logistics Information Management **8**(2): pp. 38-44.

Tan, C. K., B. S. Lyman, et al. (2002). "Supply chain management: a strategic perspective." International Jorunal of Operations & Production Management **22**(6): pp. 614-631.

Thomas, D. J. and T. S. Graham (1996). "Co-ordinated supply chain management." European Journal of Operational Research **94**(3): pp. 1-15.

Toni, A. D., G. Nassimbeni, et al. (1994). "Service Dimensions in the Buyer-Supplier Relationship: A Case Study." International Journal of Physical Distribution & Logistics Management **24**(8): pp. 4-14.

Appendix 1. The analysed articles

No	References	Type 1-4	Theoretical orientation	Methodological Orientation	Measure considered
01	Lai, K., E. W. T. Ngai, et al. (2001). "Measures for evaluating supply chain performance in transport logistics." Transportation Research **38**: pp. 439-456.	3	Measures supply chain performance	Survey, n=134	On-time delivery, SES-REL (reliability) mean 4,12 (5 item) . Cost, OE-COST, mean 3,65 (5items) Scale 1-5
02	Frolich, M. T. and R. Westbrook (2002). "Demand chain management in manufacturing and services: web-based integration, drivers and performance." Journal of Operations Management **20**: pp. 729-745.	3	Benefits of web-based integration	Survey, n=890	Faster delivery time, Reduced transaction cost: no comparable measures found
03	Petroni, A. and B. Panciroli (2002). "Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry." European Journal of Purchasing & Supply Management **8**: pp. 135-149.	3	Measures supplier performance	Survey, n=198	Delivery, Quality, Price, Flexibility: no comparable measures found
04	Chan, J. W. K. and N. D. Burns (2002). "Benchmarking manufacturing planning and control (MPC) systems." Benchmarking: An International Journal **9**(3): pp. 256-277.	2	Measures organisational performance	Survey, n=116	Cost, Product quality, Goods delivery: no comparable measures found
05	Salvador, F. and C. Forza (2001). "Supply chain interactions and time-related performances." International Journal of Operations & Production Management **21**(4): pp. 461-475.	3	Time related performances	Survey, n=164	Punctuality of delivery: no comparable measures found
06	Tracey, M. and C. L. Tan (2001). "Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance." Supply Chain Management: An International Journal **6**(4): pp. 174-188.	3	Supplier selection	Survey, n=180	Delivery service, mean : 3,95 . Selecting supplier quality, mean 4,04. Product quality, mean 4,53. Selecting supplier unit price, mean 4,02. Scale 1-5
07	Krause, D., R, M. Pagell, et al. (2001). "Toward a measure of competitive priorities for purchasing." Journal of Operations Management **19**: pp. 497-512.	2	Measures of the operations management system	Survey, n=252	Delivery, Quality, Cost, Flexibility: no comparable measures found.
08	Frolich, M. T. and R. Westbrook (2001). "Arcs of integration: an international study of supply chain strategies." Journal of Operations Management **19**: pp. 185-200.	4	Measures of Supply chain integration	Survey, n=322	Delivery lead-time, delivery frequencies, mean supplier 3,52. Quality, Cost: no comparable measures found
09	Holmberg, S. (2000). "A systems perspective on supply chain measurements." International Journal of Physical Distribution & Logistics Management **30**(10): pp. 847-868.	4	Supply chain measures	Case study, n=6	Quality, Cost: no comparable measures found
10	Jayaram, J., S. K. Vickery, et al. (2000). "The effects of information system infrastructure and process improvements on supply chain time performance." International Journal of Physical Distribution & Logistics Management **30**(3/4): pp. 314-330.	3	Supply chain time performance	Survey, n=57	Delivery speed, mean 5,14. Scale 1-7
11	Tan, K. C., V. R. Kannan, et al. (1999). "Supply chain management: an empirical study of its impact on performance." International Journal of Operations & Production Management **19**(10): pp. 1034-1052.	3	Supply Chain Management and its impact on performance	Survey, n=313	Overall product quality, Average production cost: no comparable measures found
12	Krause, D., R, R. B. Handfield, et al. (1998). "An empirical investigation of supplier development: reactive and strategic processes." Journal of Operations Management **17**: pp. 39-58.	3	Agreement on performance improvement metrics	Survey, n=84	Delivery, Quality, Cost: no comparable measures found
13	Harland, C. (1997). "Supply chain operational performance roles." Integrated Manufacturing Systems **8**(2): pp. 70-78.	4	Supply chain operational performance	Case study, n=4	Delivery, Quality, Price: no comparable measures found
14	Fynes, B. and C. Voss (2002). "The moderating effect of buyer-supplier practices and performance." International Journal of Operations & Production Management **22**(6): pp. 589-613.	3	Quality practices and performance	Survey, n=200	Conformance quality, mean 2,34. Design quality, mean 2,17. External quality in house, mean 1,96. Product cost, mean 3,65. Scale 1-5
15	De Toni, A. and G. Nassimbeni (2000). "Just-in-time purchasing: an empirical study of operational practices, supplier development and performance." The International Journal of Management Science **28**: pp 631-651.	3	Supplier development and performance	Survey, n=52	Delivery synchronisation, mean 2,92. Quality information exchange, mean 3,66. Scale 1-5

16	Jayaram, J., Vickery, S.K. and Droge, C. (1999) International Journal of Operations & Production Management, 19, pp. 1010-1033	4	Time-based Performance	Survey, n=57	Delivery speed (importance), mean 5,105. Delivery speed (performance), mean 5,140. Scale 1-7
17	Ittner, C. D., Larcker, D.F., Nagar, V and Rajan, M.V (1999) Journal of Accounting and Public Policy, 18, pp. 253-281	3	Supplier selection	Survey, n=249	Importance of on-time delivery in selection, mean (low use) 2,60. Mean (high use) 3,46. Importance of quality in selection, mean (low use) 2,90. Mean (high use) 3,65. Scale 1-5
18	Bozarth, C., R. Handfield, et al. (1998). "Stages of global sourcing strategy evolution: an exploratory study." Journal of Operations Management **16**: pp. 241-255.	3	Factors motivating the buy decision	Survey, n=97	Delivery, mean (phase 2 group) 3,48. Mean (phase 3-4 group) 2,29. Lower cost, mean (phase 2 group) 2,70. Mean (phase 3-4 group) 1,64. Scheduling flexibility, mean (phase 2 group) 3,89. Mean (phase 3-4 group) 2,68.Scale 1-5
19	Hartely, J. L., B. J. Zirger, et al. (1997). "Managing the buyer-supplier interface for on-time performance in product development." Journal of Operations Management **15**: pp. 57-70.	3	On-time performance	Survey, n=79	On time delivery, mean 83%. End product quality, mean 4,53. Scale 1-7
20	Forker, L. B. (1997). "Factors affecting supplier quality performance." Journal of Operations Management **15**: pp. 243-269.	3	Supplier quality performance	Survey, n=348	Supplier quality management, mean 3,24. Scale 1-5
21	Romano, P. (2002). "Impact of supply chain sensitivity to quality certification on quality management practices and performances." Total Quality Management **13**(7): pp. 981-1000.	3	Supply chain and quality management	Survey, n=100	Quality, On time delivery, cost, volume flexibility: no comparable measure found.
22	Krause, D. R. and M. Pagell (2002). "Strategic consensus in the internal supply chain: exploring the manufacturing purchasing link." International Journal of Production Research **4**: pp. 3075-3092.	2	Internal supply chain and purchasing	Survey, n=180	Quality, Delivery, Price, Cost, Flexibility: no comparable measures found.
23	Forker, L. B., D. Mendez, et al. (1997). "Total quality management in the supply chain: what is its impact on performance." International Journal of Production Research **35**(6): pp. 1681-1702.	3	TQM in the supply chain	Survey, n=292	Quality: no comparable measures found.
24	Tan, K. C., R. B. Handfield, et al. (1998). "Enhancing the firm's performance through quality and supply base management: an empirical study." International Journal of Production Research **36**(10): pp. 2813-2837	2	Firm performance through quality and supply base management	Survey, n=313	Quality (product), mean 5,59. On time delivery, mean 70,6%.Cost (production), mean 4,45. Scale 1-7: no comparable measures found.
25	Handfield, R. B. and R. T. Pannesi (1992). "An empirical study of delivery speed and reliability." International Journal of Operations & Production Management **12**(2): PP. 58-72.	3	Delivery speed and reliability	Survey, n= 285	Delivery speed and reliability: no comparable measures found.

Paper 2

Rundquist, J. and Chibba, A. (2004). The use of processes and methods in NPD – A survey of Swedish industry. *International Journal of Innovation and Technology Management*, 1(1): 37-54.

International Journal of Innovation and Technology Management
Vol. 1, No. 1 (2004) 37–54

World Scientific
www.worldscientific.com

THE USE OF PROCESSES AND METHODS IN NPD — A SURVEY OF SWEDISH INDUSTRY

JONAS RUNDQUIST* and ARON CHIBBA†

School of Business and Engineering, University of Halmstad
PO Box 823, S-30118, Halmstad, Sweden
http://www.hh.se
**jonas.rundquist@set.hh.se*
†*aron.chibba@set.hh.se*

Received 16 October 2003
Revised 11 January 2004
Accepted 19 January 2004

Research often suggests that formal New Product Development (NPD) processes increase the success rate of NPD projects in a firm. However, recent studies indicate a relatively low usage of formal NPD-processes. Very few studies of NPD practices have been carried out in contexts other than that of the US, thus it is of interest to explore whether or not important differences exist. The present study aims to identify the use of and practices within formal NPD-processes in Swedish manufacturing firms and to compare the results with a study conducted in a US context. The results indicate that differences exist in for example reward systems for NPD teams.

Keywords: NPD-process; survey study; best practice.

1. Introduction

In recent decades, numerous researchers and practitioners have tried to identify best practices in order to create different models for describing the New Product Development (NPD) process [Booz *et al.* (1968); (1982); Andreasen and Klein (1987); Cooper (1994); Yasdani and Holmes (1999)]. These models typically describe a process from an idea and/or a need to product launch and include activities such as Idea/Concept Generation, Idea screening, Business Analyzing, Development, Test and Validation, and Commercialization.

Formally, documented NPD-processes in firms have become more frequent since the nineties as a method to control costs, time and quality of the NPD-process. Nevertheless, although many studies [Pittiglio *et al.* (1995); Tatikonda and Rosenthal (2000)] indicate that the use of a formal NPD-process offers higher success rates in product development, as many as 38.5% of US firms did not use a formal NPD-process in 1995 [Griffin (1997)]. During the nineties, various conceptual articles have indicated that the effectiveness of the NPD-process [Cooper (1994); Yasdani and Holmes (1999)], outsourcing of the NPD-process [Quinn (1999); McDermott and Handfield (2000)], and strategies for continuous improvement of the NPD-process

[Tidd *et al.* (1997); Martensen and Dahlgaard (1999)] could be important future NPD research issues.

Abbie Griffin [1997] presented the results of a survey conducted by PDMA (Product Development Management Association) in US firms on product development best practices fielded in 1995. The objective of that study was to determine the current status of product development practice and to compare the results with a similar survey conducted in 1989 [Page (1993)].

As the PDMA study was performed in US firms, it would be interesting to conduct a study based on the same survey in a different context, for example Swedish firms. Cultural differences have been highlighted by scientific studies. Hofstede [1984] revealed, for example, that US firms depend more on monetary rewards than is apparently the case with Japanese firms. The purpose of the Swedish study was to compare results between a US and a Swedish context. The survey used in the Swedish study was also brought up to date by the inclusion of some new issues that have emerged since the early nineties. One such issue is outsourcing of product development and another is the introduction of NPD on the strategic management level of the firm.

This paper presents the results of the survey study conducted in medium-sized Swedish firms during autumn 2001. The goal of the present study was two-fold, namely to:

- determine the current status of NPD practice in Swedish firms (for example use of formal NPD-processes, type of process, and use of reward systems for NPD teams)
- compare the results with those of the 1995 PDMA study [Griffin (1997)].

The firms in the sample were categorized in two clusters as "the best" and "the rest", where the best firms were those with a high emphasis on NPD. This categorization was made with two variables; (A) sales from products developed within the firm as a percentage of turnover and (B) sales of products commercialized in the last five years as a percentage of turnover. "The best" are those firms who indicated that they were above 50% on both variables. A total of 33% of the sample met the criteria for both variables.

In a second categorization, the firms were asked to rate eight competitive factors for winning new customers. Respondents were asked to rate each competitive factor on a five-step Likert scale from not important (1) to very important (5). Both categorizations were used to compare properties of the populations. The two types of categorizations will be further discussed.

The goals of the study presented in this article are largely the same as those of the PDMA-study. However, to define a framework for complementary topics, a review of previous research in the areas was made. In the following section, the theoretical base of the present study will be presented.

2. Frame of Reference

The study is related to four areas of research. These are: (formal) NPD-processes, NPD Strategies, Outsourcing of NPD activities, and the Organizing of NPD. In the following section key issues and concepts will be described and defined.

2.1. *Formal NPD-processes*

A New Product Development (NPD) Process can be defined as the process from a new product idea (generated by marketing and/or R&D) to the promotion and sale of the product [McDermott and Handfield (2000)]. This process involves activities such as concept generation, user tests, construction, design and development for manufacturability. A formal NPD-process can be defined as "*a formal blueprint, roadmap, template or thought process for driving a new product project from the idea stage to market launch and beyond*" [Cooper (1994)]. This approach implies that, in order to qualify as formal, the NPD-process must be documented in some recognized form and be implemented to knowledge of the relevant parties, such as management, NPD-department and other departments actively involved in new product development. However, as the following discussion will show, the formal NPD-process is not necessarily rigid and inflexible. It could rather be argued that the trend among theorists has moved from *ad-hoc* to a formal and rigid process and than turned back to a formal but flexible process.

Cooper [1994] describes three types ("generations") of NPD-processes. The first generation, developed by NASA, is a purely technological process aiming at minimizing technical risks through an expanded system of checklists and stage-gates. A stage-gate is defined as a decision point at which specific criteria must be fulfilled before the go-ahead can be given for the next stage of the NPD-process [Booz *et al.* (1968)]. In the present study these models will be categorized as functional and sequential. No business aspects were considered in these early models, and the process ends with delivery of the project to a marketing department.

The first empirically based attempt to describe a practice for product development management [Booz *et al.* (1968)] delineated a six-stage process for product development activities. The study was based on data from 50 firms in various industries. The process, even though slightly modified for different industries and types of products, can be described as a typical model used by a majority of firms. This model forms the sequence of phases used by PDMA in their 1989 [Page (1993)] and 1995 [Griffin (1997)] surveys. The basic process described by Booz, Allen and Hamilton [1968] consists of six stages with the following stage-gates:

- Exploration
- Screening
- Business analysis
- Development
- Testing
- Commercialization

The second-generation process expands the process by non-technological steps and also includes a cross-functional approach to NPD. This means that functions, such as marketing and manufacturing, are integrated at all stages. The decision points or gates are also cross-functional, which is important in terms of gaining acceptance for decisions within the organization. Two results of a cross-functional stage-gate process are a stronger market orientation and the possibility of concurrent processing [Griffin (1997)]. The gates of the second-generation process are described

as formal and rigorous, which means that all sub-processes within a stage need to be completed before a go/stop decision can be made.

The third-generation process, suggested by Cooper [1994], introduces the possibility of overlapping the stages for greater speed and a less rigid stage-gate system, where each project is unique and has its own routing through the process. Cooper also introduces the term "*fuzzy gates*", which means that go-decisions can be conditional or situational. A project can for example be given a go ahead even when substantial information is missing, on the understanding that the missing information is gathered later before a fixed date. This means that decisions and timing of decisions are negotiable between the decision-maker and the team [Cooper (1994)].

This set of process models defined by Cooper [1994] is used in both the present study and the PDMA-survey, where the status for use of NPD-processes was determined for US firms [Griffin (1997)]. The respondents were asked whether they used no NPD-process, an informal NPD-process or a formal NPD-process based on the different types described by Cooper [1994]. The results from the PDMA-study [Griffin (1997)] indicated that, while nearly 60% of the firms did use a formal cross-functional stage-gate process in accordance with second or third generation NPD mentioned above, as many as 38.5% employed no formal NPD-process at all. Best practice firms had implemented formal NPD-processes to a higher extent than the other firms. It would be interesting to compare the US results to a Swedish context.

2.2. *NPD strategies*

A second study by Booz *et al.* [1982] was published in 1982. This study included interviews with 150 NPD executives and a survey of more than 700 US manufacturers in various industries. Based on their data and input from research on strategic techniques to guide NPD [Crawford (1980)], they recommended a seventh step to be added before the first step of the process, which they presented in 1968 [Booz *et al.* (1968)]. The seventh step was the formation of a new product strategy. Booz, Allen and Hamilton defined new product strategy as a strategy for deciding, which new products are to be developed. This approach is also the most frequently studied strategy in a product development context [Cooper *et al.* (1999); Kelley and Rice (2002)]. Cooper and Kleinschmidt [1995] point out that "*a clear and well-communicated new product strategy*" is the second most important performance driver that separates the top performers from the rest. They also conclude that the strategies of the leading firms focused on and showed synergy with existing market strategies as well as existing in-house technology.

New strategic issues connected to the NPD-process suggested in recent years include strategic outsourcing of innovation [Quinn (2000)] and product platform strategies [Meyer and Lehnerd (1997)]. Meyer and Lehnerd [1997] define a product platform as "the development of a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced". The issue of innovation outsourcing will be described in a subsequent section of this article.

According to Cooper and Kleinschmidt [1995], a high quality NPD-process is also dependent on continuous improvements to the process. The authors argue that too many firms just formalize the activities that are already being performed instead of focusing on learning from previous processes. Their study concludes that this issue is the most important difference between the leading firms and the rest and that, therefore, a strategy for continuously improving the NPD-process would be valuable [Cooper and Kleinschmidt (1995)].

In the 1995 PDMA-study [Griffin (1997)], the respondents were asked whether or not they had "*a specific strategy for their new product activities*" although the type of strategy was not stated. The result of the study was that 62.7% of those who answered the question gave a positive response. This is an increase on a previous PDMA-study [Page (1993)], where only 56.4% stated that they had a specific strategy for their new product activities. It would be interesting to compare these results with a Swedish context and to include a question as to the type of strategy employed.

2.3. *Outsourcing of NPD*

Outsourcing can be defined as the "purchase of an externally produced good or service that was previously internally produced" [Lacity and Hirscheim (1993)]. This implies that, to be defined as outsourcing, an activity must previously have been produced internally. The decision whether to purchase the goods or service externally or to produce them internally can be analyzed from a number of perspectives such as transaction cost and resource based perspective. A transaction cost perspective [Williamson (1985)] implies that if goods or a service can be more cheaply produced externally than internally when transaction costs are added to external costs, the goods or service should preferably be outsourced. Transaction costs refer to the extra costs involved in the outsourcing decision, such as negotiations, monitoring or legal disagreements. Williamson [1985] argues that transaction costs increase as a result of three factors:

- Asset specificity which refers to the uniqueness of the firm's knowledge and hardware and the possibility of alternative use of assets. A higher degree of uniqueness would lead to higher transaction costs.
- Uncertainty (i.e. unpredictable market, technological uncertainty, or contractual complexity) could lead to higher transaction costs due to the need for structured control mechanisms and/or adaptation to standards.
- Infrequent outsourcing may lead to higher transaction costs due to relation-building or low economy of scale in legal matters.

A resource-based perspective is concerned with the use and development of a firm's resources. In his five-stage plan for a resource-based approach to strategy formulation, Grant [1991] describes the necessity of upgrading and extending the firm's resources to fill the gap between identified internal resources and resources required. Grant [1991] argues that in order for both to fully exploit a firm's existing resources and to develop competitive advantage, the external acquisition of complementary resources may be necessary. According to Grant, filling this gap by means

of outsourcing maintains and increases the firm's resources, extends competitive advantage and broadens the firm's set of strategic opportunities.

In a conceptual article in 2000, Quinn [2000] claims that strategic outsourcing of innovation is a necessary action to gather sufficient knowledge and manage the insecurities of a rapidly changing world. Almost any stage of the NPD-process can, according to Quinn, be profitably outsourced. Basic research and early stage development could be outsourced to universities or government laboratories, and advanced development and product innovation should, according to Quinn, preferably be outsourced to suppliers. Even later stages of the NPD-process such as business processes or new product launches could be outsourced to distributors or wholesalers.

A trend today is that firms use outsourcing in order to acquire competencies that external suppliers of knowledge can offer. By using more sophisticated outsourcing and new electronic communications, modeling and monitoring techniques, firms can decrease cycle times, costs, investments and risks. Furthermore, Quinn [1999] claims that larger system producers in aerospace (Boeing, Aerospatiale), transportation (Ford, Newport News), communications (AT&T, GTE), and energy (Mobile, Enron) have increasingly realized that their central R&D departments cannot match the innovative capabilities of a well-managed supplier system except in the few areas that comprise their core competencies.

Feldman [2001] argues that, from the point of view of NPD and product improvement, there appears to be an important hidden cost in outsourcing activities. The Japanese have continually improved their products over the years through a greater willingness to entertain suggestions from line workers that could improve production processes, cut costs and sometimes even change the nature of the product itself. When production is handed over to a contract manufacturer, especially one that is offshore, the feedback pertaining to product improvements that originate on the factory floor may be greatly diminished [Feldman (2001)]. Outsourcing of innovation or NPD could probably lead to a similar loss of knowledge creation within the firm.

It would be interesting to investigate to what extent outsourcing of NPD is used, the rationales behind the outsourcing of NPD, to whom NPD is outsourced and which function within the firm decides on the outsourcing of NPD.

2.4. *Organizing NPD*

Several studies have addressed the structural issues of organizing NPD, such as the problem of who has responsibility for NPD in the firm [McGrath and Romeri (1994)]. Booz *et al.* [1968] have described two basic forms of organization; a permanent staff of people in an NPD-department versus a new product committee that evaluates and coordinates NPD on a part-time basis. In the latter case, the committee members have primary tasks and responsibilities other than NPD. A third structure could be that each business unit is responsible for NPD decisions in their market area, i.e. NPD is decentralized to a business unit level. If there is no NPD-department, one function, such as marketing or production, may be responsible for NPD. This is a structure that describes a fourth case. The above-mentioned case of outsourcing NPD represents the fifth. These approaches are not exclusive in the sense that one approach excludes the others.

A recent type of structure examined in the PDMA-survey of 1995 [Griffin (1997)] is the introduction of NPD-process owners. A process owner is responsible for the NPD-process as well as for the improvement and implementation of an improved NPD-process across firms or divisions.

It would be interesting to examine to what extent the firms of the sample identify their NPD-processes according to the above structures.

3. Method

A mail survey was used to determine the current status of product development practices in medium-sized Swedish firms. The main reason for using a mail survey was the possibility of reaching a large number of respondents with a broad range of questions. Another reason was the opportunity to compare some of the results with the PDMA-study of 1995 [Griffin (1997)]. The present survey was partly based on the PDMA-survey. All the questions from the PDMA-instrument was present, but the questionnaire was extended to include outsourcing, as the PDMA-survey was carried out five years ago, at which time the outsourcing of NPD was not an issue. The subject of NPD strategies was present in the PDMA-instrument, but was divided into a greater number of variables in the present study in order to obtain a more detailed picture. The new variables were based on the theoretical framework presented above.

A professional translator translated the PDMA-survey into Swedish, and the Swedish version was tested on a sample of academics and practitioners. After the test phase, the instrument was simplified in order to improve the response rate and to focus on the most important issues.

The firms targeted in the study were medium-sized, Swedish manufacturing firms of between 200 and 800 employees. The targeted firms covered products of varying complexity as well as varying production processes and markets. A database search at Statistics Sweden (SCB) resulted in a selection of 338 potential respondents registered as manufacturing firms with between 200 and 800 employees. Of the 338 potential respondents, a sample of 80 respondents was randomly selected. Each firm in the sample was contacted by phone, and the person responsible for product development was identified, informed about the survey and agreed to respond to it him/herself. This method was chosen to present a high response rate. The mail survey, together with a covering letter and a stamp-addressed envelope, was then sent to each person responsible for product development. Respondents who failed to return the completed survey form within one month were reminded on two occasions by phone. This method produced a response rate of 57%, which could be considered a reasonable response rate for a mail survey. As indicated in Table 1, a majority of the respondents could be classified as mechanical engineering firms.

The nine-page survey, which came with a list of instructions, was divided into five parts covering issues surrounding the NPD-process:

- questions to categorize the responding organization
- NPD strategies
- NPD-processes within the organization
- processes for outsourcing NPD
- organizing NPD

Table 1. The respondents divided into industries.

Industry	Respondents (%)
Mechanical	67
Chemical	13
Paper and pulp	4
Construction	3
Other	13
Total	100

The first category of questions was used to classify respondents according to industry and to categorize them in two ways. The first category distinguishes between firms with a high and those with a low emphasis on NPD. For this purpose, two variables were used; (A) sales from products developed within the firm as a percentage of turnover and (B) sales of products commercialized in the last five years as a percentage of turnover. In the instrument, both issues were open questions where the respondents answered by indicating percentage of turnover. "The best" are those firms who indicated that they were above 50% on both variables. A total of 33% of the sample met the criteria for both variables.

To perform the second categorization, the firms were asked to rate eight competitive factors for winning new customers (order winners). The factors in the survey were lower price, better product design, higher product quality, reliable deliveries, faster deliveries, better after sale, broader product line and frequency of new product launch. Respondents were asked to rate each competitive factor on a five-step Likert scale from not important (1) to very important (5). This rating was compared with the use of NPD-processes in the population (see Table 2).

4. Results and Discussion

Our literature review indicated a shift from the more normative view of NPD-processes in the earlier literature to the more flexible view contained in the recent literature. In the early literature, authors attempted to identify best practices and recommended the incorporation of specific stages into the NPD-process. In the more recent literature, authors often focused on the variety of possible NPD-processes, claiming that every firm must develop and continuously improve their own NPD-process in view of the fact that every new product has individual characteristics and therefore demands a specific process. Firms can implement improvements based on the experience gained from earlier NPD projects, although it is not possible to predict whether or not a given process is optimal for every NPD-process in the firm. In the following section, the results of the survey are presented in addition to comments and the discussion.

4.1. *Use of formal NPD-processes*

As described earlier, in many studies the use of a formal NPD-process has proved to be the difference between success and failure at project level [Pittiglio *et al.*

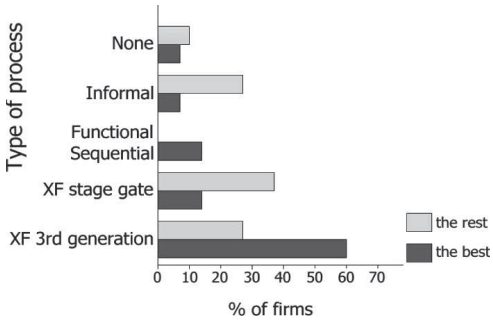


Fig. 1. NPD-processes: The best versus the rest. The categories "None" and "Informal" indicate no formal processes. XF = Cross-functional teams. Chi-square = 11.0, $p < 0.05$.

(1995); Tatikonda and Rosenthal (2000)]. However, 29% of the firms across the entire sample of the present study do not use a formal process (response: "none" or "informal"). This figure is considerably lower than the 38.5% in the PDMA-study [Griffin (1997)]. One reason for this could be that all firms in the sample are certified in accordance with ISO 9000. When the PDMA-study was performed in 1995, the ISO 9000 was not very widespread. Even today the ISO 9000 is more common in Europe than in the US. This means that there could be a time factor affecting the use of formal NPD-processes in addition to the geographical factor.

Firms in the mechanical engineering industry are more likely to use a formal NPD-process, with up to 80% stating that they use such a process compared to 50% in firms in processing industries, such as chemical or paper/pulp.

The best firm group uses formal NPD-processes to a higher extent than the other firms (Fig. 1). Up to 87% of the best firms use a formal NPD-process, compared to 63% of the rest/others (functional sequential, XF stage gate or XF 3rd generation as illustrated in Fig. 1). An unexpected result is that 60% of the best firms use a cross-functional third generation process. In the 1995 PDMA-study, only 23% of the best firms used a cross-functional third generation process.

In the questionnaire used in the present study, the alternatives were directly translated from the PDMA-study and were thus identical. Therefore, the difference between the present study and the PDMA-study can only be explained by means of other parameters. Possible explanations could be the time factor and/or the cultural factor. In the Swedish context, a rich store of literature as well as knowledge clusters has enhanced the NPD-process since the late nineties. One of the major results is the importance of formality in NPD although, on the other hand, too formal an approach has been criticized, as it both blocks creativity and leads to the risk that relevant functions will be excluded from NPD. In our extended study based on interviews with NPD executives, there seems to be a surprisingly high awareness of organizational matters and also an understanding of the need for flexibility in the NPD-process.[a]

[a]Interviews performed during 2002 and 2003 in five medium-sized manufacturing firms. Early results were presented at the 10th EIASM Product Development Management Conference in Brussels.

Table 2. The use of a formal NPD-process related to competitive factors. 1 = Least important competitive factor, 5 = most important competitive factor.

	Lower price*	Better product design*	Higher product quality**	Reliable deliveries	Faster deliveries	Better after sales*	Broader product line	Frequency of new product launch**
Formal NPD-process	3.5	3.8	4.2	4.4	3.6	3.7	3.6	3.3
No formal NPD-process	3.4	3.3	3.6	4.6	4.0	3.7	2.9	2.4

*Chi-square $p < 0.12$; **Chi-square $p < 0.05$.

Table 3. The best and the rest related to competitive factors.

	Lower price	Better product design	Higher product quality*	Reliable deliveries	Faster deliveries	Better after sales	Broader product line*	Frequency of new product launch
The Best	3.2	4.1	4.4	4.5	4.0	3.9	3.9	3.2
The Rest	3.6	3.4	3.9	4.5	3.6	3.6	3.1	3.0

*Chi-square $p < 0.12$; **Chi-square $p < 0.05$.

To enable another type of categorization, the firms were asked to rate eight factors that could be important to win new costumers (order winners) to the firm. This rating was compared to the extent of use of formal NPD-processes. The mean values presented in Table 2 indicate that firms that consider product properties such as "higher product quality" and "frequency of new product launch" as more important use a formal NPD-process more frequently than firms that rate these factors as less important. In the group of variables describing organizational properties, such as "lower price" and "better after sales", this difference was not visible.

The ISO 9001 international quality management standard stipulates that the design procedure should be described, although the level and detail of the description is left to the firm to decide. It could be argued that firms rating higher product quality as important have worked more actively in defining and describing the NPD-process. This argumentation is supported by the fact that the means of competitive factors categorized according to the best and the rest are less significant. There is a stronger connection between competitive factors and the use of formal NPD-processes than between competitive factors and the best/the rest, as indicated in Table 3.

4.2. *NPD strategies*

In the 1995 PDMA-study, 62.9% of the total sample had a strategy for "new product activities" [Griffin (1997)]. In the present study, the result is 73.3%. This could indicate a continuation of the trend that began with 54.5% in the PDMA-study of 1989 [Page (1990)] and/or the geographical difference.

Table 4. The use of a formal NPD-process related to the existence of a documented strategy for different aspects of NPD.

	Strategy for product line** (%)	Strategy for outsourcing innovation (%)	Strategy for product platforms (%)	Strategy for continuous improvements* (%)
Formal NPD-process	94	28	78	87
No formal NPD process	23	31	62	53

*Chi-square $p < 0.12$; **Chi-square $p < 0.05$.

Table 5. The existence of a documented strategy for different aspects of NPD.

	The firm has a documented strategy for ...			
	Product line (%)	Outsourcing innovation (%)	Product platforms* (%)	Continuous improvements of NPD-process (%)
The best	87	27	60	87
The rest	67	30	30	73

*Chi-square $p < 0.05$; **Chi-square $p < 0.01$.

Furthermore, the firms were asked if they had any documented strategies for different types of situations. The strategy aspects examined in the present study were product line, supplier involvement, product platforms and continuous improvements of the NPD-process. As indicated in Table 4 firms with a formal NPD-process have a more documented strategy for product line aspects and for continuous improvements in the NPD-process. This pattern could not be identified in the strategies regarding outsourcing of innovation or product platforms.

In comparison with similar studies [Cooper and Kleinschmidt (1995); Griffin (1997)], the present study reveals no significant differences between the best and the rest in terms of NPD strategies. In the best firm group, 87% had a product line strategy compared to only 67% of the rest (Chi-square $p = 0.153$).

The only significant difference between the best and the rest in respect of type of strategy was found in the area of product platforms. As indicated in Table 5 the best group had a significantly higher percentage of product platform strategies.

4.3. *Strategic outsourcing of NPD*

Outsourcing of production has been a trend during the nineties, which has led to increased supplier involvement in the NPD-process. It is therefore interesting to note that 67% of the firms in our sample outsourced parts of the NPD-process. This is also a surprising result considering that only 29% of the firms have a documented strategy for innovation outsourcing. The group outsourcing NPD was asked to state the most important reasons for this decision, and all respondents gave more than one reason. In the group of firms outsourcing the NPD-process, 59% claimed that the main reason was the need for technological competence while 40% mentioned

greater effectiveness in the production phase. Supplier involvement can provide both, especially effectiveness, in the production phase. Technological competence can be found in universities or through consultancy firms, which are major beneficiaries of NPD outsourcing in the study. Other reasons (19%) for outsourcing NPD were the need for design knowledge and lack of economic or personal resources, which is also supported by the high percentage of outsourcing to consultancy firms.

Firms that outsource NPD activities most frequently chose to collaborate with present or prospective future suppliers. 63% of the firms outsourcing NPD used current suppliers and 29% potential future supplier (a supplier with whom discussions are in progress although no formal agreement has yet been made) (Fig. 2). The second and third choices for outsourcing NPD activities were consultancy firms (53%) followed by universities (43%).

This supports the claim that technological competence is a major reason for outsourcing NPD. Another interesting finding is that a minority of the firms used almost all types of partners, while the majority collaborated with only one or two types of partners; normally present suppliers and consultancy firms.

The firms in the sample using customers for outsourcing of NPD are often subcontractors, whose products are developed by the customers. However several respondents are special machinery suppliers supplying tailor-made products to their customers.

The firms in the sample were also asked to rank which function in the firm that was mainly responsible for initiating the outsourcing of NPD, as well as the function with the next highest degree of responsibility. The results are presented in Table 6. According to our survey, the most frequent function to initiate the outsourcing of NPD is R&D. This result is not surprising in view of the fact that the R&D function is usually responsible for NPD. However, the high level of R&D involvement is rather surprising as, for example, purchasing is usually the function most frequently in contact with suppliers while marketing has the highest level of contact with the clients. Thus, both groups are highly involved in the outsourcing of NPD. This could be the result of efficient cross-functional processes, where contacts made by the purchasing department are passed on to R&D whenever the need for specific competence arises for the NPD or parts thereof.

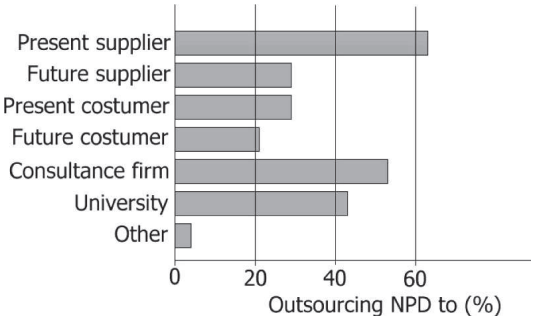


Fig. 2. Who the firm cooperates with when outsourcing parts of the NPD-process. Only firms that use outsourcing of NPD activities were included.

Table 6. Functions most frequently initiating the outsourcing of NPD.

	Initiating outsourcing		
Function	1st (%)	2nd (%)	Total 1st and 2nd (%)
R&D	83	13	96
Purchasing	0	38	38
Production	3	36	39
Marketing	7	13	20
Other	7	0	7
Total	100	100	

Table 7. NPD-organization.

	The best			The rest		
Organizational approaches to NPD	Yes (%)	No (%)	Total (%)	Yes (%)	No (%)	Total (%)
New product department with permanent staff members*	87	13	100	57	43	100
NPD projects are outsourced to external actors**	33	67	100	0	100	100
A new product committee oversees all development efforts	20	80	100	40	60	100
Each business unit's general manager directs their own NPD efforts	7	93	100	20	80	100
A process-owner is responsible for spreading the process to the entire firm	13	87	100	37	63	100
A single function is responsible for NPD*	33	67	100	80	20	100

*Chi-square $p < 0.05$; **Chi-square $p < 0.01$.

4.4. *Organizing NPD*

The survey listed six organizational structures based on the theoretical framework and asked the respondents to state all structures that described the structure of their firm's NPD projects.

As indicated in Table 7, the best firms use a new product department with permanent staff members to a much higher extent than the rest of the firms. In the best firms, cross-functional responsibility is used to a greater extent than in the rest of the firms. 67% in the best group had no specific function responsible for NPD compared to 20% in the rest group. The remaining 33% in the best group all answered that R&D was responsible for NPD as indicated in Fig. 3. In the "rest" category, only 20% have cross-functional responsibility and R&D function has sole responsibility for NPD in 57% of the firms. This is a surprisingly big difference but it corresponds well with the result that 60% of the best firms use cross-functional third generation NPD-processes. The result also indicates that a cross-functional group with permanent members and responsibility for NPD could be a fruitful approach.

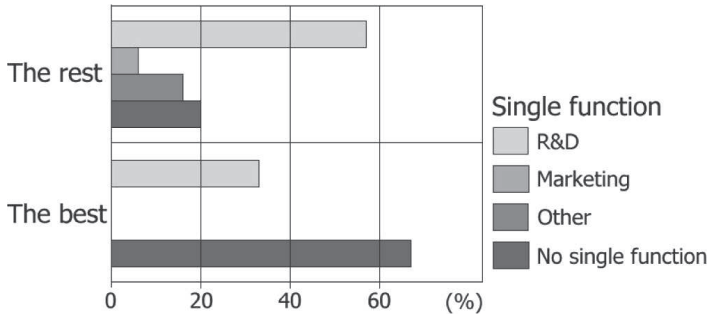


Fig. 3. Functions responsible for NPD Chi-square = 11.0, $p < 0.05$.

Table 8. Types of rewards used for team leaders and team members, categorized and compared between the best and the rest.

	The best		The rest	
Type of reward used	Sometimes/Always (%)	Never (%)	Sometimes/Always (%)	Never (%)
Recognition in organization's newsletter	68	32	50	50
Completion dinner with the group	60	40	43	57
Other financial reward	20	80	17	83
Compensation time	18	82	7	93
Award dinner	11	89	17	83
Non-financial team award	13	87	10	90
Project-based profit-sharing	13	87	10	90
Project-based stock or options	13	87	7	93
Other non-financial reward	13	87	0	100
Plaques, pins etc	0	100	7	93

4.4.1. *Reward systems for NPD teams*

Surprisingly, there seem to be very few reward systems for NPD project leaders and NPD team members (see Table 8). Our material also indicates that there is no difference between rewards for team leaders and team members. Both categories are offered the same types of rewards and with the same frequency. The most frequent types of rewards are "recognition in the organization's newsletter" and "completion dinner with the group". These two types of rewards are used in more than 50% of the firms. The best firms seem to make slightly better use of reward systems than the rest, but there is no significance difference.

The use of completion dinners and recognition in the organization's newsletter is similar to the PDMA-study of US firms [Griffin (1997)], though the difference between the best and the rest was greater in the US study. The other variables (types of rewards) are also the same as in the US study, except for two variables that are remarkably different. These are award dinners (11% and 17% compared to 42% and 29%) and plaques (0% and 7% compared to 52% and 43%). This result can be explained by the cultural differences between the US and the Swedish

(European) context. Both "award dinners" and "plaques" are examples of symbolic awards with an individual focus [Wilson (1995)]. In contrast, both "recognition in the organization's newsletter" and "completion dinner/lunch with the group" are examples of social awards with a group focus. The individual focus in the US context is also supported by the result of the PDMA-study indicating that project leaders are more often acknowledged than project members [Griffin (1997)]. This was not found in the Swedish context.

5. Comparison with Former Studies

As stated before, some of the results from the present study could be compared with the 1995 PDMA-study [Griffin (1997)]. The comparison of the results will be presented in Table 9. As discussed earlier, it is hard to determine whether the differences in the results are due to the time factor or cultural differences. However, it is evident that the use of a formal NPD-process in general and a cross-functional 3rd generation process in particular is markedly higher in the present study.

Table 9. Comparison of the results of the present study and the 1995 PDMA study [Griffin (1997)].

The findings of this study (survey carried out in 2001)	The findings of the PDMA-study (survey carried out in 1995) [Griffin (1997)]
Use of NPD-processes	
The best firm group uses formal NPD-processes to a greater extent than the rest (87% versus 63%).	The best firm group uses formal NPD-processes to a greater extent than the rest (69% versus 52%)
60% of the best firm group use a cross-functional third generation model	Nearly 25% of the best firm group use a cross-functional third generation model.
Strategies for NPD	
73.3% of the total sample had a strategy for new product activities.	62.9% of the total sample had a strategy for new product activities. 54.5% in the PDMA-study of 1989 [Page (1993)].
Organizing NPD	
The most common structure in the total sample seems to be a permanent staff (67%).	The most common structure in the total sample seems to be a single function responsible for NPD (39%). The second most common structure in the total sample seems to be a permanent staff (35%).
R&D is the most common function to have sole responsibility for NPD (76%), followed by the Marketing function (7%). No respondents mentioned the Engineering function.	The most common function with sole responsibility for NPD is Engineering (38%), followed by R&D (33%) and Marketing (30%).
The most frequent source of reward for NPD project teams and project leaders was recognition in the organizations' newsletter (62%) and the second most frequent was completion dinner (55%). There were no differences observed between best practice firms and the rest in terms of rewards. Symbolic awards were very seldom used (5% and 14%).	The most frequent source of reward for NPD project teams and project leaders was completion dinner (54%) and recognition in the organization's newsletter (54%). Rewards were considerably more common in the best practice firms than in the rest. Symbolic awards such as plaques and award dinners were used to a relatively great extent (43% and 32%).

6. Conclusion

The present study has provided some managerial implications that are summarized in a normative form in the following section. Finally, our concluding remarks offer a description of the operational future of our research project.

6.1. *Managerial implications*

The managerial implications of the present study are presented in the form of three recommendations, based on the findings from the best group of firms. It is however, necessary to evaluate the recommendations in order to find the best organization for every situation and context.

6.1.1. *Use of formal NPD-processes*

The use of formal NPD-processes seems to be more extensive in the best practice firms. A documented and widely known NPD-process helps all functions to coordinate and participate in activities in a cross-functional way. All functions involved know when and how they are expected to contribute to the NPD-process result. The formal process can also be seen as a way of controlling and measuring the results produced in the process, in order to offer senior management an opportunity to evaluate and compare projects.

However, the results indicate that the best practice firms have adopted the cross-functional 3rd generation NPD-processes to a much greater extent than the rest of the firms. These models typically have a flexible approach to activities and decision gates. Cooper [1994] suggests that all activities are not always essential and that all gates do not need to be passed. The project team must decide how to use the models in meeting the particular needs of the specific project. This means that the formal NPD-process should be seen more as a roadmap than a rulebook. It is, however, important to remember that the decision to exclude an activity or decision gate must not be made *ad hoc* or for the wrong reason. A reason could be lack of competence, which should instead lead to a careful decision in agreement with the team and the gatekeepers at the preceding gate, taking many aspects into consideration.

6.1.2. *Use of an NPD-department with permanent staff members*

The use of an NPD-department with permanent staff members seems to be more extensive in the best practice firms. This means that an NPD committee with part-time staff is a less common type of organization in the best practice firms. A permanent staff provides an opportunity to work continuously with the NPD-process and avoids interruption and concentration being divided between different tasks.

6.1.3. *Share responsibility for the NPD-process between various functions*

A single function with sole responsibility for the NPD-process is less widespread in the best practice firms. This indicates an awareness of the importance of using

experience from various functions in the development and improvement of the NPD-process. The different functions are not only employed for executing activities in the NPD-process but also in the evaluation of the use of the process.

6.2. *Final remarks*

The present study will be repeated on a regular basis in order to track development over time. An agreement has been made with PDMA to synchronize future studies. This means that the survey and the selection of the sample will be identical to future PDMA-studies in order to obtain results that can be directly compared. A network of research groups in Europe has also been created under the auspices of the EIASM in order to ensure that an identical survey is performed in various European countries. This will provide a useful means of tracking trends in NPD-practices in an international context.

References

Andreasen, M. M. and Klein, L. (1987). *Integrated Product Development*. Springer Verlag, Berlin.

Booz, E., Allen, J. and Hamilton, C. (1968). *Management of New Products*. Booz-Allen & Hamilton, New York.

Booz, E., Allen, J. and Hamilton, C. (1982). *New Products Management for the 1980s*. Booz-Allen & Hamilton, New York.

Cooper, R. G. (1994). Third-generation new product processes. *Journal of Product Innovation Management*, **11**: 3–14.

Cooper, R. G. and Kleinschmidt, E. J. (1995). Benchmarking the firm's critical success factors in new product development. *Journal of Product Innovation Management*, **12**: 374–391.

Cooper, R. G., Edgett, S. J. and Kleinschmidt, E. J. (1999). New product portfolio management: practices and performance. *Journal of Product Innovation Management*, **16**: 333–351.

Crawford, C. M. (1980). Defining the charter for product development. *Sloan Management Review*, **21**: 2–12.

Feldman, L. P. (2001). NPD viewpoint: Impact of outsourcing — Are we losing touch with the new product function? *PDMA Visions Magazine*, April.

Grant, R. M. (1991). The resource-based theory of competitive advantage: Implications for strategy formulation. *California Management Review*, **33**, 114–135.

Griffin, A. (1997). PDMA research on new product development practices: Updating trends and benchmarking best practices. *Journal of Product Innovation Management*, **14**: 429–458.

Hofstede, G. (1984). *Culture's Consequences* (Second edition). Sage Publications: Beverly Hills, California.

Kelley, D. J. and Rice, M. P. (2002). Advantage beyond founding: The strategic use of technologies. *Journal of Business Venturing*, **17**: 41–57.

Lacity, H. C. and Hirscheim, R. (1993). The information systems outsourcing bandwagon. *Sloan Management Review*, **34**, 73–86.

Martensen, A. and Dahlgaard, J. (1999). Integrating business excellence and innovation management, developing vision, blueprint and strategy for innovation in creative and learning organizations. *Total Quality Management*, **10**: 627–635.

McDermott, C. and Handfield, R. (2000). Concurrent development and strategic outsourcing: Do the rules change in breakthrough innovation? *Journal of High Technology Management Research*, **11**: 35–57.

McGrath, M. and Romeri, M. (1994). From experience: The R&D effectiveness index: A metric for product development performance. *Journal of Product Innovation Management*, **11**: 213–220.
Meyer, M. and Lehnerd, A. P. (1997). *The Power of Product Platforms — Building Value and Cost Leadership*. Free Press: New York.
Page, A. L. (1993). Assessing new product development practices and performances: Establishing crucial norms. *Journal of Product Innovation Management*, **10**: 273–290.
Pittiglio, Rabin, Todd and McGrath (1995). *Product Development Leadership for Technology-Based Companies*. Pittiglio, Rabin, Todd & McGrath, Weston, Mass.
Quinn, J. B. (1999). Strategic outsourcing: Leveraging knowledge capabilities. *Sloan Management Review*, **40**: 9–21.
Quinn, J. B. (2000). Outsourcing innovation—the new engine of growth. *Sloan Management Review*, **41**: 13–28.
Tatikonda, M. and Rosenthal, S. (2000). Successful execution of product development projects: Balancing firmness and flexibility in the innovation process. *Journal of Operations Management*, **18**: 401–425.
Tidd, J., Bessant, J. and Pavitt, K. (1997). *Managing Innovation*. John Wiley & Sons Ltd: Chichester.
Williamson, O. E. (1985). *The Economic Institutions of Capitalism*. Free Press, New York.
Wilson, T. B. (1995). Innovative Reward Systems for the changing workplace. Sage Publications, Newbury Park.
Yasdani, B. and Holmes, C. (1999). Four models of design definition: Sequential, design centered, concurrent and dynamic. *Journal of Engineering Design*, **10**: 25–37.

Biography

Jonas Rundquist graduated with a MSc in Innovation Management and Product Development at the University of Halmstad. He has spent more than ten years as a Project Manager and Managing Director of design intense firms. During these years he was frequently invited as a lecturer in project management. At present his research interests focus on the organizing of NPD activities, the flow of knowledge in NPD processes, the outsourcing of NPD activities, and knowledge integration when activities in the NPD-process out-sourced. In earlier research projects he has analyzed the management of corporate venturing in large firms and the board's roles in recently started firms.

Aron Chibba graduated with a MSc in Quality Management at the University of Halmstad. He has been the Managing Director for a certification body and is also today the Senior Manager for a technological firm. Chibba has assisted in over 100 projects within the area of Quality Management. His major research interests focus on information logistics with a supply chain perspective. He has a special interest in securing information flows within and between organizations.

CPDR (Centre for Product Development Research)

enkätundersökning rörande produktinnovationsprocesser

2001

Enkäten har utvecklats för att kartlägga modeller och processer som används inom medelstora företag i Sverige vid utveckling av nya produkter eller produktinnovationer. Svaren kommer att samlas in och bearbetas under hösten 2001 och resultatet kommer att presenteras och distribueras under 2002. Samtliga som besvarar enkäten kommer att få ta del av resultatet så snart detta är sammanställt.

Notera att alla svar behandlas konfidentiellt och att all bearbetning sker anonymt. Resultaten kommer endast att användas som empiri vid akademisk forskning.

Enkäten är uppdelad i fem delar:

- Allmänna frågor om företaget
- Produktutvecklingsstrategier
- Processen för att utveckla nya produkter inom företaget
- Processer vid outsourcing av produktutveckling
- Organisering av produktutveckling

Svaren ska spegla situationen inom företaget som helhet.

Enkäten ska besvaras av Produktutvecklingschef eller chef för Forskning & Utveckling, eller om sådan inte finns, av den person som närmast ansvarig för produktutveckling.

Var vänlig returnera enkäten i det bifogade svarskuvertet då enkäten är besvarad.

Tack för er medverkan!

Jonas Rundquist – jonas@rundquist.nu - 035-167593

CPDR
Sektionen för Teknik & Ekonomi
Högskolan i Halmstad
Box 823
301 18 Halmstad

I. Allmänna frågor om företaget

Syftet med avdelningen ”allmänna frågor om företaget” är att skapa en generell bild av företaget.

Besvarar frågorna som representant för hela företaget, dvs. besvara frågorna så att svaren gäller för hela företaget, inte endast för en affärsenhet eller geografisk anläggning.

1. Företag: _____

   Adress: _____

   Telefon/e-mail: _____

   Respondentens namn: _____

   Respondentens funktion: _____

2. Genomsnittligt antal årsanställda under år 2000 _____

3. Företagets omsättning under år 2000 _____

4. Inom vilken bransch ligger företagets huvudsakliga verksamhet.
   - ❑ Verkstadsindustri
   - ❑ Kemisk industri
   - ❑ Livsmedelsindustri
   - ❑ Textilindustri
   - ❑ Papper & Trä industri
   - ❑ Byggvaruindustri
   - ❑ Annat (vilken, skriv på linjen)

   _____

5. Är företaget certifierat enligt någon kvalitetsstandard?

Ja	Arbete med certifiering pågår	Arbete med certifiering är Planerat	Certifiering är inte planerad (Gå förbi fråga 6)
[ ]	[ ]	[ ]	[ ]

   Vid ja; årtal för certifieringen _____

6. Enligt vilken standard arbetar företaget?

   [ ] ISO 9000 [ ] Annan standard, Vilken _____

7. Ungefär hur stor andel av företagets omsättning kommer från produkter/tjänster som är utvecklade inom företaget? _____%

8. Ungefär hur stor andel av företagets omsättning består av produkter utvecklade under de fem senaste åren? _____%

9. Ungefär hur stor andel av företagets omsättning kommer från export?_____%

10. Hur skulle du beskriva utvecklingen under de senaste två åren för de marknader där företagets huvudsakliga produktlinje konkurrerar?

snabbt ökande	ökande	stabil	minskande	snabbt minskande
[ ]	[ ]	[ ]	[ ]	[ ]

11. Ungefär hur stor andel av företagets omsättning genererades av företagets tre största kunder?

Mindre än 25%	25-50%	51-75%	76-90%	mer än 90%
[ ]	[ ]	[ ]	[ ]	[ ]

12. I vilken utsträckning är följande mål betydelsefulla för företagets viktigaste kunder (Markera alla lämpliga alternativ). Jämfört med era konkurrenter, vinner ni orders genom att sikta mot:

	Inte viktig				Mycket viktig	Hur är målets prioritet jämfört med för 3 år sedan?		
Lägre försäljningspris	1	2	3	4	5	lika	lägre	högre
Bättre produktdesign	1	2	3	4	5	lika	lägre	högre
Högre produktkvalitet	1	2	3	4	5	lika	lägre	högre
Pålitligare leveranser	1	2	3	4	5	lika	lägre	högre
Snabbare leveranser	1	2	3	4	5	lika	lägre	högre
Bättre kundservice (Efterförsälj-ning och teknisk support)	1	2	3	4	5	lika	lägre	högre
Bredare produktsortiment	1	2	3	4	5	lika	lägre	högre
Nya produkter oftare	1	2	3	4	5	lika	lägre	högre
Övrigt (Specificera) : _____	1	2	3	4	5	lika	lägre	högre

II. Produktutvecklingsstrategier

Denna del av enkäten har som syfte att kartlägga strategiska val som gjorts av företaget.

13. A) Har ert företag en uttalad strategi[1] för utveckling av nya produkter vad gäller val av **produktlinjer** eller områden där nya produkter ska utvecklas?

Ja □ Nej □ (hoppas över B)

B) Baseras denna strategi främst på information från …

Ledningsgrupp/styrelse	_____%
Marknadsavdelning	_____%
Utvecklingsavdelning	_____%
Produktionsavdelning	_____%
Annan	_____%

14. Har ert företag en uttalad strategi vid utveckling av nya produkter som bygger på **produktplattformstänkande**?
(Med produktplattform avses här en gemensam grundkonstruktion eller en uppsättning gemensamma nyckelkomponenter som kan utnyttjas för flera olika slutprodukter.)

Ja □ Nej □

15. Har ert företag en uttalad strategi vid utveckling av nya produkter som bygger på **modultänkande**?
(Med modultänkande avses här en uppsättning delkomponenter som är direkt utbytbara mellan ett stort antal slutprodukter.)

Ja □ Nej □

16. Har ert företag en uttalad strategi när det gäller vilka delar av nyproduktutveckling som ska vara föremål för **outsourcing** av produktutvecklingsfunktionen?
(Med outsourcing avses här att huvuddelen av produktutvecklingsprocessen eller centrala delar av produktutvecklingsprocessen ligger utanför företaget.)

Ja □ Nej □

17. Har ert företag en uttalad strategi för förändring/förbättring av enskilda produktutvecklingsaktiviteter och/eller produktutvecklingsprocess?

Ja □ Nej □

[1] Med uttalad strategi avses formellt dokumenterad strategi eller tydlig och, inom företaget, allmänt vedertagen strategi.

III. Processen för att utveckla nya produkter inom företaget

Syftet med denna delen av enkäten är att kartlägga företagets produktutvecklingsaktiviteter och sammansättning av produktutvecklingsaktiviteter.

Besvara frågorna så som företaget hanterar **nyproduktutveckling**. Med nyproduktutveckling avses här produkter som är världsnyheter eller nya produkter/produktgrupper för företaget. Med nyproduktutveckling avses inte mindre produktförbättringar eller ren konstruktionsförenkling av befintliga produkter.

18. Kryssa i rutan framför den mening som bäst beskriver er produktutvecklingsprocess (**kryssa endast i en ruta**):

□ Vi har ingen formellt dokumenterad process för nyproduktutveckling. (hoppa över fråga 2)

□ Även om vi inte följer någon formellt dokumenterad process, har vi en tydlig och vedertagen kedja av aktiviteter som ska fullföljas vid produktutveckling. (hoppa över fråga 2)

Vi har en formellt dokumenterad process där ..

□ .. en avdelning fullföljer en uppsättning aktiviteter, en ledningsgrupp granskar resultatet och ger klartecken för nästa avdelning att ta över och påbörja en annan uppsättning aktiviteter.
□ .. en tvärfunktionell grupp fullföljer en uppsättning aktiviteter, en ledningsgrupp granskar resultatet och ger klartecken för den tvärfuktionella gruppen att påbörja nästa uppsättning aktiviteter.
□ .. tvärfunktionella grupper använder en process med flera steg och beslutspunkter, men där stegen flyter i och överlappar varandra och där ledningsbeslut fattas vid behov och i öppen dialog mellan ledning och grupp.

□ Annat (Vänligen beskriv): _____

19. Under hur många år har ert företag följt en formellt dokumenterad produktutvecklingsprocess?

0-1 år □ 2-3 år □ 4-5 år □ 6-10 år □ mer än 10 år □

20. Utvecklingen av nya produkter beskrivs ofta som en serie oberoende och möjligen överlappande steg eller aktiviteter. I tabellen nedan beskrivs flera sådana aktiviteter.

A. Markera med ett "X" i den första kolumnen om ert företag har med aktiviteten i sin produktutvecklingsprocess vid nyproduktutvecklingsprojekt.

B. Betrakta de nyproduktutvecklingsprojekt som har kommersialiserats. I hur stor andel av dessa projekt fullföljdes de olika typerna av aktiviteter nedan.

C. Uppskatta hur lång tid (i veckor) som används för varje typ av aktivitet.

	(A) Vår process inkluderar	(B) % av projekten innehöll	(C) Antal veckor använda
Idé/Koncept Generering: Identifiera möjligheter och inledande generering av möjliga lösningar.	☐	_____%	_____ veckor
Idéutvärdering: Sortera och rangordna lösningar, ta bort olämpliga lösningar.	☐	_____%	_____ veckor
Affärsanalys: Värdera konceptet ekonomiskt, skriva marknadsscenarior, förbereda utvecklingskontrakt.	☐	_____%	_____ veckor
Utveckling: Från koncept till en fungerande produkt	☐	_____%	_____ veckor
Test och verifiering: Funktionstest samt fält-, marknads- och överensstämmelse-test med kund.	☐	_____%	_____ veckor
Produktionsutveckling: Pilottillverkning, utveckling och uppstart av tillverkningsprocesser.	☐	_____%	_____ veckor
Överföring till löpande verksamhet: Släppa produkten eller tjänsten till fullskalig produktion och försäljning.	☐	_____%	_____ veckor
Annat: Alla andra aktiviteter som finns med i er produktutvecklingsprocess. (Vänligen beskriv): _____	☐	_____%	_____ veckor

21. Många nya produktidéer når aldrig fram till kommersialisering. Vilket procenttal av de totala nya produktidéerna/koncepten (100%) når vart steg i utvecklingsprocessen nedan? Försök uppskatta andelen idéer som passerar till respektive steg vare sig denna process är formellt dokumenterad eller inte.

Idé/koncept generering 100%	Idéutvärdering _____%	Affärs-analys _____%	Utveckling _____%	Test och validering _____%	Produktions-utveckling _____%	Överföring _____%

IV. Processer vid outsourcing av produktutveckling

Syftet med denna delen av enkäten är att kartlägga den del av produktutvecklingen som bedrivs utanför företaget.

22. Har ert företag någon outsourcing av produktutvecklingsaktiviteter?

Ja □ Nej □

23. Vilka kriterier väger tyngst vid valet om en produktutvecklingsaktivitet ska gå till outsourcing?

□ Produktutvecklingsaktiviteten kräver tekniska kunskaper som inte finns i tillräcklig omfattning inom företaget.
□ Produktionen av produkten/delkomponenter hos underleverantören blir effektivare om underleverantören även genomför produktutvecklingsaktiviteten.

□ Annan orsak till outsourcing (vilken?) _____

_____

24. Vilken eller vilka typer av företag utför produktutvecklingsarbete utanför ert eget företag? Markera med kryss om outsourcing av produktutveckling till nedanstående företagstyper förekommer och uppskatta hur stor andel av era nyprodukt-utvecklingsprojekten som det förekommer inom.

		% av projekten innehöll
□	Nuvarande leverantörer	_____%
□	Eventuella framtida leverantörer	_____%
□	Nuvarande kunder	_____%
□	Eventuella framtida kunder	_____%
□	Konsulter	_____%
□	Universitet eller högskola	_____%
□	Annan (vilken) _____	_____%

25. Vid vilken funktion inom företaget initieras outsourcing av produkt-utvecklingsaktiviteter? Markera med etta [1] den funktion som oftast initierar outsourcing, därefter med tvåa [2] den funktion som näst oftast initierar outsourcing osv.

_____ Inköp
_____ Produktion
_____ Forskning och utveckling/Konstruktion
_____ Marknad
_____ Distribution/Logistik
_____ Annan (vilken) _____

V. Organisering av produktutveckling

Syftet med denna delen av enkäten är att kartlägga hur av nyproduktutvecklingen inom företaget är organiserad.

Även dessa frågor hanterar **nyproduktutveckling**.

26. Vilka av följande påståenden beskriver bäst strukturen för hur nyproduktutveckling organiseras i er Företag? (Kryssa för alla påståenden som överensstämmer.)

- ☐ Nyproduktutvecklingsavdelning med en permanent stab av medarbetare.
- ☐ Delprojekt inom nyproduktutvecklingen läggs ut till underleverantörer. (outsourcing)
- ☐ En styrgrupp för nya produkter granskar alla utvecklingsidéer.
- ☐ Chefen för varje affärsenhet leder utvecklingen av strategin på sin egen enhet.
- ☐ En process-ägare för varje produktutvecklingsprojekt ansvarar för att sprida processen over hela Företagen.

27. Är en ensam funktion ansvarig för nyproduktutvecklingen: (Vilken funktion?)

☐ Ja, Forskning & Utveckling ☐ Ja, Konstruktion

☐ Ja, Planering ☐ Ja, Marknadsföring

☐ Ja, Annan (vilken?) _____

28. Hur belönar ni projektledare och projektmedlemmar vid nyproduktutveckling? Vänligen markera alla som används och uppskatta i vilken utsträckning som varje typ av belöning används för respektive projektledare och projektmedlemmar. **(Vänligen markera samtliga som stämmer överens med er Företag.)**

	Projektledare			Projektmedlemmar		
Används (✓)	Aldrig	Ibland	Alltid	Aldrig	Ibland	Alltid
□ Ekonomisk belöning efter slutfört projekt.	1	2	3	1	2	3
□ Ägarandel eller option på ägarandel i spin-off-verksamhet.	1	2	3	1	2	3
□ Kompensationstid i form av ledighet	1	2	3	1	2	3
□ Omnämnande i personaltidning.	1	2	3	1	2	3
□ Omnämnande vid gemensam företags-middag.	1	2	3	1	2	3
□ Plaketter, medaljer eller projektfotografier.	1	2	3	1	2	3
□ Festlunch/middag vid projektavslutning.	1	2	3	1	2	3
□ Icke-finansiella belöningar som väljs av projekt-gruppen (t.ex. resor, familjemiddagar)	1	2	3	1	2	3
□ Andra finansiella belöningar (vänligen specificera).	1	2	3	1	2	3
□ Andra icke-finansiella belöningar (vänligen specificera).	1	2	3	1	2	3

Andra finansiella belöningar (vänligen specificera nedan): _____

_____

_____

Andra icke-finansiella belöningar (vänligen specificera nedan): _____

_____

_____

Paper 3

Chibba, A. (2007). Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers. *Conference proceedings, 14th International Annual EUROMA conference* in Ankara, Turkey.

Measuring supply chain performance upstream and downstream the supply chain – two case studies from Swedish heavy vehicle manufacturers

Aron Chibba

School of Business and Engineering
University of Halmstad
PO.Box 823
S-301 18 Halmstad, Sweden
Phone: +46-35167231
Fax: +46-35167500
Aron.Chibba@set.hh.se

ABSTRACT
The purpose of this study is to outline different measures that manufacturers of Heavy vehicles use in various situations in the supply chain, e.g. upstream or downstream. The method used in this research is based on a case study with two large multinational manufacturers of Heavy Vehicles: Dynapac and Kalmar Industries. In order to gather empirical evidence, interviews were conducted with top managers of different functions e.g. Purchasing, Production, Quality. The empirical work consists of in depth interviews with 7 managers. The findings reveal that these two manufacturers operate in the same part of the supply chain. Their supply chain can be presented as a hybrid supply chain. They only integrate with their 1st tier supplier and work close to the end customer. They focus on measuring the quality of their own products, cost related to suppliers and delivery reliability to the customer.

Keywords: supply chain, performance, measure and metrics

INTRODUCTION
Several studies have highlighted the need for vital performance measures in the supply chain, e.g. Lai & Ngai et al (2001); Petroni & Panciroli (2002); Holmberg (2000); Tracey & Tan (2001), and attempted to outline and describe different performance measures across and between organizations. The importance of measuring the correct metric of performance within an organisation is vital, due to the fact that it may affect the decision process. For example, if the measure fails to provide correct facts about the process being measured, it could lead to poor decisions followed resulting in catastrophic actions. The car industry is one example, where on occasions the OEM (Overall Equipment Manufacturer) is obliged to recall cars from the market because they are faulty. All the actors within the car industry manufacturing supply chain can be responsible for corrective actions. The supply chain of Heavy Vehicle manufactures is similar to the car industry i.e. OEM and vehicles. However, there are some differences: 1) the weight: the products of Heavy Vehicle manufacturers, e.g. fork lifts, container handlers, rollers, pavers, planners etc, are designed to be heavy, in contrast to car manufactures, where lighter cars are considered better; 2) the number of suppliers: the parts, e.g. engine, transmission. A few large manufactures of e.g. engines, supply many competitors in the market, unlike the car industry, where several manufacturers offer a variety of models, thus providing a range of engine options. These are just two examples of differences

between the supply chains of Heavy Vehicle and car manufactures. In contrast to other branches, the car industry is often mentioned as a good example of how to measure the performance of their supply chain. The primary aim of this study is to present the Supply Chain Performance measures and its metrics focused on by two Heavy Vehicle manufacturers, Kalmar Industries and Dynapac, as a result of the type of supply chain (efficient, quick, lean, hybrid or agile supply chain) they operate in and their position in it. We will also attempt to describe what type of supply chain performance measures should be measured, depending on where in the supply chain the supplier or customer operates e.g. upstream or downstream. The aim is also to present suitable measures, sub-measrues and metrics that manufacturers of Heavy Vehicles could measure to track performance within their supply chain. This may be an interesting contribution to existing theory and the project could deepen existing knowledge of the types of Supply Chain Performance Measures and metrics that are vital for Heavy Vehicle manufacturers to measure. The following four will be analysed in depth: quality, delivery, cost/price and flexibility. These measures are often directly connected to the physical material flow, referred to by purchasing managers when selecting suppliers, and used as supply chain performance measures.

THEORETICAL FRAMEWORK

A general description of the supply chain and its performance

There are many descriptions of supply chains (Singh 1996; Christopher 1998; Mason-Jones and Towill 1998). Several researchers appear to agree that it mainly consists of three elements**:** physical material flow, information flow and the financial flow. The supply chain also includes several members who are positioned within it, either upstream or down stream. However, the view of the supply chain has changed over time from an internal to a more external focus i.e. an internal supply chain to an integrated synchronised supply chain. The performance of the supply chain has been widely covered in research. Several recent studies (Shepard and Günter 2005; Gunasekaran, Patel et al. 2001; Hoek van 2001; Landeghem van and Persoons 2001; Otto and Kotzab 2001; Lambert and Pohlen 2001) highlight the need to measure the efficiency of an integrated supply chain. Efficiency can best be described by customers. Petroni and Panciroli (2002) ague that customers usually retain a supplier who has the highest aggregate score on: price, quality, flexibility of production and delivery times. De Toni, Nassimbeni et al. (1994) claim that an efficient, high quality supply chain depends on achieving high-level performance in terms of cost, quality and time-to-market. Hayes and Wheelwright (1984) were the first to present methods for assessing operational strategy by means of four generic competitive priorities; quality, cost, flexibility and delivery. These priorities are the dimensions on which a company chooses to compete within a target market. Their original formulation was applicable to all functions. Hill (2002) also addresses competitive priorities such as price, cost reduction, delivery reliability, delivery speed, quality conformance, increased flexibility – demand as well as product range and design, which he describes as order-winners or qualifiers. Since the beginning of the manufacturing era, performance measures have been important for organisations as a means of trying to obtain knowledge about what is happening around them. Lambert & Pohlen state that a well crafted system of supply chain metrics can lead to competitive advantage through differentiated services and lower costs. A supply chain performance measurement system consists of a set of parameters that can fully describe the logistics and manufacturing performance of both the whole supply system, as perceived by end customers, and of each actor in the chain, as perceived by downstream players. Several researchers (Beamon, 1999; Chan and Qi 2003; gunasekaran et al., 2004; De Toni and Tonchia, 2001; Chan, 2003) have tried to design measurement systems to evaluate supply chain performance, but these designs appear to have several limitations: no reference to strategy; focus on cost to the detriment of non-cost indicators; lack of a balanced approach; insufficient focus on customers and competitors; loss of supply chain context, thus encouraging local optimization and lack of system thinking (Shepherd and Günter, 2006). Perhaps the best known is the supply chain operations reference (SCOR) model,

developed by the Supply Chain Council in 1997 and described as a "systematic approach for identifying, evaluating and monitoring supply chain performance". The idea behind the model is to measure the supply chain at multiple levels. Single indicators e.g. cost or time, cannot adequately measure supply chain performance. Shephard and Gunter argue that one of the main limitations of this model is that it does not offer a systematic method for prioritising measures, although recently some attempts have been made to address this weakness (Huang et al., 2004; Li, S. et al., 2005; Chan and Qi, 2003). The performance of a supply chain can be viewed as a system of measures e.g. quality, delivery, flexibility and cost/price. An example of a supply chain performance measure could be the measurement of quality might be: *"the number of products delivered without defects or the probability of a product malfunctioning within a given period*". Metrics can then be described as the system of parameters or methods of quantitative assessment of a process, in addition to the means of carrying out such measurements. Metrics define what is to be measured and are usually area specific, which means they are only valid within a certain domain and cannot be directly benchmarked or interpreted outside it e.g. supply chain measure and metrics. Table 1 shows and example of supply chain performance hierarchy.

Supply Chain Performance		
Measure	**Example of sub measures**	**Example of metrics**
Quality	The degree to which a product is manufactured to the agreed specification	% of reclamation
Delivery	The ability to consistently deliver on the agreed due date	% of on time delivery
Flexibility	The ability to effectively produce a wide variety of different products	X pieces of variances
Cost/price	The ability to produce products at a low cost. The ability to offer a lower product price than direct competitors.	X SEK

Table 1, Example of supply chain performance measures and its metrics

Organisations today try to measure their overall performance in terms of customer satisfaction, and while the measures vary, they usually include quality (of the product) and delivery time. To generate this knowledge the organisations have to figure out what performance measure and its metric that are to be prioritised. As Robson (2004) states "without the knowledge of the exact circumstances under which a measurement system either will or will not improve the performance, it is difficult to genuinely justify the additional cost of implementing a measurement system".

Different types of supply chains

Cigolini et al (2004) present three main factors that could play a major role in prompting organisations to adopt a particular SCM strategy. 1) the dominant phase in the end product's life cycle 2) the inherent structural complexity of the end product and 3) the type of supply chain. The first factor is described by Hayes and Wheelwright (1984), who defined four phases, which are now classical; introduction, growth, maturity and decline. The type of product an organisation manufactures can be categorised by means of this classic model. The second factor is defined by Cigolini et al as the structural complexity of the end product, namely the number of parts, subassemblies and levels of the bill of materials involved in the end product, which determine the number of manufacturing processes, suppliers and technologies that have to be managed and co-coordinated. They also point out that the higher the product complexity, the harder the managerial challenges associated with procurement and manufacturing. Huang, Upphal et al (2002) claim that products can be categorised into three types; functional, innovative and hybrid, and provide examples of each. *Functional products* are generally simple and synonymous with standard and

commodity products. Demand for such products can be accurately forecast, and their market share remains fairly constant. The manufacturing process is well defined and involves an established, long-term relationship with suppliers in terms of material quality, delivery times and quantity discounts. Huang, Uppal et al (2002) claim that this type of product should be manufactured and introduced to the market with the help of an LSC. *Innovative products* can be new products developed by organisations to capture new markets and are designed to be acceptable to potential customers. They can also be derivative products aimed at capturing a larger share of the market. Huang, Upphal et al (2002) argue that *hybrid products* consist of either different combinations of standard components, or a mix of standard and innovative components. The third determinant, the supply chain characteristic, refers to efficient, quick or lean supply chains. An *efficient supply chain, ESC*, brings product to the market which can be broadly considered as commodities and are often sold in high volumes (e.g. groceries, newspapers …). Because of the stability of product flows, these organizations can invest in large and capital-intensive facilities, and improvement initiatives are focused on operations rather than product innovation. A *quick supply chain, QSC*, (e.g. fashion apparel, white products) can be defined as "products whose demand is difficult to forecast". These types of organisations invest in manufacturing systems with a high variable vs. fixed costs ratio, due to the fact that manufacturing flexibility is highly valuable. A *lean supply chain, LSC*, (e.g. automobile) has intermediate characteristics: firms do not mainly compete on product price or novelty, but simultaneously on price, novelty, quality, and customer service. A LSC employs continuous improvement processes to focus on the elimination of waste or non-value stops across the chain and employs both lean production and time compression in parallel in order to be economical, flexible and responsive. Meanwhile, innovative products have a different focus that can lead to the capture of new markets and are designed to be acceptable to potential customers. Huang, Uppal et al (2002) argue that these types of products are usually characterized by uncertain demand, unstable design and are in the introduction or growth stage of the product life-cycle, thus justifying the use of an agile supply chain (ASG). Huang, Uppal et al (2002) state that a hybrid supply chain could be the best choice for a car manufacturer and provide an example of the manufacture of an automobile in order to illustrate the fact that some components with different specifications may contain innovative features. As a result, these components may be produced using either lean or agile techniques. A hybrid supply chain could therefore be appropriate, as it consists of a mix of both lean and agile techniques. Cigolini, Cozzi et al. (2004) provide an example of how different types of products lead to a certain supply chain i.e. efficient, lean or quick. There are several types of supply chain described in the literature. The hybrid supply chain presented by Huang, Uppal et al (2002) seems to be the newest. These different types of supply chains described above are those discussed and referred to in research.

Scope for measuring supply chain performance

Often the first step in assessing performance is to analyze the way in which order-related activities are carried out. In order to do this, the most important issues, i.e. the order-entry method, order lead-time and path of order traverse, must be considered (Gunasekaran, Patel et al. 2001). The production process in manufacturing organisations is often an activity that has a major impact on production cost, quality and speed of delivery. These metrics could correspond to three headings (Gunasekaran, Patel et al. 2001): Range of products and services, capacity utilization and effectiveness of scheduling techniques. These measures could be called functional measures. *Functional measures* (type 1) depict the performance of a single activity within a function of the chain, e.g. flexibility (mix) of production – the ability to effectively produce a wide variety of different products. These measures do not actually represent a supply chain measure but rather a functional one. However, Holmberg (2000) claims that in order to implement SCM within an organisation, the internal perspective on performance measures has to be expanded to include both "interfunctional" and "partnership" perspectives and inward-looking and self focused attitudes in

the management approach avoided. There are also measures that span over several functions and show the performance of several connected functions i.e. head-processes. Metrics such as cost (total cost), quality (part per million defects, PPM), non-conformities and delivery lead-time are appropriate for measurement. These type of measures could be called *Internal integrated measures* (type 2), as they depict performance across functional boundaries within the firm, e.g. quality (conformance) – the ability to manufacture a product whose operating characteristics meet established performance standards; Cost (total cost) the ability to minimize the total cost of production (labour, materials, and operating costs) – through efficient operations, process technology, and or scale economies; Delivery (speed) – the ability to minimise the time between the receipt of a customer order and final delivery. Other measures to consider are quality (conformance, reliability), delivery performance (reliability), product price and flexibility of scheduling and production. These types of measures can be called *One sided integrated measures* (type 3), as they depict performance across organisational boundaries and measure chain performance across supplier or customer boundaries, e.g. total cost, total lead-time, delivery (speed) – the ability to respond in a timely manner to customer needs. Some researchers (Rushton and Oaxly 1991; Thomas and Graham 1996) claim that the largest cost component of logistics is transportation costs in the total chain. They hold that the transport cost is always the highest part of the total distribution cost. It therefore seems important to treat delivery and cost as a high priority metric. Stewart (1995) identifies the following measures of delivery performance: delivery-to-request date, delivery-to-commit date, and order fill lead-time. These types of measures can be identified as *Total chain measures* (type 4) that depict performance across organisational boundaries and measure the performance of the complete supply chain, including links to suppliers and customers, e.g. total chain costs – the ability to minimise the total cost from supplier to end customer. The measurement situations (type 1-type 4) presented above can be linked to a model developed by the Supply-Chain Council (SCC), an independent, non-profit, global corporation, and based on a process view of the supply chain using four distinct management processes e.g. PLAN, SOURCE, MAKE and Deliver.. The SCOR model combined with different supply chain performance measure situations, (figure 1).

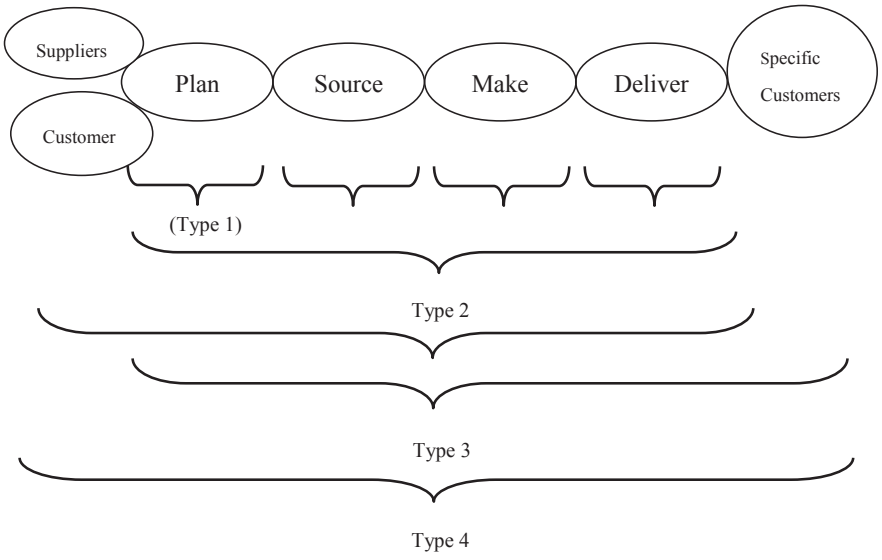


Figure 1. Four different types of supply chain performance measurement situations

RESEARCH APPROACH

The two heavy vehicle manufacturers are part of a "heavy vehicles" group, and also support CIL, Centrum for Informationlogistics, Ljungby, Sweden. The manager of CIL first contacted these two manufacturers to invite them to take part in the research project, after which we contacted them and described the research project. The companies that we where about to study gave us their full support at the start of this project. Top executives allowed us to access to required data i.e. personnel and meetings. We employed a qualitative research process, as our aim was to present the supply chain performance measures and metrics focused on by these two Heavy Vehicle manufacturers as a result of their position in the supply chain. We limited our interviews with managers to 2-3 hours per interview. At an early stage we made it clear that we wanted to interview the "owners" of the performance measure i.e. those who were responsible for measuring the supply chain performance, e.g. quality, delivery, cost (price) and flexibility. Together with the two manufacturers, we then defined our respondents as follows: Dynapac's Quality Assurance Purchasing Manager, Production Manager and Purchasing Manager and Kalmar Industries' Quality Manager (also production manager at site 1 (Lidhult), Production Manager site 1 and Production Manager site 2 (Ljungby), Purchasing Manager (site 1 and 2) and finally Operating Purchasing Manager (site 1). The total number of respondents was seven.

The interview questions were:

Questions related to the supply chain

- How would you characterise the supply chain that you operate, efficient, quick, agile, or lean?
- In which part of the supply chain does your organisation operate (upstream or downstream)?
- Are you currently working in a project to improve the actors in any part of the supply chain?
- *Questions related to performance, measures and metrics*
- Could you describe how the organisation measures performance as a whole?
- Which of the following measures are important for your organisation as a whole: Quality, delivery, flexibility, cost (price), or others?
- Could you rank the following performance measures, Quality, delivery, cost, flexibility?
- What performance measures do you measure within our function?
- What metrics do you use when you measure?
- What metrics do you measure across organisational boundaries?
- How do your products win orders in the marketplace?

The issues addressed in the interviews were based on earlier supply chain performance research (Chibba, Hörte 2003) and supply chain performance theories (Robson, 2004; Cigolini, Cossi et al, 2004; mlf. Staff interviewed included the managers from each company responsible for supply chain performance. The theoretical framework was then compared with the results from the empirical data. The main theoretical base discussed above (supply chain performance) provided the necessary framework for sorting and analysing the data generated. The SCOR model combined with different supply chain performance measure situations (figure 1) was used to sort the supply chain performance measures and its metrics of these two manufacturers.

RESULT AND ANALYSIS

The characteristics of the heavy vehicle supply chain

The supply chain of the two heavy vehicle manufacturers can be described as a hybrid one (Huang, Uppal et. al, 2002) i.e. cost minimisation, mass customisation, and adaptability for future changes. However, most respondents mentioned an ambition to work towards a lean supply chain, LSC. The respondents seemed to agree that the lean supply chain concept is right for the heavy vehicle industry. The skill required by these two heavy vehicle manufacturers can be described as twofold, products and service. They provide a service based on several years of "know how" e.g. core competence: lifting heavy goods, making roads etc. This is in contrast to the automotive industry,

where the core competence is engine design and development, although engines of varying horsepower may be produced for the same model, as per customer requirement. Both of the heavy vehicle manufacturers have a significant difference in their sources of components and articles. All of the respondents were clear about the part (upstream or downstream) of the supply chain in which their organisation operates. Both heavy vehicle manufacturers see themselves as an Overall Equipment Manufacturer, OEM that works close to the end customer.

Both heavy vehicle manufacturers interact with their suppliers to a limited extent. Only Kalmar Industries have a relatively structured form of interaction with suppliers, while Dynapac have more of an ad hoc interaction with suppliers. At present, Kalmar Industries do not have the resources to interact to a greater degree with suppliers and therefore only help and interact with their 1st tier supplier. No systematic on-going projects with suppliers were taking place at Dynapac, although there were a number of small projects with expected outcomes related to shorter lead-times from the supplier and in house, delivery performance to customer and average lead-time.

Performance measures and its metrics
Both manufacturers measure the performance within their own organisation and across the supply chain. They make use of measures within internal functions and measure the internal supply chain as well as their suppliers' performance and their own customer performance, i.e. 1st tier supplier and collect the voice of the customer. However, they do not fully capture the whole supply chain performance, i.e. measures over organisational boundaries e.g. from 3rd suppliers to end customer and user.

Functional performance measures within the internal supply chain – Type 1
Kalmar Industries' purchasing department measures price development (%), payment (days), number of suppliers, number of articles, volume flexibility (% per year for flexibility, stock turnover (times per year) and stock value in SEK. The production at site 1 is measured internally by means of the following measures and metrics: lead-time, productivity (hours, time wasted, time waiting), quality (PPM, defects per manufactured item) and slack in production plan. The production at site 2 is measured by means of: direct labour i.e. % of minutes registers, pre-calculated time divided by used time, the target is 1. According to the Production Manager (site 2) direct labour should be over 80% (=direct time/appearance time), total productivity and quality (PPM, defects per manufactured item). At Dynapac the purchasing department measures: the purchasing price per unit (changes), which is measured every month, the number of orders that are not completed, how much is bought in from low salary countries, how many articles/parts can be ordered through call off (30-50%) and stock value. The production at Dynapac points out that the most important measures for both workers and owners are: cost (work-time and machine) productivity (money), how often a worker is present at work (present time/machine).

Internal Integrated measures – type 2
Kalmar Industries measure the lead-time (weeks) and cost (SEK) from order to delivery to end customer. They also measure inventory turnover (times per year) and quality (PPM). Dynapac measures internal delivery performance i.e. "how close they are to the production plan", the customer receives information once a week and Dynapac measures the following on a daily basis; lead-time and inventory turnover (times per year), line stop (time), quality (PPM), the number of orders that are not completed, total cost (order to delivery) and productivity.

One sided integrated measures – type 3
At Kalmar Industries the external measures are: delivery performance of suppliers, quality of suppliers (PPM), lead-time of suppliers (weeks). They also measure when they receive the product

from the suppliers i.e. the right day, too late, too early (days) and cost (SEK), lead-time average and claims. They keep statistics of how much is purchased from low salary countries and how many parts can be ordered through call off (30-50%). They measure the number of payment days from suppliers (at least once a month). Many of these measures are presented to top management. Dynapac uses almost identical performance measures. They measure suppliers in terms of: quality (PPM), claims (st, cost) and delivery precision (measured by material planner). Dynapac's customers are interested in the following: the right quality, i.e. the number of zero defects machines and turnover - poor quality costing and claims from market. Dynapac also measure several aspects of the delivery performance to customers. Every week they measure the performance of the sell companies, distributors, their workshop although this varies. They also measure the lead-time to customer (weeks). Dynapac works with the concept of modular thinking.

Total chain measures - measures across organisational boundaries – type 4
Total chain measures depict performance across organisational boundaries, i.e. suppliers, the organisation and customers. In both cases an organisation's supply chain performance is measured with KPI, Key Performance Indicators, i.e. indicators of how well the organisation manages to deliver to the market. In both cases these KPI are input to top management, who can then interpret the facts and use the information to undertake necessary actions. Typical measures used by Kalmar Industries are delivery reliability, total lead time and real cost from supplier order to end customer (sell company). These types of measures exist in certain supply chains i.e. parts which are important, due to the fact that there are few suppliers, critical componets/parts etc. Kalmar Industries mention delivery reliability as one measure, but divided into several parts i.e. suppliers, customers, internal and the site delivery reliability to the market. Quality, warranty % of total turnover, direct cost reduction, productivity, (hours for respective group), product cost (index), material price (index), quality (warranty against product lines in SEK), stock value (SEK), lead-time, cost and quality (PPM). Kalmar Industries keep a list of its 20 worst 1st tier suppliers and also have an open day with their first tier suppliers. Dynapac argued that lead-time is extremely important due to the fact that almost everything has to do with the time factor. They measure the "total lead-time" from point of order to when the machine is booked and ready for delivery, which could be classified as a total chain measure. Dynapac has identified some Key Performance Indicators for their overall business: Quality, Delivery and Productivity (QLP). However, these performance indicators are not applicable for all functions within Dynapac.

Performance that wins orders
These two multinational heavy vehicle manufacturers have a very sound reputation and history. Dynapac was founded in 1934 and focused its efforts on supplying the best in terms of machine performance to the road and to the civil construction industries. Dynapac is a full line global supplier. Kalmar Industries has a long history dating back to the end of 1940. Since then it has delivered more than 65 000 machines to over 140 countries. Both LEs win orders as a result of their good reputation and history, their focus on quality, delivery and cost. One can say that they are in the premium segment of their type of products. The measure of quality is the most important measure among the respondents. Quality (metric: quality conformance, the degree to which a product is manufactured to the agreed specification) is the most important measure but also, as stated by one respondent: *"quality is important but also service after the first 50 hours of use"* i.e metric: quality serviceability, the ease of servicing (planned or breakdown) to include the speed and provision of after sales service). The measure of delivery (metric: delivery reliability), the ability to deliver consistently on the agreed due date, is rated in second place by the respondents. One respondent argued that all measures are equally important because they are connected to each other. Below presents the different supply chain performance measures that these two large multinational manufacturers of Heavy Vehicles use in different measurement situations.

Measurement situation	Performance measure	Sub measure	metric
Type 1	Quality	Quality conformance	PPM
Functional measures	Cost	Productivity	Man hour/machine
Type 2	Delivery	Lead time	Days
Internal supply chain measures	Cost	Direct labour cost	SEK/machine
Type 3	**Supplier**	**Supplier**	**Supplier**
One sided integrated measures i.e. supplier or customer	Quality	Quality conformance	PPM
	Delivery	Reliability	%
	Price	Price/purchased item	SEK/item
	Customer	**Customer**	**Customer**
	Delivery	Reliability	%
	Quality	Quality conformance	PPM
	Service after delivery	Time to establish service for customer	Hours
Type 4	Total cost	-	SEK
Total chain measures	Total lead time	-	Weeks

Table 2 S*upply chain performance measures at two heavy vehicle manufacturers*

Conclusion

These two multinational heavy vehicle manufacturers (Dynapac and Kalmar Industires) have a history of over 50 years in their sector, and both claim that their products are in the premium segment i.e. high quality. Both manufacturers have a identical type of supply chain. Their supply chain can be characterised as a *hybrid supply chain*. Huang, Uppal et al. (2002) argue that the purpose of a *hybrid supply chain* is to allow companies to interface with the market to understand customer requirements and maintain adaptability. They also try to achieve mass customization by postponing product differentiation until final assembly by adding innovative components to existing products. Their approach when choosing suppliers is focused on low cost and high quality, along with the capacity for speed and flexibility. Both manufacturers focus on shorter lead-times buy not at the expense of cost. They also operate in the same part of the supply chain i.e. downstream and near the sales company and end customer. Their supply chain measures and metrics are almost identical. Both have consistent and well defined internal supply chain measures. Quality (product quality) and delivery (on time) seem to be the most important measures and metrics focused on by these two heavy vehicle manufacturers. They have defined their Key Performance Indicators as a measure to describe *"how well the organisation manage*s *to deliver to market"*. Most of these performance indicators can be defined as "one sided integrated measures" which include first tier suppliers, the organisation, sales company and end customer. However, they do not measure the total chain, i.e. from 2nd and 3rd suppliers to end user, thus it would be interesting to do so, especially with regard to critical components i.e. engine, transmission parts. They measure: delivery reliability, quality, cost and lead-time. They interact with their suppliers to some extent. Kalmar interacts systematically with 1st tier suppliers. They do not have the resources to interact to a greater degree with other suppliers upstream the supply chain. Kalmar Indutries works towards prevention actions while Dynapac have more of an ad hoc interaction with suppliers. At Dynapac the interactions with suppliers have a corrective action focus, as opposed to preventative actions. The respondents were clear that the most important supply chain measure is quality with its metric: "the degree to which a product is manufactured to the agreed specification", followed by delivery and its sub measure: delivery reliability (time). Dynapac and Kalmar Industires have a supply chain performance focus on quality, delivery and cost, which constitute their order winning criteria in the marketplace. It seems to be more important to their customers to receive their orders on time rather than the product arriving late but without the risk of some defects or malfunctioning parts. Therefore it is extremely important for these two large multinational manufactures to provide after sales service.

REFERENCES

Beamon, B. M. (1999), "Measuring supply chain performance," *International Journal of Operations & Production Management*, Vol. 19, No. 3, pp. 275-292.

Chan, F.T.S. (2003), "Performance measurement in a supply chain", *International Journal of Advanced Manufacturing Technology*, Vol. 21, pp. 534-48.

Chan, F.T.S. and Qi, H.J. (2003), "An innovative performance measurement method for supply chain management", *Supply Chain Management: An International Journal*, Vol. 8, Nos. 3-4, pp. 209-23.

Christopher, M. (1998), *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improvning Service*, Financial Times - Prentice Hall, Harlow.

Cigolini, R., M. Cozzi, et al (2004), "A new framework for supply chain management" *International Jorunal of Operations & Production Management*, Vol. 24, No. 1, pp. 7-41.

De Toni, A., G. Nassimbeni, et al. (1994), "Service Dimensions in the Buyer-Supplier Relationship: A Case Study" *International Journal of Physical Distribution & Logistics Management*. Vol 24, No. 8, pp. 4-14.

De Toni, A. and S. Tonchia (2001), "Performance measurement systems: Models, characteristics and measures." *International Journal of Operations & Production* Management Vol. 21, No.1/2, pp. 46-70.

Gunasekaran, A., C. Patel, et al. (2001), "Performance measures and metrics in a supply chain environment" *International Jorunal of Operations & Production Management* Vol. 21, No.1/2, pp. 71-78.

Gunasekaran, A., Patel, C. and McGaughey, R.E. (2004), "A framework for supply chain performance measurement", *International Journal of Production Economics*, Vol. 87, No. 3, pp. 333-47.

Hayes, R. H. and S. C. Wheelwright (1984). *Restoring our Competitive Advantage.* Wiley. New York.

Hill, T. (1993), *Manufacturing strategy, second edition*, Palgrave, New York.

Hill, T. (2000), *Manufacturing strategy, third edition*, Palgrave, New York.

Hoek van, R. I. (2001), "The contribution of performance measurement to the expansion of third party logistics alliances in the supply chain", *International Jorunal of Operations & Production* Management Vol. 21, No. 1/2, pp. 15-29.

Holmberg, S. (2000), "A systems perspective on supply chain measurements" *International Journal of Physical Distribution & Logistics Management* Vol. 20, No. 10, pp. 847-868.

Huang, S.H., M. Uppal, (2002), "A product driven approach to manufacturing supply chain selection" *Supply Chain Management: An International Journal*, Vol. 7, No. 4, pp. 189-199.

Huang, S.H., Sheoran, S.K. and Wang, G. (2004), "A review and analysis of supply chain operations reference (SCOR) model", *Supply Chain Management: An International Journal*, Vol. 9, No. 1, pp. 23-9.

Krause, D. R. and M. Pagell (2002), "Strategic consensus in the internal supply chain: exploring the manufacturing purchasing link", *International Journal of Production Research* Vol. 4, pp. 3075-3092.

Lai, K., E. W. T. Ngai, et al. (2001), "Measures for evaluating supply chain performance in transport logistics", *Transportation Research*, Vol 38, pp. 439-456.

Lambert, D.M. and Pohlen, R.L. (2001), "Supply chain metrics", *The International Journal of Logistics Management*, Vol. 12 No. 1, pp. 1-19.

Landeghem van, R. and K. Persoons (2001), "Benchmarking of logistical operations based on a casual model" *International Jorunal of Operations & Production* Management, Vol. 21, No. 1/2, pp. 254-266.

Li, S., Subba Rao, S., Ragu-Nathan, T.S. and Ragu-Nathan, B. (2005b), "Development and validation of a measurement instrument for studying supply chain practices", *Journal of Operations Management,* Vol. 23, pp. 618-41.

Maloni, M.J. and Benton, W.C. (1997), "Supply chain partnerships: opportunities for operations research", *European Journal of Operations Research*, Vol. 101, pp. 419-29.

Mason-Jones, R. and R. D. Towill (1998), "Time compression in the supply chain: information management is the vital ingredient" *Logistics Information Management*, Vol. 11, No. 2, pp. 93-104.

Otto, A. and H. Kotzab (2001), "Does Supply Chain Management really pay? - Six perspectives to measure the performance of managing a supply chain", *Nurnberg, Lehrstuhl fur Logistik, Friedrich-Alexander-Universiteät***:** Vol. 6 No. 4, pp. 174-188.

Petroni, A. and B. Panciroli (2002), "Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry", *European Journal of Purchasing & Supply Management*, Vol. 8, pp. 135-149.

Robson, I. (2004), "From process measurement to performance improvement", *Business Process Management Journal,* Vol. 10, No. 5, pp 510-521.

Shepherd, C. and Gunter, H. (2006), "Measuring supply chain performance: current research and future directions", *International Journal of Productivity and Performance Management*, Vol. 55, No.3/4, pp, 242-258.

Singh, J. (1996), "The importance of information flow within the supply chain", *Logistics Information Management* Vol. 9, No. 4, pp. 28-30.

Stewart, G. (1995), "Supply chain performance benchmarking study reveals keys to supply chain excellence", *Logistics Information Management*, Vol. 8, No. 2, pp. 38-44.

Tracey, M. and C. L. Tan (2001), "Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance", *Supply Chain Management: An International Journal*, Vol. 6, No. 4, pp. 174-188.

Paper 4

Hörte, S.Å., Barth, H., Chibba, A., Florén, H., Frishammar, J., Halila, F., Rundquist, J. and Tell, J. (2008). Product Development in SMEs: a literature review. *International Journal of Technology Intelligence and Planning*, 4(3): 299–325.

Product Development in SMEs: a literature review

Sven Åke Hörte*, Henrik Barth, Aron Chibba and Henrik Florén

Centre for Technology, Innovation and Marketing Management (CTIM2), School of Business and Engineering, Halmstad University, Box 823, S-301 18 Halmstad, Sweden
E-mail: sven-ake.horte@hh.se E-mail: henrik.barth@hh.se
E-mail: aron.chibba@hh.se E-mail: henrik.florén@hh.se
*Corresponding author

Johan Frishammar

Department of Business Administration and Management, Luleå University of Technology, Sweden
E-mail: johan.frishammar@ltu.se

Fawzi Halila, Jonas Rundquist and Joakim Tell

Centre for Technology, Innovation and Marketing Management (CTIM2), School of Business and Engineering, Halmstad University, Box 823, S-301 18 Halmstad, Sweden
E-mail: fawzi.halila@hh.se E-mail: jonas.rundquist@hh.se
E-mail: joakim.tell@hh.se

Abstract: Product Development (PD) in Small and Medium-sized Firms (SMEs) is a long-neglected research area, and little cumulative work has been conducted previously. The purpose of this paper is to provide a first overview of the area of PD in SMEs. In doing so, we draw upon a sample of 149 peer-reviewed research papers selected from an initial sample of 5694 papers. The review provides tentative answers to issues such as the analytical and methodological approaches of the papers, which topics or areas of research have been focused on by previous scholars, and what kinds of topics that are well covered.

Keywords: product; development; SMEs; small and medium-sized firms; literature review.

Reference to this paper should be made as follows: Hörte, S.Å., Barth, H., Chibba, A., Florén, H., Frishammar, J., Halila, F., Rundquist, J. and Tell, J. (2008) 'Product Development in SMEs: a literature review', *Int. J. Technology Intelligence and Planning*, Vol. 4, No. 3, pp.299–325.

Biographical notes: Sven Åke Hörte is a Professor in Sociology at Halmstad University and Professor in Industrial Management at Luleå University of Technology. He is also the leader for the Centre for Technology, Innovation and Marketing Management (CTIM2) at Halmstad University.

Henrik Barth, Henrik Florén, Fawzi Halila and Joakim Tell are all Assistant Professors at Halmstad University.

Johan Frishammar is an Assistant Professor at Luleå University of Technology.

Aron Chibba and Jonas Rundquist are both doctoral students in Industrial Management at Halmstad University.

1 Introduction

The importance of Product Development (PD) for renewal, growth, and survival of the firm has created incentives for researchers in different fields and disciplines to study this activity. PD is often described as a form of meta-competence in the literature, as it is thought to influence many other competences in the firm (see e.g., Harmsen et al., 2000). More specifically, PD is important since it contributes to competence building, product differentiation, and firm renewal (Bounfour, 1999; Harmsen et al., 2000) but also to competitiveness and growth of the firm (Clark and Fujimoto, 1991; Cooper and Kleinschmidt, 1991; Griffin, 1997; Bogue, 2001).

Although PD might be less important for some types of firms (e.g., craft-based firms and firms in highly stable industries), the importance of PD applies to firms of all sizes – large as well as small. As 99% of all firms can be classified as being Small or Medium-sized (SMEs) (European Commission, 2002) and since SMEs are often acknowledged to be an important source of growth and innovation in society (Davidsson et al., 1996; Acs and Preston, 1997), it is somewhat paradoxical that the literature on PD is so heavily biased towards large firms.

An examination of classical studies in the field of PD reveals that these papers either exclude, or at least do not deliberately focus on, the situation of SMEs. The older empirical studies (e.g., Booz-Allen and Hamilton, 1968, 1982) do not explicitly focus on the situation of SMEs. For example, the firms in many studies are quite large, often with sales of at least $1 billion. The same can be said for literature reviews conducted during the 1990s (Craig and Hart, 1992; Rubinstein, 1994; Brown and Eisenhardt, 1995; Griffin, 1997) as well as more recent ones (Jong and Vermeulen, 2003; Perks and Wong, 2003). Recently conducted empirical studies (e.g., Griffin, 1997; Cooper et al., 2004) also neglect the SME angle.

Despite the importance of PD for SMEs, we note that this area is largely neglected. Although we have engaged in extensive literature searches, we have failed to locate any review paper or papers providing a comprehensive overview of the field. The present paper aims to diminish this knowledge gap with a survey of literature in the area, covering nearly 150 peer-reviewed research papers. The purpose of the paper is threefold. First to give an initial grasp of the area of PD in SMEs by describing and analysing the existing work on the topic, second to discuss the development of the field of research in

terms of degree of maturity, and third, suggests research themes to be addressed in the future.

The paper is structured as follows. First we give an account of the methodological approach adopted in this study, and thereafter the results are presented. The paper ends with conclusions and suggestions about future research.

2 Methodological approach and 'data'

This section describes the approach that we have followed to develop the reference database. The approach is a review of literature, in our case scientific journal papers, following the suggestions by Hart (2001). He describes a literature review as the selection of available documents on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed.

2.1 Selection of journal papers

The selection of journal papers was done in four main steps. The aim of the first step was to build a database consisting of papers on PD in SMEs. The second step aimed to 'clean up' the database by removing all papers not meeting a set of predefined criteria. The third step consisted of a second clean-up operation as well as quality assessment of the remaining papers. The papers 'surviving' the three steps were used in the subsequent analysis. The main selection of papers was conducted between September 2003 and December 2004, with some subsequent updates during the fall of 2007. The selection process is summarised in Table 1 and briefly commented.

Table 1 Selection process of journal papers for further analysis

Step	*Activity*	*No. of data bases*	*No. of papers*
1: 1	Selection of databases and papers	13	5694
1: 2	First removal of duplicates		3397
2: 1	Papers not meeting the peer-review criterion removed. Correction of bibliographic references in endnote database.		1863
2: 2	Review based on reading abstracts. Removal of papers not meeting stated criteria and of some additional duplicates. Correction of bibliographic references in database		919
3: 1	Removing papers not meeting stated criteria. Based on full paper. Correction of bibliographic references in database		656
3: 2	Last quality control of the database		197
4	Removing papers about innovation and innovation systems		136
5	Adding papers published 2004–2005		13
6	The result: A database of selected papers to be analysed		149

The first step of the selection process started with a survey of journal databases available at the institution where all authors were affiliated at the time. In total, 68 databases covering journals were found, but only 13 databases contained references to peer-reviewed scientific papers. The following databases were used: Academy of Management, ABI/Inform Global, Ebsco host/Academic search elite, Emerald, Cordis, First Search/EconLit, First Search/Papers, First Search/Proceedings, First search/Applied Science and Technology, IEEE Explore, ISI-Web of Science, Science Direct, and Sociological Abstracts.

All papers meeting a predefined set of search criteria were imported into a reference database (End Note). As the main focus of this paper is on PD in SMEs, the search criteria were combinations of the words in the two groups below:

1 small firm(s)/small company/small companies/
small enterprise(s)-/SME/SMF/entrepreneurship

2 PD/PD/'research and development'/R&D.

These terms were chosen as they are synonyms to the two main concepts of this paper (PD and SME). An example of a search string is [entrepreneurship AND research and development]. In a second phase of the first step, all identified duplicates were removed, resulting in a database consisting of 3397 references.

The second step started with a review of the journals where the papers were published. In order to secure the scientific quality of the research included in the review, all papers not published in journals using a double-blind review process were removed from the database. As a second phase of step 2, all abstracts of the papers were reviewed and all papers not focusing on SMEs and PD were removed. A review of the database containing identified papers was done subsequently and bibliographic references were corrected. Additional duplicates were then removed. After step 2, the database contained 656 papers.

The third step started with the utilisation of the same two criteria, but here the full papers were judged. This action resulted in 197 papers deemed relevant.

During the initial analysis it became evident that many papers discussed different aspects of innovation, not always related to product innovation or PD. The selected papers were once more examined and papers discussing innovations and innovation systems, not directly related to the development of products (goods and services), were removed from the database, making us ending up with 136 papers.

In 2007 an additional collection of papers published in 2004–2005 was made. The reason for leaving out 2006 and 2007 was that some journals are not accessible on-line before one year after publication. Both the selection and the classification of the resulting selection of papers followed a more simple procedure compared to the main study. The four databases giving the largest numbers of returns in the first step were searched: ABI, Emerald, JSTOR and Academy of Management. The search criteria were combinations of the following words: small firm(s)/small enterprise(s), small company/small companies/SME/SMF and Product Development/PD/research and development/R&D. The selection process started with approximately 250 papers and ended up with 13 papers. Adding the 13 papers to the 136 provides a total of 149 papers to be analysed.

All in all, eleven researchers were involved in the selection process. The first two steps were carried out individually; each researcher searched one or two databases and

removed papers according to the criteria described above. The third step was done by teams of researchers. Each paper was read by a team of at least two researchers and removed if both researchers in the team agreed. A couple of papers were difficult to judge; when this situation arose, the decision to remove an paper was discussed by the complete team of researchers.

2.2 The quality of the classification

The 136 papers were classified according to the classification schemes described in section 3 below. All classifications were done twice by teams of two to three researchers, with rotation of the teams between classifications. All papers not classified in the same way in the two classification rounds were discussed first between the members of the classification teams and, if they could not agree, by the whole group of researchers. The idea with using multiple teams for classification was to increase the reliability of the classification procedure. The 13 selected papers from 2004-2005 were all classified by a single researcher.

3 Results

In order to classify and make sense of the papers, we used an a priori constructed classification scheme. There are indeed many ways to design such a scheme. One of our guiding principles was to use rather few categories, another being that it should be easy to decide whether an paper met the criteria of a specific classification. The categories are mutually exclusive or nearly so, but finding papers that belonged to only one category proved difficult since topics and research approaches often span several categories. Hence, when the papers were classified according to the topics covered in an paper, it was necessary to allow multi-classifications, as many papers covered more than one topic.

In the classifications of the papers according to their analytic and methodological approaches, we looked for the dominant approach. An paper that largely reports on a survey study, but also includes an illustrative case, has been classified as an empirical and quantitative paper. A detailed presentation of the classifications is presented in the following sections.

3.1 Analytical and methodological approaches of the papers

Many reviews of literature in a field of research discuss the methods used and the topics covered in the selected papers. Filippini (1997), for example, explores the field of operations management research. He discusses the research approaches and methods used in the papers that are published in leading journals of the field and the topics covered. The review of Dangayach and Deshmukh (2001) focuses on the field of manufacturing strategy. It discusses the topics covered and the analytical and methodological approaches of the published papers. In the field of PD research, Biemans et al. (2007) sum up 20 years of published papers in the Journal of Product Innovation Management. The papers cover, among other things, the research methodology of the papers and the subject areas covered.

Even if these reviews all discuss methodological issues, there is no consensus on the criteria for classifying the papers according to analytical or methodological approach. However, most researchers distinguish between papers based on empirical research and papers that are purely theoretical or conceptual. They also make a distinction among papers that aim to explore, describe or explain phenomena. Finally, researchers usually make a distinction between qualitative and quantitative research (Hardy and Bryman, 2004).

The classification scheme that we use follows and combines these lines of reasoning. We distinguish between three analytical and two main methodological approaches. The distinction between analytical approaches is based on the aim or purpose of the research. We follow the classical distinction between explorative, descriptive and explanatory types of studies, as discussed by, for example, Selltiz et al. (1967) and, with a focus on case studies, by Yin (1994). Exploratory studies have the purpose of formulating a problem for more precise investigation or for formulating hypotheses, while the purpose of descriptive studies is to portray accurately the characteristics of someone or something, or to determine the frequency with which something occurs or with which it is associated with something else. The purpose of an explanatory study is to test a hypothesis or a causal relationship between variables (Selltiz et al., 1967). The analytical approach, then, is about the formulation of purposes, aims and research questions of a study.

The methodological approach, on the other hand, concerns how the researchers plan to answer the research questions of the study. We define two main types of methodological approaches. The first does not make use of empirical data, except for illustrative purposes, but focuses on concept development, theoretical discussions and development of methods, approaches or theoretical models. We call this a conceptual approach. The other main type makes use of empirical data in the form of qualitative or quantitative research, or a combination of these two. We call this an empirical approach, with qualitative and quantitative empirical research as two main categories.

3.1.1 The analytical approach of the papers

It is common that the approach of the papers is to '*explore*' a phenomenon, often with the intention to provide a better understanding or to provide improved possibilities of further investigation. Among the papers with an explorative purpose is, for example, a study exploring the difficulties encountered in the implementation of changes to new PD in a Small to Medium-sized Enterprise (SME) in South Wales (Filson and Lewis, 2000).

Among the papers, the purpose of '*describing*' different types of phenomena is the most common. An example of an paper with a descriptive approach is a case study describing the efforts to improve new PD at a medium-sized cable manufacturer (Albin and Crefeld, 1994); a second example is an paper which examines two in-depth case studies that were carried out to establish whether and how learning occurred within companies developing new products (Gieskes et al., 2002). A third example is an paper providing empirical information on the problems experienced by engineers developing innovative products and processes for environmental protection. The study is based on information from a sample of 33 engineers (Caird et al., 1994).

About a quarter of the selected papers had an '*explanatory*' approach. They test hypotheses or model relationships considered to be causal. Papers with an explanatory purpose in the database are exemplified by a paper (Keizer et al., 2002) aiming to

determine which factors enhance innovative efforts of SMEs. This study uses a regression-based methodology to examine the importance of each factor, controlling for the other factors. Another example is a paper (Cohen et al., 1987) studying the relationships among firm and business-unit size and R&D intensity. The paper concludes that business-unit and firm sizes jointly explain less than 1% of the variance in R&D intensity, while industry effects explain nearly half the variance.

There are also some papers, often very theoretical, without any stated purpose or aim, which is more or less impossible to classify. These are listed as *Not applicable* in Table 2.

Table 2 The analytical approach of the papers

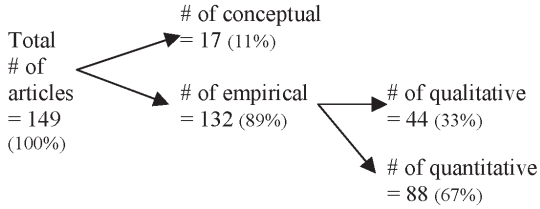
	No. of papers	*Percentage*
Explorative	47	32
Descriptive	57	38
Explanatory	38	25
Not applicable	7	5
Total	*149*	*100*

3.1.2 The methodological approach of the papers

Most of the selected papers are based on empirical data, although purely theoretical or conceptual papers also occur. The main difference between the two categories is that papers classified as empirical make use of empirical data for explorative, descriptive or explanatory purposes, while papers that do not use empirical data for such purposes, or do not use empirical data at all, are considered conceptual.

Only 17 papers in the database (11% of all selected papers) are conceptual (Figure 1). One of the papers classified as conceptual analyses some topics that characterise innovation in small enterprises, aiming to provide a theoretical landmark to be used by more empirically oriented research (Andreassi, 2003). Another example of a conceptual paper is a study that deals with technological and managerial innovation transfer to small and medium-sized enterprises. The paper presents a comprehensive framework, identifying a networked architecture in which different actors (universities, other R&D centres, consulting companies, the European Union, national government, local public administration) interact (Caputo et al., 2002).

Figure 1 The methodological approaches of the papers



Most of the 132 empirical papers present results based on analyses of quantitative data. Many papers analyse data collected with surveys, for example a study that investigates how product innovativeness moderates the relationship between development time and initial market performance, utilising data from a survey of 110 small manufacturing firms

in computer-related industries (Ali, 2000). The most favoured qualitative approach among the papers is the case study. One paper, for example, studies the quality of industrial new PD in five SMEs in the Finnish metal industry (Lindman, 2002).

To summarise the analytical and methodological approaches of the papers it is clear that the analytical approach is dominated by descriptive papers (38%), but substantial proportions of the papers are explorative (32%) and explanatory (25%). The methodological approach is heavily dominated by studies based on empirical, quantitative data.

3.2 Areas of research covered in the papers

Based upon the general literature on PD (e.g., Cooper, 1988; Clark and Fujimoto, 1991; Wheelwright and Clark, 1992; Clark and Wheelwright, 1994; Ulrich and Eppinger, 1995; Rosenau et al., 1996) who have classified areas of research within the PD literature, and our own research we have identified three main areas of research and six sub-categories within PD in SMEs. The classification scheme (Figure 2), consequently, contains three main aspects or themes: Management, Operations, and Performance.

Figure 2 The classified areas of research of the papers

AREA	SUB-AREA
MANAGEMENT	Leadership and governance Information and business environment Finance of PD
OPERATIONS	Methods and techniques Capability and competence Chain dependence
PERFORMANCE	

Management is treated as a broad concept, not only related to the administration of the firm, but also including other aspects. Papers covering topics of strategic leadership, corporate governance, procurement and allocation of financial resources, and analysis of information and of the business environment are all categorised as belonging to this theme.

Leadership and governance are considered as sub-themes of management. Management and governance in the PD process refers to how PD is managed and led, including administrative processes as well as aspects of leadership.

Information and business environment is treated as a second sub-theme of management. Papers included here concern different means of information acquisition (environmental scanning, market research, market orientation, technological gatekeepers) which are described as important means of achieving organisation–environment alignment in a PD context. Further, papers on information sharing (cross-functional integration, collaboration, interaction, communication) also belong here, described as important means for making functions/departments work together during PD. Moreover, some papers on actual information use are included. Finally, papers on how significant stakeholders in the business environment affect PD are included (e.g., investors,

governments, institutions, and various macro-factors such as broader technological development).

Considering that we focus on PD, we add financing of the PD efforts as a sub-theme to management. The manager, or a group of managers, and the board of the firm are responsible for providing the necessary financial resources for the PD activities (Dewar and Dutton, 1986).

Operations: The second main aspect or theme is about the operations of the firm. This theme contains three sub-themes. One is about the methods and techniques utilised in the development process. Papers included here treat the use of methods and techniques for handling ideas, concepts or detailed development of products (e.g., Yasdani and Holmes, 1999). Methods could be used to create, analyse, select among or verify solutions in PD. Examples of methods are creative methods like brainstorming, analytical methods such as SWOT analysis, or selection methods such as matrices. Papers describing methods or sets of methods belong to this category (e.g., Karkkainen et al., 2001) as well as studies describing the frequency of use of methods (e.g., Griffin, 1997; Meyer, 2002). Furthermore, papers discussing the process of PD, such as sequential or concurrent processes, are included (e.g., Griffin and Page, 1996; Griffin, 1997; Yasdani and Holmes, 1999; DeToni and Nassimbeni, 2003). The second sub-theme of operations is about the capabilities and competence of the firms. Papers included in this category refer to the abilities and competences needed to explore and exploit resources necessary for a firm's PD.

The third sub-theme concerns the firm's relation to other actors in the PD process. Papers in this category focus on the organisation's degree of dependence on earlier stages in the supply chain, and typically argue that all organisations to some extent are dependent on the earlier steps in the supply chain. Papers here address the flow of goods and information, and the interaction between these flows (Christopher, 1998; Handfield and Nichols, 1999). An example of such an paper among the ones selected is Stroeken's analysis of the introduction of IT in SMEs and its impact on process innovation (internal and external), followed by product innovation in the sense of more diverse, cheap and customer-specific products. Supply chain integration is the central concept in the paper (Stroeken, 2000).

The two themes of management and operations are sometimes discussed in the same paper, and the paper is then classified as belonging to both categories.

Growth and Performance: The third main aspect focuses on PDs (often treated as independent variables) and their link to growth and performance (often treated as dependent variables). Typically, these papers are written from an economic point of view. Among the selected papers is, for example, Audretsch's analysis which shows that new firms that are able to adjust and offer a viable product experience higher rates of growth and a greater likelihood of survival (Audretsch, 1995).

In Table 3 we have combined the information about the topics covered by the selected papers with the methodological and analytical approach of the papers. As an paper may contain more than one topic, they are sometimes classified into more than one category. The number of papers about e.g., management issues is, then, the sum of papers covering one or more of the three sub-themes of management and governance, financial issues, and information and business environment.

An analysis of the papers reveals that management and operations are the most common topics: 97 (65%) papers discuss management issues while 93 (62%) discuss operations. Many of the papers cover both themes; 56% of the management papers also discuss operations issues. Considering under what premises the papers are selected for the study, being about PD in Small and Medium-sized Firms (SMEs), this is not surprising. In such firms it is often the owner, who often also is the only executive manager, who is responsible for both management issues and operational issues. The owner/manager plays the central role in such firms and is involved in all, or most of, the activities of the firm (Mintzberg, 1983; Miller and Toulouse, 1986).

Table 3 A summary of the research approaches of the 149 papers. A paper could be 'multi-classified', e.g., as both management and operations

	Analytical approach				*Methodological approach*				
Covered topics	*Explorative*	*Descriptive*	*Explanatory*	*Not applic.*	*Conceptual*	*Empirical*	*Empirical qualitative*	*Empirical quantitative*	*No. of paper*
Management	*28*	*37*	*26*	*6*	*15*	*82*	*32*	*50*	*97*
Leadership and governance	23	30	18	2	10	63	23	40	
Information and business environment	8	7	2	2	4	15	5	10	
Finance of PD	2	5	9	3	6	13	0	13	
Operations	*32*	*34*	*25*	*2*	*7*	*86*	*31*	*49*	*93*
Methods and techniques	14	15	1	1	1	30	22	8	
Capability and competence	18	19	24	1	6	56	13	43	
Chain-dependence	4	2	3	0	1	8	2	6	
Performance	*4*	*3*	*4*	*0*	*0*	*11*	*1*	*10*	*11*

Only 11 papers (7% of the 149) discuss performance while approximately two out of three papers discuss management or operations. Table 3 summarises much of the descriptive information provided.

The most common analytical approaches of the papers are the explorative and descriptive approaches, regardless of what type of topic the papers are about. There are, however, also many papers with an explanatory approach. The explorative/descriptive focuses among the papers about management and operations are almost the same, and the same is true for explanatory papers (in both cases 27%).

The methodological approach of all four main themes is heavily dominated by an empirical approach: 85% of the management papers, 92% of the operations papers, and all the performance papers. In the empirical papers, a quantitative approach is favoured; 61% of the empirical management papers, 57% of operations, and 91% of the performance papers use this approach.

The distributions of methodological and analytical approaches of the papers are similar for the two dominating themes – management and operations. The empirical,

quantitative papers dominate heavily, but there are some differences among the sub-themes. All empirical finance papers, compared to slightly over 60% of the empirical management and governance papers, are quantitative.

3.3 The evolution of research about Product Development in SMEs

It is important to remember that our database of selected papers only contains papers with at least the abstract and title available on-line. Papers that were published only in printed issues of journals, the once dominant form of publishing, are thus not included in the analysis. The number of papers published before 1990 is therefore somewhat uncertain, although many databases provide journal papers which go further back.

Another factor to consider is the general expansion of the market for scientific journals. There has been a great increase in the number of scientific journals during recent decades, and many of today's most influential journals publishing papers about PD in SMEs have been started during the last 30 years. Examples include *Technovation* in 1981, *International Journal of Technology Management* in 1986, *Small Business Economics* in 1988, and *International Journal of Entrepreneurship and Innovation Management* in 2001. An increase of the number of published papers since the 1990s could therefore be expected.

3.3.1 The maturity of the research field

Kuhn's concept of a paradigm (Kuhn, 1964) has stimulated much study of scientific development and levels of maturity in science as well as in specific fields of research. This section proposes a theoretical general model of the development of a research field, and it positions the field of PD according to the proposed model.

Some previous studies of scientific development or maturity of a research fields are, for example, Pfeiffer's analysis of the advance of organisational science (Pfeffer, 1993), and Boyd et al. analysis of the strategy paradigm (Boyd et al., 2005). The paradigm model asserts that research activities vary as a function of a field's level of maturity (Boyd et al., 2005). Within a mature field there is a high degree of consensus among researchers about the research questions considered to be important, the ways relevant variables should be defined and measured, the methods used to collect and analyse relevant data, the general research approaches of how to measure, analyse and comprehend the phenomena of interest, and the rules for determining which is the most fruitful approach to use (Cole, 1983; Pfeffer, 1993). In a field of high maturity there is not much need for extensive discussion about which are the important research questions, concepts and research methods. In a less developed field many theories compete, and there is no consensus about important research questions and how to answer them. As a consequence of this, research papers in mature fields have shorter review times, the time to publication is much shorter, and the rejection rate is lower (Garvey et al., 1970; Beyer, 1978), which can lead to a higher volume of publications.

The level of maturity, or the level of development, of a research field has been measured in many ways. One proposed way is to ask faculty members about the degree of consensus within different fields of science (Lodahl and Gordon, 1972). A second way is to analyse the editorial board seats held among faculty, and the publication and citation patterns (Boyd et al., 2005) among researchers. Close networks of researchers citing each other are referred to as 'invisible colleges' (Pfeffer, 1993).

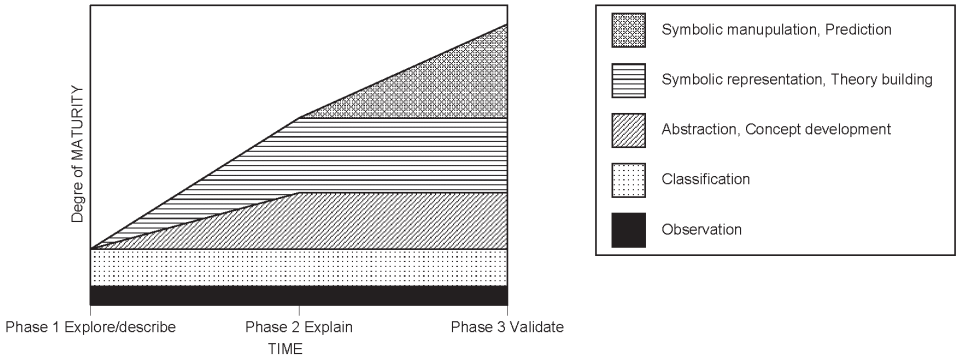
In this paper we approach the level of maturity in a slightly different way. We make use of the notion that new fields of research often start out from an explorative and descriptive origin (Buffa, 1980), followed by a expansion of studied topics (Voss, 1995; Malhotra et al., 2005) and a variety of analytical and methodological approaches (Dangayach and Deshmukh, 2001).

In a survey of papers published in the field of operations management, Filippini (1997) proposes three phases: exploration and descriptive research, a phase focusing on explanation, and a third phase focusing on theory-testing, modification and development of both concepts and theoretical models, for example with the use of simulation techniques. Meredith (1993) proposes a sequence, with feedback loops, of research developing from description to explanation and then to testing of models and theories in order to validate them or motivate their replacement by more valid theories.

A less mature field of research could then be defined as a field dominated by explorative and descriptive research, using less well developed concepts and less well validated theories within a narrow scope of covered topics. Theory development and discussion about the proposed concepts and how to measure them play an important role. The introduction of new concepts is seen as a virtue. A more mature field could be described as the opposite. It makes use of well-established analytical and methodological approaches, and the explanation of phenomena plays an important part of the research. The scope of topics covered is substantial, and there exists research aiming to validate the knowledge base of the field. As there is a high level of consensus about theories, concepts and the appropriate way to measure them, research papers spend less effort on this, and instead focus on explanation and validation.

Figure 3 depicts in a schematic way this line of reasoning. During the first phase, when the field of research is young and starts to develop, research aims to explore and describe the new field. New concepts and theories are proposed, often with the help of empirical generalisations which contribute limited theoretical generalisations. Swamidass (1991), identifying empirical theory-building as a methodological void in operations management research, notes that there are many different types of empirical studies during this phase, but that the development of theories is weak and there are almost no tests of theories. He also identifies a second and a third level of theory development, connected with the second phase in Figure 3.

Figure 3 A general model of the development of the field of research over time



Exploration and empirical observations continue also during the second phase, but are now complemented with an increased emphasis on development of concepts and theories. The aims of research projects are also to explain the studied phenomena, not only to describe and classify. The range of theories might be limited; we talk about 'midrange theories' (Swamidass, 1991) or theories of middle range (Merton, 1968). Such theories lie between working hypotheses and a unified theory that will explain all the observed and classified uniformities.

The last phase adds a new component. There is a focus not only on theory-building but also on the testing and validation of theory (Filippini, 1997). During this phase a comprehensive theoretical perspective develops and new scientific results are added to existing ones. A consensus about research questions, theories, concepts and how to measure them has started to emerge.

Table 4 depicts the analytical and methodological approaches of the studied papers. The period of time covered, excluding the first period, is approximately 15 years. This might be a too short period of time to reveal all the type of changes of phases discussed above. The field seems to have reached at least the second phase, however. There is a rather even distribution of analytical and methodological approaches during the studied period, and about a quarter of all papers have the aim of explaining the phenomena they focus upon. This indicates that the field has reached beyond the phase of observation. The researchers now focus also on classification and pay attention to concept development and, to some extent, abstraction.

Table 4 Papers during the studied period of time, distributed according to analytical and methodological approaches

Approaches	*(1978)–1989*	*1990–1994*	*1995–1999*	*2000–2005*	*Total*
Analytical approach					
Explorative	27%	20%	33%	36%	32%
Descriptive	40%	44%	33%	38%	38%
Explanatory	33%	36%	19%	23%	25%
Not applicable	0%	0%	13%	3%	5%
Methodological approach					
Conceptual	7%	8%	19%	10%	11%
Empirical	93%	92%	81%	90%	89%
All 149 papers	*15 (10%)*	*25 (17%)*	*36 (24%)*	*73 (49%)*	*149 (100%)*

Another aspect of the maturity of a field of research is the range of topics covered. A more mature field covers many topics, utilising more abstract and general theories.

The percentage of papers discussing the three main topics (see Table 5) is about the same during the different periods of time. Issues related to the operations of PD and management issues dominate. It is difficult to distinguish a specific topic that has changed in popularity. A breakdown of the main topics into subtopics (see Table 3) does not change the picture. As the row-percentage indicates, about half of all papers are published after 2000 for all topics. And there are no big differences among the periods.

About two thirds of the papers cover management issues; a slightly lower proportion deal with operation issues and only a few papers discuss performance.

Table 5 Papers covering different topics related to Product Development in SMEs over time. Some papers may cover more than one topic

Topics	*(1978)–1989*	*1990–1994*	*1995–1999*	*2000–2005*	*Total (100%)*
Management	8 (9%)	17 (18%)	23 (24%)	49 (49%)	97
Operations	9 (10%)	15 (16%)	19 (20%)	50 (54%)	93
Performance	0 (0%)	4 (36%)	1 (9%)	6 (55%)	11
Total No. of papers	15 (10%)	25 (17%)	36 (24%)	73 (49%)	149

The conclusion is that no major changes have occurred during the last 15 years. This is similar to the conclusion from a study of changes during the 1990s in the field of operations management; no important changes occurred (Walton and Handfield, 1996). That conclusion has, however, been challenged. A closer look at the topics covered indicates that different studies focus on more specific aspects of the topics in operations management (Voss, 1995; Filippini, 1997). It is possible that the same is true for the field of PD in SMEs.

The stage of development of the field of PD is not easy to decide in a conclusive manner. However, the majority of papers published during the studied period of time are of an empirical, explorative and descriptive nature. This indicates that the field is still rather immature, even if there are quit a few papers (25%) focusing on explanation and theory building.

3.3.2 Journals publishing papers in the field of Product Development in SMEs

The 149 papers are published in 77 different journals, indicating that the researchers in this area seem to lack a common forum for exchanging ideas, as well as for communication with practitioners. Some more important journals could, however, be identified; 54% of the papers were published in 19 different journals. These 19 journals all had three or more papers published. Another nine journals had two papers each, leaving 49 journals with only one paper published on PD in SMEs. Thus, there have been many journals publishing just one or a few papers, and there are new journals specialising in publishing papers in this field of research.

A closer look at the journals reveals that seven of them represent 30% of all publications. These seven journals (see Table 6) are *Technovation* (nine publications); *International Journal of Technology Management* (eight publications); *Small Business Economics* (seven publications); *International Journal of Entrepreneurship and Innovation Management* (sic publications); *Journal of Small Business Management* (six publications); *Research Policy* (five publications) and *R&D Management* (five publications).

Table 6 The seven most important journals in which work on Product Development in SMEs is published

Journal	*Total*	*1989*	*1990–1994*	*1995–1999*	*2000–2005*
Technovation (First volume 1981)	9	1	1	4	3
International Journal of Technology Management (First volume 1986)	8	1	0	5	2
Small Business Economics (First volume 1988)	7	0	2	2	3
International Journal of Entrepreneurship and Innovation Management (First volume 2001)	6	–	–	–	6
Journal of Small Business Management (First volume 1963)	6	1	1	1	3
Research Policy (First volume 1971)	5	0	0	2	3
R&D Management (First volume 1970)	5	1	2	1	1

For more recent studies (i.e., published during the present decade), *International Journal of Entrepreneurship and Innovation Management*, established in 2001, seems to be the journal where most of this work has been published. Further, Table 6 shows that papers on PD in small firms were rare before the 1990s. During the 1970s, *Journal of Small Business Management*, *Research Policy* and *R&D Management* were the only established journals in the field.

Two of the journals, *Small Business Economics* and *Journal of Small Business Management*, have an academic research profile. They publish scholarly research papers with a focus on the advancement of theory. The aims and scopes of the other four journals are to publish papers written by academic researchers, practitioners, managers and policy makers. One of the journals, *International Journal of Entrepreneurship and Innovation Management*, explicitly invites case studies. However, only one of the six papers published in that journal has a qualitative methodological approach, compare to five of eight papers published in *International Journal of Technology Management* and four of the nine papers published in *Technovation*. The two most scholarly devoted journals have together only one qualitative paper of 12 published. Papers making use of a qualitative approach are then rather uncommon in journals publishing scholarly research papers.

4 Conclusions and discussion of proposed research themes to be addressed in the future

This paper presents an analysis of papers published in the field of PD in SMEs. This is, to our knowledge, the first study of its kind in this field of research. Our main conclusion is that research on PD in SMEs is characterised by its heterogeneity and lack of cumulative knowledge creation. Our interpretation is that the field is still rather immature, without

showing the distinct development patterns that could be expected from the theoretical framework developed to investigate the maturity of the field.

The contents of the papers were organised into three main areas of research: Management, Operations, and Performance. The analytical approach of the papers surveyed is dominated by explorative and descriptive approaches, but there are also papers with an explanatory purpose (approximately one quarter of all papers). The papers are written in a field where empirical research predominates. Most papers are empirical and use a quantitative approach.

The topics covered in the papers are mostly about management or operational issues. The review reveals that the number of papers published which meet the stated selection criteria is rather low. During the period of 1990–2005, nine such papers per year were published on average. The average number of published papers during the first five years of the 1990s was seven papers per year, compared to 17 papers per year during the first years of the 2000s. Although the trend seems to be an increased number of publications, the area has not attracted sufficient interest from the scholarly community, keeping in mind the importance of SMEs to the global economy. There are no clear trends during the studied period that show a shifting interest in specific topics among the researchers. About the same percentage of papers is published about the studied topics of the field during each sub-period of time, and there are no significant changes of analytical and methodological approaches.

The high proportion of papers aiming to explore and describe, compared with papers meant to explain and validate, indicates that the field of research is still rather immature, as measured in this study. Explorative and descriptive approaches try to portray the characteristics of phenomena and to determine their frequency and whether some phenomena are associated with others. A heterogeneous assembly of theoretical fragments, concepts and suggestions for how to measure these concepts is common in a less mature field of science. This makes it difficult to integrate results from previous research, and to combine theory fragments and midrange theories into a comprehensive theory about PD in SMEs. It is difficult to measure the degree of maturity of a research field. The discussion in Section 3.3.1 offers a theoretical ground for the development of such measures to be used in future research. Such research should pay attention both to the order of the sequence of phases, as indicated in Figure 3, and to the length of the phases. Some areas might reach a state of maturity in a shorter period of time compared to other fields, perhaps with the help of overlapping phases.

One aim for future research efforts in the field should be to increase the consensus of the research community about the important research questions, the most fruitful concepts and how to measure these concepts. The efforts of the *Product Development and Management Association (PDMA)* to bring about consensus on concepts, definitions, and suggested measures in the field of PD (Rosenau et al., 1996) are in line with this reasoning. In PDMA's handbook of PD (Rosenau et al., 1996) a significant work is done focusing on creating a joint base of definitions regarding concepts and methods in PD research.

As the review shows, the number of papers discussing performance-related issues is rather low. Only 11 out of 149 papers have such a focus. If this field of research is to deliver results of high importance for the development of sustainable new products, and contribute to economic growth and societal welfare, there should be an increased focus on performance. A greater consensus on performance measures is needed to make it possible to use more integrated research approaches, for example meta-analysis.

This approach is not applicable in an immature field of science, since the necessary consensus on concepts and measures is lacking.

The development of a higher degree of consensus and an increased focus on performance issues are the two most important future challenges for the development of the field of PD in SMEs, according to the results of this study. A higher degree of consensus among the researchers about relevant theories, concepts and how to measure these concepts are prerequisites if the field is to develop further and reach the stages of symbolic representation and manipulation.

The number of papers in the field of PD in SMEs has increased over time. It seems to be an area that has gained in interest, at least in the scholarly literature. Before the 1980s, PD in SMEs was virtually nonexistent among electronically available papers. Fewer than 20 papers were published during the 1980s, but in recent years the area has grown, at least if we measure the number of papers in peer-review journals.

References

Acs, Z.J. and Preston, L. (1997) 'Small and medium sized enterprises, technology and globalization: introduction to special issue on small and medium sized enterprises in the global economy', *Small Business Economics*, Vol. 9, No. 1 pp.1–6.

Albin, S.L. and Crefeld, P.J. (1994) 'Getting started – concurrent engineering for a medium-sized manufacturer', *Journal of Manufacturing Systems*, Vol. 13, No. 1pp.48–58.

Ali, A. (2000) 'The impact of innovativeness and development time on new product performance for small firms', *Marketing Letters*, Vol. 11, No. 2, pp.151–163.

Andreassi, T. (2003) 'Innovation in small and medium-sized enterprises', *International Journal of Entrepreneurship and Innovation Management*, Vol. 3, Nos. 1–2, p.99.

Audretsch, D.B. (1995) 'Innovation, growth and survival', *International Journal of Industrial Organization*, Vol. 13, No. 4, pp.441–457.

Beyer, J.M. (1978) 'Editorial policies and practices among leading scientific journals in for scientific fields', *Sociological Quarterly*, Vol. 19, pp.68–88.

Biemans, W., Griffin, A. and Moenaert, R. (2007) 'Twenty years of the journal of product innovation management: history, participants, and knowledge stock and flows', *The Journal of Product Innovation Management*, Vol. 24, No. 3, pp.193–213.

Bogue, J. (2001) 'New product development and the Irish food sector: a qualitative study of activities and processes', *Irish Journal of Management*, Vol. 22, No. 1, pp.17–192.

Booz-Allen and Hamilton (1968) *Management of New Products*, Booz-Allen and Hamilton, New York.

Booz-Allen and Hamilton (1982) *New Products Management for the 1980s*, Booz, Allen and Hamilton, New York.

Bounfour, A. (1999) 'Is outsourcing of intangibles a real source of competitive advantage?', *International Journal of Applied Quality Management*, Vol. 2, pp.127–151.

Boyd, B.K., Finkelstein, S. and Gove S. (2005) 'How advanced is the strategy paradigm? The role of particularism and universalism in shaping research outcomes', *Strategic Management Journal*, Vol. 26, pp.841–854.

Brown, S. and Eisenhardt, K. (1995) 'Product development: past research, present findings and future directions', *Academy of Management Review*, Vol. 20, pp.343–378.

Buffa, E.S. (1980) 'Research in operations management', *Journal of Operations Management*, Vol. 1, No. 1, pp.1–7.

Caird, S., Roy, R. and Wield, D. (1994) 'Problems experienced by engineers with environmental product development-projects', *Technology Analysis and Strategic Management*, Vol. 6, No. 2, pp.177–188.

Caputo, A.C., Cucchiella, F., Fratocchi, L., Pelagagge, P.M. and Scacchia, F. (2002) 'A methodological framework for innovation transfer to SMEs', *Industrial Management and Data Systems*, Vol. 102, Nos. 5–6, pp.271–283.

Christopher, M. (1998) *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*, Financial Times-Prentice Hall, London, UK.

Clark, K. and Fujimoto, T. (1991) *Product Development Performance. Strategy, Organization, and Management in the World Auto Industry*, Harvard Business School Press, Boston.

Clark, K.B. and Wheelwright, S.C. (Eds.) (1994) *The Product Development Challenge – Competing Through Speed, Quality, and Creativity*, A Harvard Business Review Book.

Cohen, W.M., Levin, R.C. and Mowery, D.C. (1987) 'Firm size and R&D intensity: a re-examination', *Journal of Industrial Economics*, Vol. 35, No. 4, pp.543–565.

Cole, S. (1983) 'The hierarchy of sciences?', *American Journal of Sociology*, Vol. 89, pp.111–139.

Cooper, R.G. (1988) *Winning at New Products*, Kogan Page, London, UK.

Cooper, R.G., Edgett, S. and Kleinschmidt, E.J. (2004) 'Benchmarking best NPD practices-I', *Research Technology Management*, Vol. 47, No. 1, pp.31–43.

Cooper, R.G. and Kleinschmidt, E. (1991) 'New product processes at leading industrial firms', *Industrial Marketing Management*, Vol. 20, pp.137–147.

Craig, A. and Hart, S. (1992) 'Where to now in new product development research?', *European Journal of Marketing*, Vol. 26, pp.1–49.

Dangayach, G.S. and Deshmukh, S.G. (2001) 'Manufacturing strategy. Literature review and some issues', *International Journal of Production Management*, Vol. 21, No. 7, pp.884–932.

Davidsson, P., Lindmark, L. and Olofsson, C. (1996) *Näringslivsdynamik under 90-talet.* Stockholm, NUTEK.

DeToni, A. and Nassimbeni, G. (2003) 'Small and medium district enterprises and the new product development challenge: evidence from Italian eye-wear district', *International Journal of Operations and Production Management*, Vol. 23, No. 6, pp.678–697.

Dewar, R.D. and Dutton, J.E. (1986) 'The adoption of radical and incremental innovations: an empirical analysis', *Management Science*, Vol. 30, pp.682–695.

European Commission (2002) *SMEs in Europe, Including a First Glance at EU Candidate Countries*, Brussels.

Filippini, R. (1997) 'Operations management research: some reflections on evolution, models and empirical studies in OM', *International Journal of Operations and Production Research*, Vol. 17, No. 7, pp.655–670.

Filson, A. and Lewis, A. (2000) 'Cultural issues in implementing changes to new product development process in a Small to Medium sized Enterprise (SME)', *Journal of Engineering Design*, Vol. 11, No. 2, pp.149–157.

Garvey, W.D., Lin, N. and Nelson, C.E. (1970) 'Some comparisons of communication activities in the physical and social sciences', in Nelson, C.E. and Pollock, D.K. (Eds.): *Communication Among Scientists and Engineers*, Heath, Lexington, MA.

Gieskes, J.F.B., Hyland, P.W. and Chapman, R. (2002) 'Continuous product innovation – learning behaviours and knowledge management', *International Journal of Entrepreneurship and Innovation Management*, Vol. 2, No. 6, pp.485–500.

Griffin, A. (1997) 'PDMA research on new product development practices: updating trends and bench-marking best practice', *Journal of Product Innovation Management*, Vol. 14, pp.429–458.

Griffin, A. and Page, A.L. (1996) 'PDMA success measurement project: recommended measures for product development success and failure', *Journal of Product Innovation Management*, Vol. 13, pp.478–496.

Handfield, R.B. and Nichols, E.L. (1999) *Introduction to Supply Chain Management*, Prentice-Hall, New Jersey.

Hardy, M. and Bryman, A. (Eds.) (2004) *Handbook of Data Analysis*, SAGE Publications, London, UK.

Harmsen, H., Grunet, K. and Bove, K. (2000) 'Company competencies as a network: the role of product development', *Journal of Product Innovation Management*, Vol. 17, pp.194–211.

Hart, C. (2001) *Doing a Literature Review*, Sage, London, UK.

Jong, J. and Vermeulen, P. (2003) 'Organizing successful new service development: a literature review', *Management Decisions*, Vol. 41, pp.844–858.

Karkkainen, M., Piippo, P. and Touminen, M (2001) 'Ten tools for customer-driven product development in industrial companies', *International Journal of Production Economics*, Vol. 69, No. 2, pp.161–176.

Keizer, J.A., Dijkstra, L. and Halman, J.I.M. (2002) 'Explaining innovative efforts of SMEs. An exploratory survey among SMEs in the mechanical and electrical engineering sector in The Netherlands', *Technovation*, Vol. 22, No. 1, pp.1–13.

Kuhn, T.S. (1964) *The Structure of Scientific Revolution*, University of Chicago Press, Chicago, Ill.

Lindman, M.T. (2002) 'Open or closed strategy in developing new products? A case study of industrial NPD in SMEs', *European Journal of Innovation Management*, Vol. 5, No. 4, pp.224–236.

Lodahl, J.B. and Gordon, G. (1972) 'The structure of scientific fields and the functioning of university graduate departments', *American Sociological Review*, Vol. 37, pp.57–72.

Malhotra, N.K., Wu, l. and Withelock, J. (2005) 'An overview of the first 21 years of research in the *International Marketing Review*, 1983–2003', *International Marketing Review*, Vol. 22, No. 4, pp.391–398.

Meredith, J. (1993) 'Theory building through conceptual methods', *International Journal of Operations and production Management*, Vol. 13, No. 5, pp.3–11.

Merton, R.K. (1968) S*ocial Theory and Social Structure*, The Free Press, New York.

Meyer, J-A. (2002) 'Knowledge and use of innovation methods in young SMEs', *International Journal of Entrepreneurship and Innovation Management*, Vol. 2, Nos. 2–3, pp.246–267.

Miller, D. and Toulouse, J.-M. (1986) 'Chief executive personality and corporate strategy and structure in small firms', *Management Science*, Vol. 32, No. 11, pp.1389–1409.

Mintzberg, H. (1983) *Structure in Fives. Designing Effective Organizations*, Prentice-Hall International Inc., London.

Perks, H. and Wong, V. (2003) 'Guest editorial: research in international new product development – current understanding and future imperatives', *International Marketing Review*, Vol. 20, pp.344–352.

Pfeffer, J. (1993) 'Barriers to the advance of organizational science: paradigm development as a dependent variable', *Academy of Management Journal*, Vol. 18, No. 4, pp.599–620.

Rosenau, M.D., Griffin, A., Castellion, G.A. and Anschuetz, N.F. (Eds.) (1996) *The PDMA Handbook of New Product Development*, John Wiley and Sons, Inc., New York, NY.

Rubinstein, A. (1994) 'Trends in technology management revisited', *IEEE Transactions on Engineering Management*, Vol. 41, pp.335–341.

Selltiz, C., Jahoda, M., Deutsch, M. and Cook, S.W. (1967) *Research Methods in Social Relations*, Holt, Rinehart and Winston, New York.

Stroeken, J.H.M. (2000) 'Information technology, innovation and supply chain structure', *International Journal of Technology Management*, Vol. 20, Nos. 1–2, pp.156–175.

Swamidass, P.M. (1991) 'Empirical science: new frontier in operations management research', *Academy of Management Review*, Vol. 16, No. 4, pp.793–814.

Ulrich, K.T. and Eppinger, S.D. (1995) *Product Design and Development*, McGraw-Hill, Inc., Boston, MA.

Walton, S. and Handfield, R. (1996) 'Recent trends in operations management research', *Proceedings of the 1996 Annual Decision Sciences Institute Conference*.

Wheelwright, S.C. and Clark, K.B. (1992) *Revolutionizing Product Development. Quantum Leaps in Speed, Efficiency and Quality*, Free Press, New York, NY.

Voss, C. (1995) 'Operations management – from Taylor to Toyota – and beyond?', *British Journal of Management*, Vol. 6, pp.17–29.

Yasdani, B. and Holmes, C. (1999) 'Four models of design definition: sequential, design centered, concurrent, and dynamic', *Journal of Engineering Design*, Vol. 10, pp.25–37.

Yin, R.K. (1994) *Case Study Research. Design and Methods*, Sage Publications, Thousand Oaks, CA.

Bibliography

Acs, Z.J. and Audretsch, D.B. (1987) 'Innovation, market structure, and firm size', *The Review of Economics and Statistics*, Vol. 69, No. 4, pp.567–574.

Acs, Z.J. and Audretsch, D.B. (1988) 'Innovation in large and small firms: an empirical analysis', *American Economic Review*, Vol. 78, No. 4, pp.678–690.

Adams, A.H. and Walbank, W.M. (1983) 'New products – strategies and risks for smaller firms', *International Journal of Operations and Production Management*, Vol. 3, No. 2, pp.33–36.

Akün, A.E., Lynn, G.S. and Byrne, L. (2004) 'Taking the guesswork out of new product development: how successful high-tech companies get that way', *The Journal of Business Strategy*, Vol. 25, No. 4, pp.41–46.

Aldrich, H.E. and Fiol, C.M. (1994) 'Fools rush in? The institutional context of industry creation', *Academy of Management Review*, Vol. 19, No. 4, pp.645–670.

Ali, A., Krapfel, R.J. and LaBahn, D. (1995) 'Product innovativeness and entry strategy: impact on cycle time and break-even time', *The Journal of Product Innovation Management*, Vol. 12, No. 1, pp.54–69.

Appiah-Adu, K. and Singh, S. (1998) 'Customer orientation and performance: a study of SMEs', *Management Decision*, Vol. 36, No. 6, pp.385–394.

Armstrong, M.J. and Levesque, M. (2002) 'Timing and quality decisions for entrepreneurial product development', *European Journal of Operational Research*, Vol. 141, No. 1, pp.88–106.

Arundel, A. (2001) 'The relative effectiveness of patents and secrecy for appropriation', *Research Policy*, Vol. 30, No. 4, pp.611–624.

Arundel, A. and Steinmueller, E. (1998) 'The use of patent databases by European small and medium-sized enterprises', *Technology Analysis and Strategic Management*, Vol. 10, No. 2, pp.157–173.

Atuahene-Gima, K. (1993) 'Buying technology for product development in smaller firms', *Industrial Marketing Management*, Vol. 22, No. 3, pp.223–232.

Atuahene-Gima, K. and Lowe, J.F. (1994) 'The role of external technology acquisition in product development: attitude-behaviour inconsistency among small firms', *Asia Pacific Journal of Marketing and Logistics*, Vol. 6, No. 3, pp.26–47.

Audretsch, D.B. and Acs, Z.J. (1991) 'Innovation and size at the firm level', *Southern Economic Journal*, Vol. 57, No. 3, pp.739–744.

Bagchi-Sen, S. (1999) 'The small and medium sized exporters' problems: an empirical analysis of Canadian manufacturers', *Regional Studies*, Vol. 33, No. 3, pp.231–245.

Bagchi-Sen, S. (2001) 'Product innovation and competitive advantage in an area of industrial decline: the Niagara region of Canada', *Technovation*, Vol. 21, No. 1, pp.45–54.

Bagchi-Sen, S. and MacPherson, A.D. (1999) 'Competitive characteristics of small and medium-sized manufacturing firms in the US and Canada', *Growth and Change*, Vol. 30, No. 3, pp.315–336.

Barreyre, P-Y. (1978) 'The management of innovation in small and medium-sized industries', *International Studies of Management and Organization*, Vol. 7, Nos. 3–4, pp.76–98.

Beaver, G. and Prince, C. (2002) 'Innovation, entrepreneurship and competitive advantage in the entrepreneurial venture', *Journal of Small Business and Enterprise Development*, Vol. 9, No. 1, pp.28–37.

Biondi, V., Iraldo, F. and Meredith, S. (2002) 'Achieving sustainability through environmental innovation: The role of SMEs', *International Journal of Technology Management*, Vol. 24, Nos. 5–6, pp.612–626.

Birchall, D.W., Chanaron, J.J. and Soderquist, K. (1996) 'Managing innovation in SME's: a comparison of companies in the UK, France and Portugal', *International Journal of Technology Management*, Vol. 12, No. 3, pp.291–305.

Bommer, M. and Jalajas, D. (2002) 'The innovation work environment of high-tech SMEs in the USA and Canada', *R&D Management*, Vol. 32, No. 5, pp.379–386.

Calabrese, G., Coccia, M. and Rolfo, S. (2005) 'Strategy and market management of new product development and incremental innovation: evidence from Italian SMEs', *International Journal of Product Development*, Vol. 2, Nos. 1–2 p.170.

Carayannopoulos, S. (2005) 'Research in motion: a small firm commercializing a new technology', *Entrepreneurship Theory and Practice*, Vol. 29, No. 2 p.219.

Chakrabarti, A.K. (1991) 'Industry characteristics influencing the technical output: a case of small and medium size firms in the US', *R&D Management*, Vol. 21, No. 2, pp.139–152.

Chen, W-H. (1999) 'The manufacturing strategy and competitive priority of SMEs in Taiwan: a case survey', *Asia Pacific Journal of Management*, Vol. 16, No. 3, pp.331–349.

Chiva-Gómez, R., AAlgra-Vidal, J. and Lapiedra-Alcami, R. (2004) 'A model of product design management in the Spanish ceramic sector', *European Journal of Management*, Vol. 7, No. 2, pp.150–161.

Connolly, R.A. and Hirschey, M. (1990) 'Firm size and R&D effectiveness: a value-based test', *Economics Letters*, Vol. 32, No. 3, pp.277–281.

Corbett, L.M. and Campbell-Hunt, C. (2002) 'Grappling with a gusher! Manufacturing's response to business success in small and medium enterprises', *Journal of Operations Management*, Vol. 20, No. 5, pp.495–517.

Corso, M., Martini, A., Paolucci, E. and Pellegrini, L. (2003) 'Knowledge management configurations in Italian small-to-medium enterprises', *Integrated Manufacturing Systems*, Vol. 14, No. 1, pp.46–56.

Davelaar, E.J. and Nijkamp, P. (1989) 'Spatial dispersion of technological innovation: a case study for the Netherlands by means of partial least squares', *Journal of Regional Science*, Vol. 29, No. 3, pp.325–346.

De Toni, A. and Nassimbeni, G. (2003) 'Small and medium district enterprises and the new product development challenge – evidence from Italian eyewear district', *International Journal of Operations and Production Management*, Vol. 23, No. 6, pp.678–697.

Deeds, D.L. (2001) 'The role of R&D intensity, technical development and absorptive capacity in creating entrereneurial wealth in high technology start-ups', *Journal of Engineering and Technology Management*, Vol. 18, No. 1, pp.29–47.

Dou, H. and Dou, J-M.J. (1999) 'Innovation management technology: experimental approach for small firms in a deprived environment', *International Journal of Information Management*, Vol. 19, No. 5, pp.401–412.

Duhovnik, J., Starbek, M., Dwivedi, S.N. and Prasad, B. (2001) 'Development of new products in small companies', *Concurrent Engineering-Research and Applications*, Vol. 9, No. 3, pp.191–210.

Duhovnik, J., Starbek, M., Dwivedi, S.N. and Prasad, B. (2003) 'Development of innovative products in a small and medium size enterprise', *International Journal of Computer Applications in Technology*, Vol. 17, No. 4, pp.187–201.

Entrialgo, M. (2002) 'Analysis of the abilities of the manager as an explanatory factor of innovation management in Spanish small and medium enterprises', *International Journal of Entrepreneurship and Innovation Management*, Vol. 2, No. 6, pp.501–519.

Evangelista, R., Perani, G., Rapiti, F. and Archibugi, D. (1997) 'Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey', *Research Policy*, Vol. 26, Nos. 4–5 pp.521–536.

Fagerström, B. and Jackson, M. (2002) 'Efficient collaboration between main and sub-suppliers', *Computers in Industry*, Vol. 49, No. 1, pp.25–35.

Freel, M. (1999) 'The financing of small firm product innovation within the UK', *Technovation*, Vol. 19, No. 12, pp.707–719.

Freel, M. (1999) 'Where are the skills gaps in innovative small firms?', *International Journal of Entrepreneurial Behaviour and Research*, Vol. 5, No. 3, pp.144–154.

Freel, M. (2000) 'Do small innovating firms outperform non-innovators?', *Small Business Economics*, Vol. 14, No. 3 pp.195–210.

Freel, M. (2000) 'External linkages and product innovation in small manufacturing firms', *Entrepreneurship and Regional Development*, Vol. 12, No. 3, pp.245–266.

Freel, M. (2003) 'Sectoral patterns of small firm innovation, networking and proximity', *Research Policy*, Vol. 32, No. 5, pp.751–770.

Fritz, W. (1989) 'Determinants of product innovation activities', *European Journal of Marketing*, Vol. 23, No. 10, pp.32–43.

Giudici, G. and Paleari, S. (2000) 'The provision of finance to innovation: a survey conducted among Italian technology-based small firms', *Small Business Economics*, Vol. 14, No. 1, pp.37–53.

Graves, S. B. and Langowitz, N.S. (1992) 'Innovative output and firm size in the pharmaceutical industry', *International Journal of Production Economics*, Vol. 27, No. 1 pp.83–90.

Gray, C. and Allan, J. (2002) 'Role of management education in developing capacity for innovation in small firms', *International Journal of Entrepreneurship and Innovation Management*, Vol. 2, Nos. 4–5, pp.373–389.

Griffin, A. (1997) 'PDMA research on new product development practices: Updating trends and bench-marking best practices', *Journal of Product Innovation Management*, Vol. 14, p.429–458.

Guimaraes, L.E.C., Penny, J.E.T. and Moody, S. (1996) 'Product design and social needs: the case of North-East Brazil', *International Journal of Technology Management*, Vol. 12, Nos. 7–8, pp.849–864.

Hadjimanolis, A. (2000) 'A resource-based view of innovativeness in small firms', *Technology Analysis and Strategic Management*, Vol. 12, No. 2, pp.263–281.

Hadjimanolis, A. and Dickson, K. (2000) 'Innovation strategies of SMEs in Cyprus, a small developing country', *International Small Business Journal*, Vol. 18, No. 4, pp.62–79.

Hall, B.H. (2002) 'The financing of research and development', *Oxford Review of Economic Policy*, Vol. 18, No. 1, pp.35–51.

Harrison, R.T. and Hart, M. (1987) 'Innovation and market development: the experience of small firms in a peripheral economy', *Omega-International Journal of Management Science*, Vol. 15, No. 6, pp.445–454.

Haynes, I. and Frost, N. (1994) 'Accelerated product development: an experience with small and medium-sized companies', *World Class Design to Manufacture*, Vol. 1, No. 5, pp.32–37.

Heunks, F.J. (1998) 'Innovation, creativity and success', *Small Business Economics*, Vol. 10, No. 3, pp.363–372.

Hietikko, E. and Rajaniemi, E. (2000) 'Visualized data – tool to improve communication in distributed product development projects', *Journal of Engineering Design*, Vol. 11, No. 1, pp.95–101.

Hill, C.W.L. and Rothaermel, F.T. (2003) 'The performance of incumbent firms in the face of radical technological innovation', *Academy of Management Review*, Vol. 28, No. 2, pp.257–274.

Himmelberg, C.P. and Petersen, B.C. (1994) 'R&D and internal finance: a panel study of small firms in high-tech industries', *The Review of Economics and Statistics*, Vol. 76, No. 1, pp.38–51.

Honig-Haftel, S. and Martin, L.R. (1993) 'The effectiveness of reward systems on innovative output: An empirical analysis', *Small Business Economics*, Vol. 5, No. 4, pp.261–269.

Hovgaard, A. and Hansen, E. (2004) 'Innovativeness in the forest products industry', *Forest Products Journal*, Vol. 24, No. 1, pp.26–33.

Hsieh, C-H. and KoWang, S-P. (1997) 'The development of capability for tackling R&D issues in small companies: a case of a CNC-controller manufacturer in Taiwan', *International Journal of Technology Management*, Vol. 13, Nos. 5–6, pp.571–587.

Hsu, W-S. and Chang, P-L. (2000) 'Promoting technological capabilities of small and medium-sized enterprises through industry-university cooperation: case study of Taiwan machine tool industry', *International Journal of Manufacturing Technology and Management*, Vol. 1, Nos. 2–3, pp.257–270.

Huang, X., Soutar, G.N. and Brown, A. (2001) 'Resource adequacy in new product development: a discriminant analysis', *European Journal of Innovation Management*, Vol. 4, No. 1, pp.53–59.

Huang, X.L., Soutar, G.N. and Brown, A. (2002) 'New product development processes in small and medium-sized enterprises: some Australian evidence', *Journal of Small Business Management*, Vol. 40, No. 1, pp.27–42.

Hwang, I.P. and Ward, A.E. (2000) 'Which strategies affect R&D in manufacturing SMEs?', *International Journal of Manufacturing Technology and Management*, Vol. 2, Nos. 1–7, pp.844–859.

Hyvarinen, L. (1995) 'SME financiers' qualitative evaluation criteria in development projects', *International Journal of Production Economics*, Vol. 41, Nos. 1–3, pp.167–178.

Igel, B. and Islam, N. (2001) 'Strategies for service and market development of entrepreneurial software designing firms', *Technovation*, Vol. 21, No. 3, pp.157–166.

Igel, B. and Wei, Z. (2002) 'A framework to analyse the competence to innovate complex product systems in the stored program control switchboard industry', *International Journal of Entrepreneurship and Innovation Management*, Vol. 2, No. 6, pp.537–556.

Johne, A. and Rowntree, S. (1991) 'High technology product development in small firms: a challenge for marketing specialists', *Technovation*, Vol. 11, No. 4, pp.247–259.

Kajanus, M. (2000) 'A model for creating innovative strategies for an enterprise and its application to a rural enterprise', *Management Decision*, Vol. 38, No. 10, pp.711–722.

Kamala, G.V. and Swamy, K.N.K. (1985) 'A model for small-scale industry/university collaboration in the UK based on case studies', *R&D Management*, Vol. 15, No. 1, pp.41–50.

Keogh, W. and Evans, G. (1999) 'Strategies for growth and the barriers faced by new technology-based SMEs', *Journal of Small Business and Enterprise Development*, Vol. 5, No. 4, pp.337–350.

Kim, S.H. and Kang, K. (1989) 'R&D project selection in Hong Kong, Korea and Japan', *International Journal of Technology Management*, Vol. 4, No. 6, pp.673–679.

Knauber, P., Muthig, D., Schmid, K. and Wide, T. (2000) 'Applying product line concepts in small and medium-sized companies', *IEEE Software*, Vol. 17, No. 5, pp.88–95.

Langowitz, N.S. and Graves, S.B. (1992) 'Innovative productivity in pharmaceutical firms', *Research Technology Management*, Vol. 35, No. 2, pp.39–51.

Larson, E.W., Gobeli, D.H. and Gray, C.F. (1991) 'Application of project management by small businesses to develop new products and services', *Journal of Small Business Management*, Vol. 29, No. 2, pp.30–41.

Ledwith, A. (2000) 'Management of new product development in small electronics firms', *Journal of European Industrial Training*, Vol. 24, Nos. 2–4, pp.137–148.

Lee, J. (1995) 'Small firms' innovation in two technological settings', *Research Policy*, Vol. 24, No. 3, pp.391–401.

Lefebvre, E., Lefebvre, L.A. and Harvey, J. (1993) 'Competing Internationally through multiple innovative efforts', *R & D Management*, Vol. 23, No. 3, pp.227–237.

Lefebvre, L.A. and Lefebvre, E. (1993) 'Competitive positioning and innovative efforts in SMEs', *Small Business Economics*, Vol. 5, No. 4, pp.297–305.

Lehtimäki, A. (1991) 'Management of the innovation process in small companies in Finland', *IEEE Transactions on Engineering Management*, Vol. 38, No. 2, pp.120–126.

Lipparini, A. and Sobrero, M. (1994) 'The glue and the pieces: entrepreneurship and innovation in small-firm networks', *Journal of Business Venturing*, Vol. 9, No. 2, pp.125–140.

Love, J.H. and Roper, S. (2001) 'Outsourcing in the innovation process: locational and strategic determinants', *Papers in Regional Science*, Vol. 80, No. 3, pp.317–336.

MacPherson, A. (1991) 'New product development among small industrial firms: a comparative assessment of the role of technical service linkages in Toronto and Buffalo', *Economic Geography*, Vol. 67, No. 2, pp.136–146.

March-Chorda, I., Gunasekaran, A. and Lloria-Aramburo, B. (2002) 'Product development process in Spanish SMEs: An empirical research', *Technovation*, Vol. 22, No. 5, pp.301–312.

Markman, G.D., Balkin, D.B. and Schjoedt, L. (2001) 'Governing the innovation process in enterpreneurial firms', *Journal of High Technology Management Research*, Vol. 12, No. 2, pp.273–292.

Meyer, M.H. and Roberts, E.B. (1986) 'New product strategy in small technology-based firms: a pilot study', *Management Science*, Vol. 32, No. 7, pp.806–820.

Millward, H. and Lewis, A. (2005) 'Barriers to successful new product development within small manufacturing companies', *Journal of Small Business and Enterprise Development*, Vol. 23, No. 3, pp.379–394.

Miner, A.S., Bassoff, P. and Moorman, C. (2001) 'Organizational improvisation and learning: a field study', *Administrative Science Quarterly*, Vol. 46, No. 2, pp.304–373.

Mosey, S. (2005) 'Understanding new-to-market product development in SMEs', *International Journal of Operations and Production Management*, Vol. 25, No. 2, pp.114–130.

Mosey, S., Clare, J.N. and Woodcock, D.J. (2002) 'Innovation decision making in British manufacturing SMEs', *Integrated Manufacturing Systems*, Vol. 13, No. 3, pp.176–183.

Motwani, J., Dandridg, T., Jiang, J. and Soderquist, K. (1999) 'Managing innovation in French small and medium-sized enterprises', *Journal of Small Business Management*, Vol. 37, No. 2, pp.106–114.

Ngamkroeckjoti, C., Speece, M. and Dimmitt, N.J. (2005) 'Environmental scanning in the Thai food SMEs – the impact of technology strategy and technology turbulence', *British Food Journal*, Vol. 107, No. 5, pp.285–305.

Noci, G. and Verganti, R. (1999) 'Managing 'green' product innovation in small firms', *R&D Management*, Vol. 29, No. 1, pp.3–15.

North, D. and Smallbone, D. (2000) 'The innovativeness and growth of rural SMEs during the 1990s', *Regional Studies*, Vol. 34, No. 2, pp.145–157.

O'Shea, A. and McBain, N. (1999) 'The process of innovation in small manufacturing firms', *International Journal of Technology Management*, Vol. 18, Nos. 5–8, pp.610–626.

Perry, T.S. (1995) 'How small firms innovate: designing a culture for creativity', *Research Technology Management*, Vol. 38, No. 2, pp.14–17.

Prasanth, S. (2005) 'Management of technology in an SME: a case study of Hind High Vacuum', *International Journal of Technology Management*, Vol. 2, Nos. 1–2, p.73.

Randolph, W.A., Sapienza, H.J. and Watson, M.A. (1991) 'Technology-structure fit and performance in small businesses: an examination of the moderating effects of organizational states', *Entrepreneurship Theory and Practice*, Vol. 16, No. 1, pp.27–41.

Riedle, K. (1989) 'Demand for R&D activities and the trade off between in-house and external research: a viewpoint from industry with reference to large companies and small- and medium-sized enterprises', *Technovation*, Vol. 9, Nos. 2–3, pp.213–225.

Roberts, E.B. (1989) 'Managing technological innovation in the medical devices industry', *Research Technology Management*, Vol. 32, No. 4, pp.34–41.

Rodwell, J. and Shadur, M. (1997) 'What's size got to do with it? Implications for contemporary management practices in IT companies', *International Small Business Journal*, Vol. 15, No. 2, pp.51–62.

Romano, C.A. (1990) 'Identifying factors which influence product innovation: a case study approach', *The Journal of Management Studies*, Vol. 27, No. 1, pp.75–95.

Romijn, H. and Albaladejo, M. (2002) 'Determinants of innovation capability in small electronics and software firms in southeast England', *Research Policy*, Vol. 31, No. 7, pp.1053–1067.

Roper, S. (1999) 'Under-reporting of R&D in small firms: the impact on international R&D comparisons', *Small Business Economics*, Vol. 12, No. 2, pp.131–135.

Rosen, R.J. (1991) 'Research and development with asymmetric firm sizes', *RAND Journal of Economics*, Vol. 22, No. 3, pp.411–429.

Roy, R. and Riedel, J.C.K.H. (1997) 'Design and innovation in successful product competition', *Technovation*, Vol. 17, No. 10, pp.537–548.

Salavou, H. (2002) 'Profitability in market-oriented SMEs: Does product innovation matter?', *European Journal of Innovation Management*, Vol. 5, No. 3, pp.164–171.

Salavou, H. (2005) 'Do customer and technology orientations influence product innovativeness in SMEs? Some new evidence from Greece', *Journal of Marketing Management*, Vol. 21, Nos. 3–4, p.307.

San, S.H.T. and Chung, W.W.C. (2003) 'A model for assessing ideas for new venture products', *Business Process Management Journal*, Vol. 9, No. 1, pp.60–68.

Shrader, R.C. (2001) 'Collaboration and performance in foreign markets: the case of young high-technology manufacturing firms', *Academy of Management Journal*, Vol. 44, No. 1, pp.45–60.

Sikka, P. (1999) 'Technological innovations by SME's in India', *Technovation*, Vol. 19, No. 5, pp.317–321.

Simon, M. and Houghton, S.M. (2003) 'The relationship between overconfidence and the introduction of risky products: evidence from a field study', *Academy of Management Journal*, Vol. 46, No. 2, pp.139–149.

Simon, M., Elango, B., Houghton, S.M. and Savelli, S. (2002) 'The successful product pioneer: Maintaining commitment while adapting to change', *Journal of Small Business Management*, Vol. 40, No. 3, pp.187–203.

Simon, M., Houghton, S.M. and Savelli, S. (2003) 'Out of the frying pan …? Why small business managers introduce high–risk products', *Journal of Business Venturing*, Vol. 18, No. 3, pp.419–440.

Skalak, S.C., Kemser, H-P. and Ter-Minassian, N. (1997) 'Defining a product development methodology with concurrent engineering for small manufacturing companies', *Journal of Engineering Design*, Vol. 8, No. 4, pp.305–328.

Snyder, D.R. and Festervand, T.A. (1985) 'University research centers and new product development for small high-technology firms', *Journal of Small Business Management*, Vol. 23, No. 3, pp.37–43.

Soderquist, K., Chanaron, J.J. and Motwani, J. (1997) 'Managing innovation in French small and medium-sized enterprises: an empirical study', *Benchmarking for Quality Management and Technology*, Vol. 4, No. 4, pp.259–272.

Starbek, M. and Grum, J. (2002) 'Concurrent engineering in small companies', *International Journal of Machine Tools and Manufacture*, Vol. 42, No. 3, pp.417–426.

Sugasawa, Y. and Liyanage, S. (1999) 'Technology and business opportunities for small and medium enterprises in Japan: the role of research networks', *International Journal of Technology Management*, Vol. 18, Nos. 3–4, pp.308–325.

van Hemel, C. and Cramer, J. (2002) 'Barriers and stimuli for ecodesign in SMEs', *Journal of Cleaner Production*, Vol. 10, No. 5, pp.439–453.

Vercalsteren, A. (2001) 'Integrating the ecodesign concept in small and medium-sized enterprises: Experiences in the Flemish region of Belgium', *Environmental Management and Health*, Vol. 12, No. 4, pp.347–355.

Vermeulen, P.A.M. (2005) 'Uncovering barriers to complex incremental product innovation in small and medium-sized financial services firms', *Journal of Small Business Management*, Vol. 43, No. 4, pp.432–452

Vonortas, N.S. and Xue, L. (1997) 'Process innovation in small firms: case studies on CNC machine tools', *Technovation*, Vol. 17, No. 8, pp.427–438.

Vossen, R.W. (1998) 'Relative strengths and weaknesses of small firms in innovation', *International Small Business Journal*, Vol. 16, No. 3, pp.88–94.

Wagner, E.R. (2005) 'Innovation in large versus small companies: insights from the US wood products industry', *Management Design*, Vol. 43, Nos. 5–6, pp.837–850

Weerawardena, J. (2003) 'Exploring the role of market learning capability in competitive strategy', *European Journal of Marketing*, Vol. 37, Nos. 3–4, pp.407–429.

Wiggins, S.N. (1995) 'Entrepreneurial enterprises, endogenous ownership, and the limits to firm size', *Economic Inquiry*, Vol. 33, No. 1, pp.54-69.

Wilson, E.J. (2005) 'The nose knows: new product development at Yankee Candle Company', *Journal of Business Research*, Vol. 58, No. 7, p.989.

Woodcock, D.J., Mosey, S.P. and Wood, T.B.W. (2000) 'New product development in British SMEs', *European Journal of Innovation Management*, Vol. 3, No 4, pp.212–221.

Wright, L.T. and Nancarrow, C. (2001) 'Improving marketing communication & innovation strategies in the small business context', *Small Business Economics*, Vol. 16, No. 2, pp.113–123.

Yan, H.S. and Jiang, J. (1999) 'Agile concurrent engineering', *Integrated Manufacturing Systems*, Vol. 10, No. 2, pp.103–112.

Yan, L. and Ning, C. (1997) 'Technological paradigm and innovation of EST of SMEs in China', *Journal of Environmental Sciences*, Vol. 9, No. 1, pp.120–126.

Yap, C.M. and Souder, W.E. (1994) 'Factors influencing new product success and failure in small entrepreneurial high-technology electronics firms', *The Journal of Product Innovation Management*, Vol. 11, No. 5, pp.418–432.

Yi, S-S. (1999) 'Market structure and incentives to innovate: The case of cournot oligopoly', *Economics Letters*, Vol. 65, No. 3, pp.379–388.

Yin, X. and Zuscovitch, E. (1998) 'Is firm size conducive to R&D choice? A strategic analysis of product and process innovations', *Journal of Economic Behavior and Organization*, Vol. 35, No. 2, pp.243–262.

Yli-Renko, H., Sapienza, H.J. and Hay, M. (2001) 'The role of contractual governance flexibility in realizing the outcomes of key customer relationships', *Journal of Business Venturing*, Vol. 16, No. 6, pp.529–555.

Young, R.C., Francis, J.D. and Young, C.H. (1993) 'Innovation, high-technology use, and flexibility in small manufacturing firms', *Growth and Change*, Vol. 24, No. 1, pp.67–86.

Paper 5

Chibba, A. and Rundquist, J. (2009). Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows. *Journal of Information & Knowledge Management*, 8(4): 331-343.

Journal of Information & Knowledge Management, Vol. 8, No. 4 (2009) 331–343

World Scientific
www.worldscientific.com

Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows

Aron Chibba* and Jonas Rundquist†
Centre for Innovation, Technology and Marketing Management, Halmstad University
*aron.chibba@hh.se
†joru@hh.se

Abstract. Information sharing is an important factor for effectiveness within the internal supply chain. In this paper we use a methodology for mapping information flows in an internal supply chain, and case studies of two Swedish multinational organisations. Eight retrospective cases were used to map, describe and analyse the information flow that supports the physical material flow from the receipt of an order to point of delivery. Every involved person was interviewed on at least one occasion each. The interviews were conducted to map and describe the information and physical material flow. The aim was to identify factors that could improve and rationalise information flows and generate a better flow within the organisation.

The study shows the importance of an integrated information system, but also clearly indicates the importance of a collaborative culture and an awareness of the human–technology interface. The study also shows that three factors of interface distortions are most frequent in the cases: (1) changes registered in the database trigger no action among the staff, (2) new knowledge to staff is stored only orally and not in the database, and (3) interface between the paper system and the database, and between the old and the new information storage culture.

Keywords: Mapping flows; information flow; logistics; internal supply chain.

1. Introduction

For many years organisations have tried to optimise and improve the performance of the physical material flow within the integrated supply chain, to gain advantages in an increasingly globalised market. However, organisations also need to improve the information flow, which is connected to the physical material flow. Information is an important mechanism for coordinating the supply chain among its members (Lee *et al.*, 1997).

Several studies point out that information sharing in the internal supply chain leads to better performance which can lead in turn to increased market shares (Baird and Griffin, 2003; Chaffe, 2001; Zhou and Benton, 2007). Information sharing could also fit under the recently developed term 'information logistics', which has attracted increasing interest from different researchers. It is not easy to provide a distinct definition of information logistics that is acceptable to all the research traditions, or to provide a description of how to use the term in different environments. In this study an industrial organisation perspective is used, focusing on the strategic, managerial and organisational aspects of developing effective work models. In this study Chaffe's (2001) definition of information logistics as 'the process of acquiring, maintaining, transporting and compiling information within and among entities' is used.

The physical material flow has been extensively described in the literature, and some interest has also been shown in the information flow surrounding the physical material flow. A literature review by Chibba and Hörte (2003b) focused on published scientific articles related to information logistics from a supply chain perspective (see Fig. 1). The focus of the literature review was to describe terms and concepts related to two different flows: the physical material flow and the supply chain information flow. The work classified 140 articles, all of which are related to two types of flows, i.e. the information flow and the physical material flow. However, the information flow can be divided into two separate classes. The first class is the information needed to produce the actual product or service information that is directly connected to the physical material flow, i.e., order, delivery quantity, information. The second class is the information that is indirectly related to the physical material flow, e.g., information about the customer, future markets, future changes or future customer demands, etc. As shown in Table 1, a large number of studies conducted is in the area of physical material flow, even though the importance of information flow is very clearly proven.

Our purpose in this study is to improve the information flow (both direct and indirect) that supports the physical

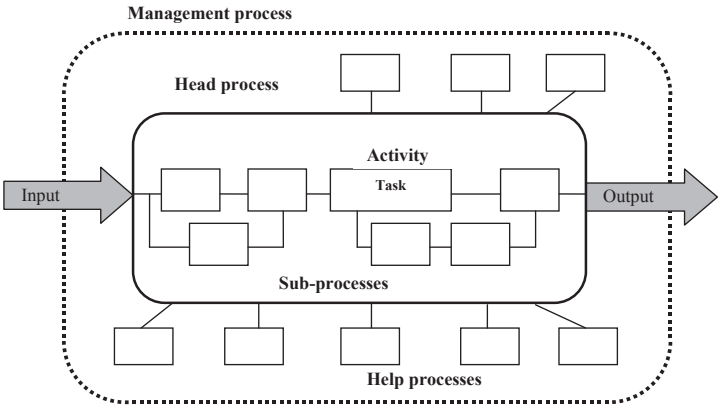


Fig. 1. Illustration of terms and hierarchy of the process concept (based on Harrington (1991)).

Table 1. Model for classification of articles — results (Chibba and Hörte, 2003b).

Perspective					
A. Model for description of the…			B. Method for calculation within the…		
1. Information flow (indirect)	2. Information flow (direct)	3. Physical material flow	1. Information flow (indirect)	2. Information flow (direct)	3. Physical material flow
Priority 1 ***14 articles***	*Priority 2* *138 articles*	*Priority 3* *138 articles*	***Priority 1*** ***0 articles***	*Priority 2* *26 articles*	*Priority 3* *22 articles*

material flow. The aim is to identify factors that could rationalise information flows and generate a better flow within the organisation. These factors could be further tested and used to develop supply chain performance measures covering the most important information flow aspects.

2. Mapping Information Flows Within a Supply Chain

Lueg (2001) argues that information can be understood as a flow of signals, while knowledge can be viewed as the interpretation of those signals. Some researchers (Nonaka and Takeuchi, 1995; Lueg, 2001) hold that information can be considered as a preliminary stage or the substance of knowledge creation. This perspective can be deemed a qualitative approach to 'information'.

Hull (2002) maintained that a data flow diagram (DFD) offers a general structure for supply chain information. He points out that the DFD can be used to map typical supply chain information flows. A DFD can be employed for both push-oriented and pull-oriented production systems. Hull states that the DFD is a primary structural component of a chain and understanding it is fundamental for reducing distortions. There are several ways to map flows, processes, activities or events within organisations, and there are many software tools that can be used for support, e.g., Business Viewer, Flowcharter, MS PowerPoint, MS Visio. Another similar way to describe or map flows, processes and activities is presented by Egnell (1994). He claims that several characteristics are necessary within the process; in short, the input to the process is measurable and could be an external or an internal supplier, i.e. representing another process.

The process consists of one or several activities that somehow transform the object into a more valuable one, with a measurable result that is fixed in advance. A process should also have clear interfaces between the processes. Further, the process is an ongoing business, i.e. those activities that form the process are performed in a more or less regular timeframe. Finally, the process should make use of the organisation's resources; for example, information, energy or working hours can transform an object into results.

The meaning of this concept can be described as cross-functional (Egnell, 1994). Instead of focusing on the various functions of the organisation, we study how all functions are connected, starting with demands and ending with the product or service delivered. If all processes are connected (which seems to be the case in every organisation), we have a supply chain (internal or external). Chiesa *et al.* (1996) argue that a process-based approach can be used as a tool for auditing an organisation's innovation capability. This approach is similar to the 'process' theory presented by Egnell (1994).

The latest version of the ISO 9001:2008 standard requires that all the key processes within an organisation are identified, described, monitored, measured and improved. All organisations that have an ISO 9001 registration must work according to the process concept, in order to achieve a process-oriented organisation. One way to implement the process concept is to use a model that employs relevant terms. Harrington (1991) suggests that a process has a flow of sub-processes and that a sub-process has a flow of activities. But it can also be appropriate to use several levels. A sub-process could be broken down into other sub-processes. The lowest levels are activities or work instructions; see the suggested model in Fig. 1.

The overall objective of mapping the processes is to achieve a smooth flow from raw material to end-user, using the least resources possible. Organisations must know how their processes are connected, which the key processes are, what processes need to be further developed and improved, what resources are required and what resources are critical to the customers. In this paper we use the process concept presented above to describe the information flow in our eight cases. Figure 2 is an attempt to describe an ordinary flow of both data and information. Data are generated from different types of activities, e.g., output data from either internal or external processes. The data can then be converted into different information formats, e.g., oral, textual, or paper-based (Kaye, 1995). When the converted data reach the receiver, they must be analysed before being deemed information that will (hopefully) lead to knowledge (it can be argued that there is an interpretation phase between information and knowledge) which can be used for a specific purpose, e.g., how to act or make a decision.

This illustrates a simple but not uncommon process employed by organisations in their day-to-day business. However, there are some problem areas. Herbig and Kramer (1994) hold that the phenomenon of information overload concerns an actor being overwhelmed by too much information, which leads to judgmental decision-making. Another problem facing organisations is that the information ends up at the wrong destination. There also appears to be difficulty in obtaining the relevant information when needed, due to the fact that the required information becomes increasingly distorted as it moves along the supply chain (Hull, 2002). In this research we will use process theory to map information flow within the internal supply chain.

2.1. *Distortions in the chain*

Mason-Jones and Towill (1997) argue that the problem of distortion and magnification of order information still exists. They point out that the many decision processes block rapid data transfer to where it is really needed. In particular, much work still remains in order to improve the order fulfilment processes by the use of undistorted point-of-sales information. Mason-Jones and Towill (1997) conclude that the only way to reduce distortion and improve the speed of response within a supply chain is to use and provide all actors with information on actual consumer demand. Chiu (1995) points out two types of distortions: physical distortions, for example, due to machine breakdown, material shortage, defective products, inadequate capacity and unexpected operating errors; and information distortions, such as changes in an order by the customer or human errors in information registration. There are several factors underlying these distortions, e.g., time pressure and late information.

2.2. *Supply chain performance measures*

The performance of the supply chain has been widely covered in the literature. Several recent studies (e.g., Koh *et al.*, 2007; Saad and Patel, 2006; Vereecke and Muylle, 2006) highlight the need to measure the efficiency of the integrated supply chain. Petroni and Panciroli (2002) argue that customers usually retain suppliers who achieve the highest aggregate score on price, quality, flexibility of production, and delivery times. Hayes and Wheelwright (1984) were the first to present methods for addressing operational strategy by means of four generic competitive priorities: quality, cost, flexibility and delivery, which are

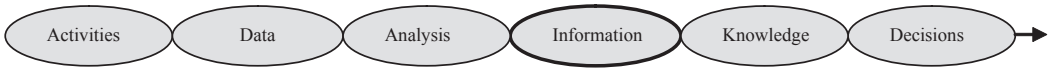


Fig. 2. The process from activities to decision making (source: Chibba and Hörte (2003a)).

the dimensions on which a company chooses to compete within a target market. Their original formulation was applicable to all functions. Hill (2000) also addresses competitive priorities such as price, cost reduction, delivery reliability, delivery speed, quality conformance, flexibility, increased demand, product range and design, which he terms order-winners or qualifiers.

In order to improve and make use of corrective actions, e.g., reduce distortions within the integrated supply chain, appropriate measures are essential. To measure the information flow over the supply chain could provide a valuable support when identifying improvement opportunities and choosing an improvement plan.

2.3. *Supply chain performance measurement situations*

Chibba and Hörte (2003a) argue that supply chain measures can be viewed from four different measurement situations, as depicted in Fig. 3. This figure presents the integrated supply chain, which is based on a model developed by the Supply Chain Council (SCC), and based on a process view of the supply chain using four distinct management processes — e.g., plan, source, make and deliver — has been divided into different types of measures (Chibba and Hörte, 2003a). This way of depicting the measurement situation provides a more concrete picture of where in the supply chain the performance measurement should be performed, i.e. internally, on the customer side, on the supplier side or in the whole supply chain. To find support in theory, the measurement situations below could be linked to Hill's (2000) description of the four phases which has similar types.

Functional measures (type 1) depict the performance of a separate activity/function of the chain, e.g., flexibility (mix) of production — the ability to effectively produce a wide variety of different products, although they are not supply chain measures as such. However, Holmberg (2000) claims that implementation of SCMs within an organisation requires that the internal perspective on performance measures be expanded, to include both 'interfunctional' and 'partnership' perspectives as well as the avoidance of an inward-looking and self-focused management approach. There are also measures that show the performance of several interconnected functions, i.e. head processes. Metrics, such as cost (total cost), quality (part per million defects, PPM), non-conformities and delivery lead time, are suitable for measurement. These types of measures are called *internal integrated measures* (type 2) and depict performance across functional boundaries within the firm, e.g., quality (conformance) — the ability to manufacture a product whose operating characteristics meet established performance standards; cost (total cost) — the ability to minimise the total cost of production (labour, materials, and operating costs) by means of efficient operations, process technology and/or scale economies; delivery (speed) — the ability to minimise the time between the receipt of a customer order and final delivery, although it can be argued whether this is a supply chain performance measure. These measures shed light on organisational performance and are included in our study as (internal) supply chain performance measures.

The one-sided integrated measures (type 3) depict performance across organisational boundaries as well as measuring chain performance across supplier or customer boundaries, e.g., total cost, total lead time and delivery (speed) — the ability to respond in a timely manner to customer needs. Some researchers (Rushton and Oaxly, 1991; Thomas and Graham, 1996) claim that the largest cost component of logistics is transportation costs in the total chain. They state that the trucking cost is always the

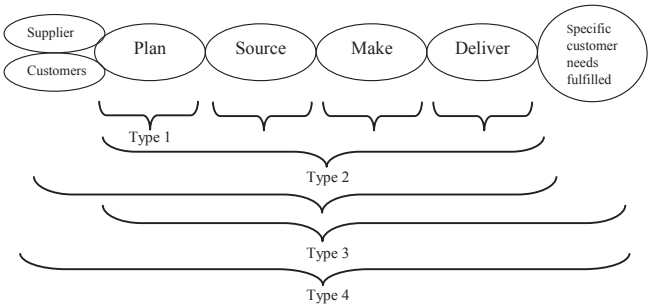


Fig. 3. Four different types of supply chain performance measurement situations (based on SCOR, freely developed by Chibba and Hörte (2003a)).

largest part of the total distribution cost. Therefore, it appears important to treat delivery and cost as a high-priority metric. Stewart (1995) identified the following measures of delivery performance: delivery-to-request date, delivery-to-commit date, and order-fill lead time. These types of measures are known as *total chain measures* (type 4), as they depict performance across organisational boundaries and measure the performance of the entire supply chain, including links to suppliers and customers, e.g., total chain costs — and provide an opportunity to minimise the total cost from supplier to end-customer. This way of depicting the measurement situation provides a more concrete picture of where in the supply chain the performance measurement should be performed, i.e. internally, on the customer side, supplier side or in the whole supply chain. This study has its focus on the internal supply chain within the organisation (type 2).

2.4. *Improvement of the integrated supply chain*

There are several terms and concepts that describe or explain continual improvement processes within organisations, e.g., Kaizen, Six Sigma, Business Process Reengineering (BPR), Total Productive Maintenance (TPM), Just-In-Time (JIT), and Manufacturing Resources Planning (MRP), etc. These concepts or terms have been adopted by organisations to improve the physical material flow. Womac *et al.* (1990) report that organisations had implemented specific pipeline process improvement techniques such as just-in-time (JIT) and manufacturing resources planning (MRP). Methodologies such as 'lean manufacturing' or 'lean production' have led to improvements in a host of industries, most notably the automotive sector where extensive research has been carried out. These methodologies have a strong focus on the physical material flow. Meanwhile, Hull (2002) argues that once information flows within a supply chain have been drawn or mapped, they can be individually analysed and improved. One can also identify information flow 'circuits' which contribute to the bullwhip effect. The bullwhip effect was identified by Jay Forrester in the 1960s (Forrester, 1961). He observed a relation among companies that made mistakes and concluded that the value of the mistakes will multiply in each step of the supply chain. Hull (2002) claimed that by focusing attention on a company's primary data flows, one can improve the overall reliability of the supply chain.

In order to compete effectively in the marketplace, much pressure has been exerted on supply chains and individual companies to improve pipeline performance by optimising their response to customer demand. The major technology behind improved information flow is electronic data interchange (EDI). It offers greatly improved information flows and is an extremely important aspect within leading organisations in the fight to decrease lead times (Evans *et al.*, 1993). Today, organisations make use of ERP (Enterprise Resource Planning) systems to integrate both customers and suppliers. However, these systems must be tailored to specific businesses and require a change in human behaviour to be implemented.

3. Methodology

In the present research we used a case study approach retrospectively, i.e. research on cases that are already closed. The reason for studying cases retrospectively was to gain in-depth understanding, contextual knowledge and knowledge of the actors' perceptions of the chain of activities. Choosing few cases offers a greater opportunity for in-depth observation (Voss *et al.*, 2002), while choosing more cases offers more generalisable results if supporting the same standpoint (Meredith, 1998).

3.1. *The cases*

Company A is a mechanical industry of laundry appliances for industrial and hotels. The company has approximately 2000 employees and manufacturing facilities in five countries. All product development is conducted at the facilities in Sweden. Company B is a printing company with 1000 employees and three production plants. The line of products covers a number of printing orders from credit cards to invoicing.

A project group was formed in each organisation to identify suitable cases. These groups comprised researchers, managers and employees involved in the process. After two meetings at each firm we identified eight cases, four at Company A and four at Company B.

3.2. *Data collection and analysis*

In order to capture the field data we used semi-structured interviews and a research protocol. This protocol (see Fig. 4) was developed from a process-oriented model (Harrington, 1991). The reason for the design of the protocol was the possibility to map the information flow, starting with the order and ending with the delivery of the product or service. The middle field in the protocol is reserved for a description of the activity conducted by the respondent. The respondent was asked to describe the activity, the time required and tools used and, if available, the documents that define the activity. To the left (see Fig. 4) the respondent was asked about the earlier

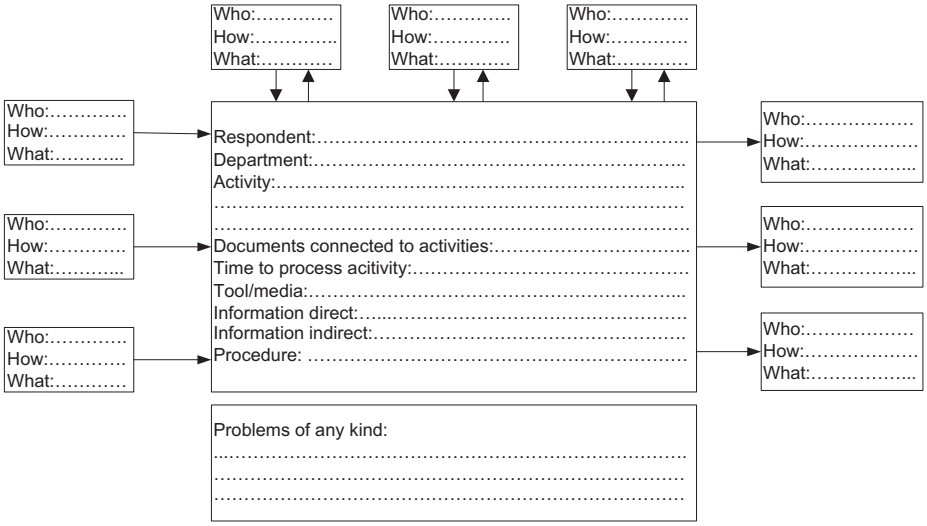


Fig. 4. The research protocol.

activities that triggered the activity in focus and what complementary information was needed to carry out the activity. This was documented in terms of what information was included in the previous activities, who (what person) performed this activity, and how the information was transferred to the respondent. To the right (see Fig. 4) the output of the activity was described in terms of what new activities were triggered by the output, who (what person) performed this activity and how the information was transferred to the next actor. Above the activity field, indirect information was documented in the same way as input and output. We piloted the research protocol at each firm and made some appropriate changes, e.g., the addition of a distortion box (a field where the respondent could include any problem areas relevant to that specific case).

To obtain the data needed for the construction of a model based on Harrington's (1991) ideas, we decided to develop a selection technique for the respondents based on the 'snowball principle'. As the process and the participants (individual employees) in each case were initially unknown, in addition to which the process itself was very complex, the sampling had a 'Wonderland' perspective. 'Begin at the beginning…and go on till you come to the end: then stop', as the king said to the white rabbit when the latter was told to describe a very complex and complicated course of events (Carroll, L, *Alice in Wonderland*, Chapter XII).

Our beginning was the person receiving the order. We tried to map all information inputs and outputs as well as all information-related activities prior to output based on the protocol in Fig. 4. Then we chose the next respondents, who were the persons supplying input and receiving output, and we stopped when all participants in the process had been interviewed. We also analysed the documents connected to each case, which regulated the process and activities, such as ISO 9001 quality documents. The 8 cases resulted in a total of 31 interviews. As most respondents were involved in more than one case, the study has a mean of 11 respondents per case.

To document the exact process in each case from order to delivery, we used a process management tool called MS Visio. To construct a model that could be easily understood by all parties involved, we decided to use only a few easily recognisable shapes to present the flow, as illustrated in Fig. 5.

We carried out two major types of analyses of the cases. First, the documented models were compared with official documentation, for example in the Quality Management System, which provided results indicating whether or not the official documentation was known and used. Second, the problems indicated by the respondents were clustered and compared between the cases. This analysis gave us a set of problems that could be compared with the theoretical framework. The analysis of the documented models of the eight cases also includes a more qualitative section with ocular inspection of the models as well as a dialogue within the research group and a discussion including the respondents.

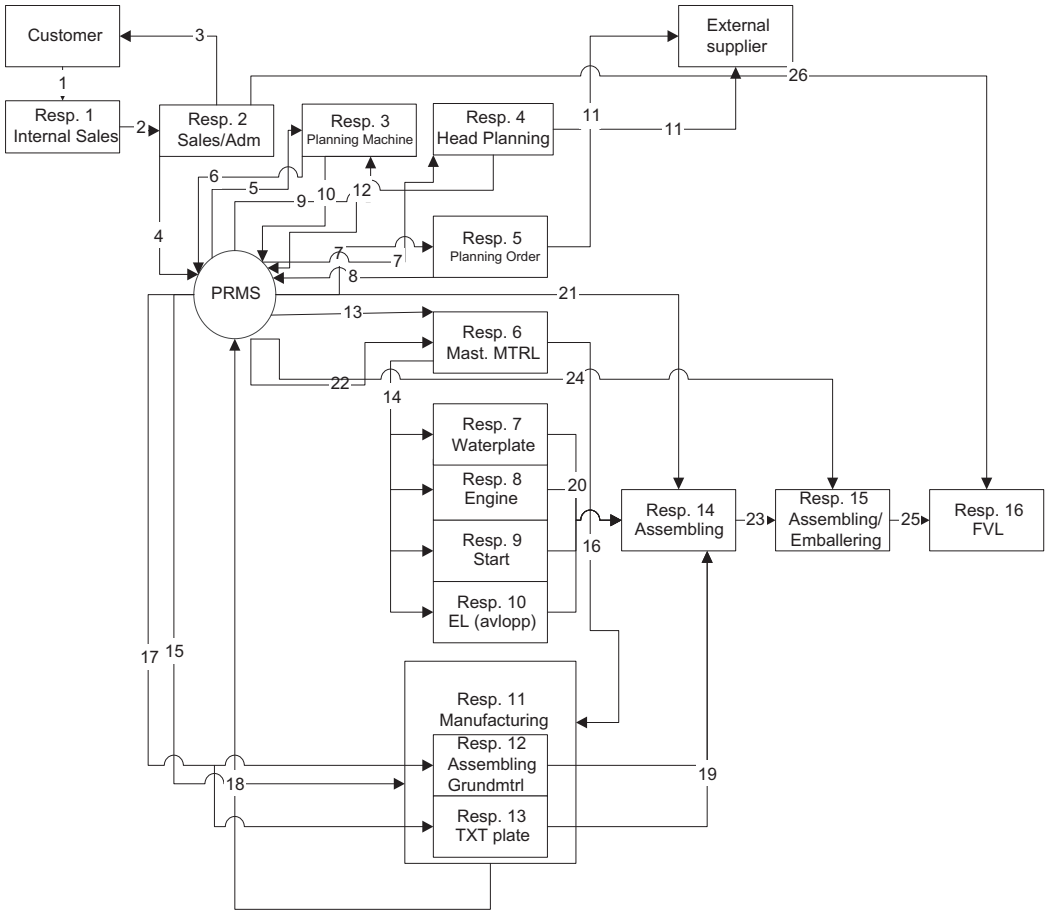


Fig. 5. Case A-1, the map of the information and physical material flow.

3.3. *Reliability and validity*

Using a case study approach retrospectively can make it difficult to determine cause and effect, as participants may or may not recall important events. Events may be subjected to bias, particularly post-rationalisation.

In the present study, reliability was strengthened by use of multiple data sources or triangulation. In addition to the interviews with all respondents, we deliberately searched for answers from multiple data sources which could lead to more reliable results (Voss *et al.*, 2002). The interviews were not taped, as many respondents would not allow this, but each respondent generated a protocol using the model from Fig. 4. These protocols form the bases for the analysis. Each protocol was sent for feedback from the respondents, as were the conclusions from each case.

Cross-case analysis was used as a means to increase the internal validity of the findings from the study (Voss *et al.*, 2002). In the present study, cross-case analysis was operationalised by comparing all eight cases, but also by comparing the four cases from the first firm as one group and the four cases from the other firm as the second group. Some findings were presented as causal relations in the concluding discussion when we could identify patterns within each organisation (Cook and Campbell, 1979).

External validity refers to whether findings can be generalised beyond the immediate case study (Yin, 1994).

Examples of external generalisation are to other populations (size, industry), other times (such as an economic situation), or other conditions (emerging/mature market). By identifying moderator variables and keeping these as similar as possible, a generalisation can be achieved within the context. An extended generalisation can also be achieved by the researcher's knowledge of and reflection over moderator variables (Schwab, 2005). The moderator variables were kept similar by using four cases from each firm. This means that external validity in a reasonable range could be achieved within each firm. Some judgmental claims of generalisations might be possible in the concluding discussion if patterns identified are valid for both organisations, as replication is the only way to establish generalisation across potential moderator variables (Schwab, 2005), in this study achieved by a reflective comparison between the two case firms.

4. Case Studies: Presentation and Analysis

We mapped the flow of information and physical materials from receiving an order to point of delivery, i.e. Firm A, Case 1, presented in Fig. 5. In order to compare the actual flow of information between humans, the information system (PRMS) and written sources, the focus was on the interviews. The open interviews are the hub of our mapping method, as procedure and human action often diverge. The minimum effect on our respondent's answers is of utmost importance. Therefore the interviews must be allowed to take the time the respondents need, even if the answers appear to be easily caught.

Each respondent generated a protocol according to Fig. 4, and the protocols were connected to flow charts according to Fig. 5. The boxes represent a process and the arrows indicate information flow or physical material flow. These flows were described as in Table 2. The methodology presented above was used to map each case separately.

We decided to present one case (A-1) in greater detail in order to illuminate the methodology to the reader. Case A-1 was chosen due to the fact that it had most distortions within the internal supply chain. Some general conclusions will be presented in the next section.

Figure 5 illustrates the presentation of the knowledge found in the interviews. It could be of value to note that two boxes (customer and external suppliers) represent actors outside the internal supply chain, and therefore are not considered in this study. The circle (PRMS) represents a database where individuals store information or load information from. The human/PRMS interface was found to be very important. The rest of the boxes are individual humans from staff, and their formal roles in the organisation are written in the box.

Figure 5 combined with Table 2 illustrates how the mapping method offers a useful map of information flow connected to the individuals employed in the organisation. For example, Arrow 1 describes an incoming order from a customer to the internal phone sales person. Arrow 2 illustrates how the phone sales person passes the order on to the sales administrator by phone. Arrow 3 describes how the sales administrator sends a printed order confirmation to the customer by mail, while Arrow 4 shows the sales administrator's action of storing the information [A] about the new order into the PRMS. The information flow supports mainly the physical flow, but also the administration of the order. As illustrated in Table 2, most of the information flows initiate an action by a member of staff. These actions are normally described as a work procedure, but as we identified following the flow, some actions are not triggered, and some actions are not formally described.

By 'not triggered', we mean that the storage of certain information does not trigger a human respondent to take an action. For example, when a change in an order is stored in the PRMS it is supposed that this will trigger an action by another human in the internal supply chain. However, the supposed receiver of the information does not find out that information has been changed until randomly checking the state of orders. In Case A-1 this had already led to delays because of no action taken upon the change in the PRMS.

By 'actions not formally described', we mean that in rarely occurring changes, the human does not have a predecided action suggested when receiving the trigger that an order is changed. A desire from the quality manager is that actions should be described in a formal format, but our interviews indicate that an organisational culture supporting a collaborative approach is indeed needed, rather than formal documents, when changes occur. However, it is important that there is a formal way of storing information on actions taken outside the formal procedures. We could see in Case A-1 that the old paper system was supported by some staff (mainly long-time employees). Therefore changes were stored in different places depending on who took the action connected to the changed order.

The case illustrated above was not successful due to insufficient communication with the customers and along the internal supply chain. The goods were produced with a short delivery time despite the fact that the customer was not ready to receive them in that short time. This resulted in lower priority being given to other orders, which led to dissatisfaction among other customers. The diagram (Fig. 5) increased our understanding of the structure of the process. The next step was to analyse

Table 2. Description of the information flow. Arrow no. refers to the numbers in Fig. 5.

Arrow no.	Resp. no.	Respondent action — receiving or loading (what and how)	Respondent action — sending (what and how)
1	1	Receives order from customer by phone	
2	2	Receives order from internal sales by phone	
3	2		Sends order confirmation to customer by mail
4	2		Sends information [A] to PRMS
5	3	Loads information [A] from PRMS	
6	3		Sends information [B] to PRMS
7	4 and 5	Loads information [B] from PRMS	
8	5		Sends information [C] to PRMS
9	3	Loads information [C] from PRMS	
10	3		Sends information [D] to PRMS
11	4 and 5		Sends order to external suppliers by fax/EDI
12	4		Sends information [E] to PRMS
13	6	Loads information [D] from PRMS	
14	6		Sends information [F] to respondents 7, 8, 9 and 10
15	11	Loads information [E] from PRMS	
16	11	Receives oral information [G] from respondent no. 6	
17	12 and 13	Loads information [E] from PRMS	
18	11		Sends information [H] to PRMS
19	14	Receives information [J] from respondent nos. 7, 8, 9 and 10 in hard copy together with physical goods	
20	14	Loads information [K] from PRMS	
21	6	Loads information [H] from PRMS	
22	15	Receives information [L] from respondent no. 14 together with goods	
23	15	Loads information [K] from PRMS	
24	16	Receives information [M] from respondent no. 15 together with goods	
25	16	Loads information [N] from PRMS	
26	2		Sends information [O] to PRMS

each information and physical material flow (arrows). The list (see Table 2) describes the information flow. Each number represents one delivery of information from Fig. 5.

The example presented above is an example of a bad case. Eight machines were missing at the point of delivery. They were placed in the wrong position in stock and therefore not found. Two of the machines had been rebuilt to fit an emergency order and had to be built from scratch. A reprioritising was carried out in the workshop, which meant that other customers had to wait for their orders even though this one did not need to be prioritised. When products were ready for delivery/were delivered, the driver found out that the customer was not ready to receive the products.

Although we have not presented all eight cases in detail similar to the above, we have summarised our findings in Table 3. Some of the phenomena identified in Case A-1 were similar in the other cases. The table presents the eight cases and the major factors, i.e. distortions in them.

We found three frequent factors, i.e. distortions, in the eight analysed cases: (1) procedures for handling changes in an order by a customer, e.g., delivery time, order size; (2) lack of information in the internal supply chain, e.g., information about changed delivery time, information about changes in stock, and missing machines; (3) procedures for handling information about delays in internal production or the delivery of wrong materials, e.g., different packaging or products. We have summarised the three recurrent factors for distortions in the internal supply chain:

(1) The major problem in the case presented is in the interface between human and PRMS, e.g., when a change in the order is sent to PRMS but fails to trigger human action further down the internal supply chain. All staff acted in accordance with procedures; they were informed about a change by the customer, processed the proper documentation and sent the information to PRMS. The problem occurred because staff

Table 3. Results of the analysis of the eight cases.

		Distortions within the supply chain					
Case	Good or bad case	Lack of information between sales dept and customer	Changes in orders by customers	Lack of information — internal supply chain	Internal supply chain failure	Information not on time	Lack of material or wrong material
Case A1	bad	X	X	X	X	X	X
Case A2	bad		X	X	X	X	X
Case A3	bad	X	X				
Case A4	good						
Case B1	bad			X			X
Case B2	bad		X	X			X
Case B3	good						
Case B4	bad	X	X	X			X

along the internal supply chain was not aware that a change had been made and, as there were no checkpoints or procedures to monitor whether available information was correct, the changes were not detected until it was too late, even though they were present in the system. After the information was sent to PRMS there was no individual responsible for passing it further down the internal supply chain. In combination with the lack of a trigger for an individual to check the information, this led to a situation where the right information existed at the right time, but never reached the right place (right individual). This is in line with results presented by Mason-Jones and Towill (1999) who conclude that new IT systems only offer more effective support, but that decisions must be taken as before.

(2) When production fails to complete internal orders in time, there is no feedback to PRMS. Information is stored only when an internal order is completed. This of course affects planning, as new schedules are not developed to organise an alternative production plan for the order in progress, thus resulting in a situation where the right information does not appear in time. This can be understood as a problem in the interface between the older paper-based system and the new electronic system. Because all the procedures with which the various departments are familiar are not present in the electronic system, a complementary system of hard copies and oral orders similar to the older system is needed to ensure that an order is processed efficiently. It appears, however, that it may be problematic when the paper system and the electronic system are not totally compatible. We found that this led to the belief that 'it is all in the PRMS', when there is actually a significant amount of information on paper or even in the form of oral communication between the actors. As a director of planning described:

> 'Production did not proceed as planned. No changes are made after order has been forwarded to production — it is better to proceed instead of creating uncertainty in the internal supply chain. This problem could have been avoided if the information had reached the head planner before a certain date. It was lack of communication between customer and sales that created the initial problem.'

Distortion number 1 is an example where the PRMS did not trigger the human to take an action, but in distortion number 2 the human did not trigger the PRMS.

(3) The interface between the paper system and the electronic system also causes insecurity and failure in producing internal standard components and ensuring a sufficiently exact record of stock values. Many respondents explicitly claim that there are often products missing from stock or that components needed for assembly are missing. We found that this could be the result of a poorly defined interface between the paper system and the electronic system; it seems that employees do not totally agree on where the correct information can be best found. According to some respondents, it is best when information is contained in hard copies accompanying the physical goods while, according to others, it is best when information is contained in the PRMS. This illustrates the interface between two cultures — an older one liking the paper system, and a newer one following the decided procedures. It is of course important that there is an equal

amount of information from all sources and that there are clear guidelines as to which information source is most appropriate.

Our cases summarise a picture of problems appearing in the interfaces — either in the interface between human and PRMS, or in the interface between the paper-based system and the new PRMS (information system). However, the problems in both interfaces are due to human mistakes rather than to badly formulated procedures. A culture based on collaboration and direct human contact is the only way to solve random or less frequently occurring problems, while well documented and implemented procedures can solve more frequently occurring problems. Or as pinpointed by Chiu (1995) an effective system needs organisational structure, an effective system and employee participation.

5. Conclusions

This study contributes to the understanding of mapping and describing information and physical material flows in an integrated supply chain. The study presents a process-oriented mapping tool which can be used to easily map and describe information flows and physical material flows. Many methods frequently used in the industry for mapping information flows are theoretically based. This presumes a deductive perspective, as the model already exists before the mapping process begins. Our methodology offers an inductive approach, which is based on interviews and which has been used to produce a model in line with the empirical findings.

The two firms exhibit similarities within the information flow — the information flow is more voluminous at the beginning of the internal supply chain. In the case presented (A-1), we found that the respondents were more 'sending-intensive' at the beginning than at the end of the flow. 'Sending-intensive' means that they tended to send information to PRMS rather than load information from PRMS. The respondents at the end of the flow were more 'loading-intensive' than at the beginning of the flow. The two firms are highly dependent on both computerised and orally communicated information.

We identified three main factors that cause distortion in the information flow. These factors could therefore be improved in order to generate a better flow within the organisation:

(1) New or changed information in the database must always trigger an employee. If not, the information will be left without needed decisions being made, impeding the information flow.
(2) Every piece of information must be stored electronically. If an oral system exists parallel to the information system, every relevant fact and decision made must be registered retrospectively.
(3) Everyone involved must use the information system. If a parallel system is allowed, chaos is at hand. The organisation must give resources for slow learners to understand and use the system.

Further, the results of the study support results from Mason-Jones and Towill (1999), who pointed out the importance of availability of information for all involved parties. Distortions caused by information not being available on time have proven to be of utmost importance. However, information must not only be available, but also trigger the employees to actually take action. Availability alone is not enough, since awareness of availability and of changes in the information must be added.

As detected by Chiu (1995), changes in a running order can cause many problems. An effective system needs organisational structure, an effective IT system and the participation of the employees. In this study the participation of the employees has been the focus, as the systems are effective per se. Participation is not enough, though, as it is also important that structure and culture collaborate. A distinct structure combined with a cultural implementation supporting an employee's acceptance of the structure is necessary. In this study the acceptance of the system is very much connected with the number of years at the firm (or with age), where the staff with more years of employment tend to ignore the new information system. The results therefore contribute to implementation practices research (e.g., Light *et al.*, 2001) where focus is on the functionality of the system.

6. Discussion

Hull (2002) argues that if information ends up at the wrong destination, it is also difficult to obtain the relevant information when needed, as the information becomes increasingly distorted as it moves along the supply chain. In our case we could conclude that the information load is 'sending-intensive' at the beginning of handling an order; also, if this information does not end up at the right destination it leads to judgmental decisions.

Therefore, if organisations could streamline the information flow at the beginning of an order and also make sure that this information only reaches the involved parties, organisations would have a better chance to produce the actual order on time, with the right quantity, and with the right quality. Or as Hull (2002) claimed: by focusing attention on a company's primary data flows, one can improve the overall reliability of the supply chain.

Today, organisations make use of ERP (Enterprise Resource Planning) systems to integrate both customers

and suppliers (Evans *et al.*, 1993). This is an important tool, and used rightly it will contribute to higher efficiency in the information flow. It is of importance that ability to store information and control information flows is also connected with a commitment to 'do good' (Lee *et al.*, 1997). Employee support for the system is a core factor. The systems must be tailored to specific businesses, and our findings support Baird and Griffin (2003) who found that effective implementation also requires a change in human behaviour. If the employees are not prepared to leave the older systems behind, double flows evolve.

6.1. *Managerial implications*

Our findings show that it is valuable to map information flows in an organisation in order to improve efficiency. Findings also indicate that it is better to use an inductive perspective when mapping information flows — that is, to follow the real flow, from source to estuary, rather than looking at the formal documentation. This approach decreases the risk of trying to confirm the supposed model instead of attending to the real flow. Our method has worked very well in the two firms, and has contributed to a more objective picture of the information flow. Therefore the firms have been able to make their decisions about improvements based on a more genuine documentation than before.

A second implication is that most of the problems have appeared when information becomes stray. This means that information is stored without an owner. When new or changed information does not trigger an individual, there is a risk of no decisions being made. Hence, managers should find systems that always activate an individual at the right time when being changed or complemented.

Further, having double systems for information is always a risk. This is a well-known fact, but both of the above firms had double (or triple) systems for information — one oral, one paper system, and one official computer-based information system. This is not an easy problem to solve, but it is important for managers to find ways of information storage that can exclude oral or written parallel storage practices that are not connected to the information system.

6.2. *Suggestions for future research*

This study will hopefully contribute to greater knowledge about the complexity of the internal supply chain and the need for suitable measures. Even though both of those organisations have sophisticated information systems, distortions still exist within the internal supply chain. One problem that has not been addressed in this study is the need for metrics. In the traditions of supply chain management and quality management there is a strong focus on the connection between a problem, a way to measure, and the metrics suitable to use. Theory shows clearly that there are measures and metrics regarding quality, flexibility, cost and delivery, yet it is not easy to find measures and metrics for information flow. In order to take research on information flow further, some functional metrics are needed that combine data flow with the human aspects of information systems.

References

Baird, L and D Griffin (2003). Time and space: Reframing the training and development agenda. *Human Resource Management*, 42(1), 39–52.

Chaffe, BC (2001). *Information Logistics: Outsourcing Solutions Can Improve Productivity*. Washington: Graduate School of Business, University of Washington.

Chibba, A and SÅ Hörte (2003a). *Information Flow and Physical Material Flows in Supply Chains*. Halmstad: Report CIL Ljungby.

Chibba, A and SÅ Hörte (2003b). Supply chain performance — A meta analysis. *Proc. Euroma-Poms Conference*, Cernobbio, Lake Como.

Chiesa, V, P Coughlan and CA Voss (1996). Development of a technical innovation audit. *Journal of Production and Innovation Management*, 13, 105–136.

Chiu, HN (1995). Combining management and information flow techniques. *Management Decision*, 33(4), 52–64.

Cook, TD and DT Campbell (1979). *Quasi-Experimentation: Design and Analysis Issues for Field Settings*. Chicago: Rand McNally.

Egnell, PO (1994). *Processledning — En arbetsmodell samt erfarenheter från svenska organisationer*. Luleå: Luleå University of Technology.

Evans, GN, MM Naim and DR Towill (1993). Assessing the impact of information systems on dynamic supply chain performance. *Logistics Information Management*, 6(4), 15–25.

Forrester, J (1961). *Industrial Dynamics*. Cambridge, MA: MIT Press.

Harrington, JH (1991). *Business Process Improvement — The Breakthrough Strategy for Total Quality, Productivity, and Competitiveness*. New York: McGraw-Hill, Inc.

Hayes, RH and SC Wheelwright (1984). *Restoring our Competitive Advantage*. New York: Wiley.

Herbig, AP and H Kramer (1994). The effect of information overload on the innovation choice process. *Journal of Consumer Marketing*, 11(2), 45–54.

Hill, T (2000). *Manufacturing Strategy*, 2nd ed. New York: Palgrave.

Holmberg, S (2000). A systems perspective on supply chain measurements, *International Journal of Physical*

Distribution & Logistics Management, 30(10), 847−868.

Hull, B (2002). A structure for supply-chain information flows and its application to the Alaskan crude oil supply chain. *Logistics Information Management*, 15(1), 8−23.

Kaye, D (1995). Sources of information, formal and informal. *Management Decision*, 33(5), 13−15.

Koh, SCL, M Demirbag, E Bayraktar, E Tatoglu and S Zaim (2007). The impact of supply chain management practices on performance of SMEs. *Industrial Management & Data Systems*, 107(1), 103−124.

Lee, HL, V Padmanabhan and S Whang (1997). Information distortion in a supply chain: The bullwhip effect. *Management Science* (43), 546−558.

Light, B, CP Holland and K Wills (2001). ERP and best of breed: A comparative analysis. *Business Process Management Journal*, 7(3), 216−224.

Lueg, C (2001). Information, knowledge, and networked minds. *Journal of Knowledge Management*, 5(2), 151−159.

Mason-Jones, R and DR Towill (1997). Information enrichment: Designing the supply chain for competitive advantage. *Supply Chain Management: An International Journal*, 2(4), 137−148.

Mason-Jones, R and DR Towill (1999). Using the information decoupling point to improve supply chain performance. *The International Journal of Logistics Management*, 10(2), 13−26.

Meredith, J (1998). Building operations management theory through case and field research. *Journal of Operations Management*, 16, 441−454.

Nonaka, I and H Takeuchi (1995). *The Knowledge Creating Company — How Japanese Companies Create the Dynamics of Innovation*. Oxford: Oxford University Press.

Petroni, A and B Panciroli (2002). Innovation as a determinant of suppliers' roles and performances: An empirical study in the food machinery industry, *European Journal of Purchasing & Supply Management*, 8, 135−149.

Rushton, A and J Oaxly (1991). *Handbook of Logistics and Distribution Management*. London: Kogan Page.

Saad, M and B Patel (2006). An investigation of supply chain performance measurement in the Indian automotive sector. *Benchmarking: An International Journal*, 13(1/2), 36−53.

Schwab, DP (2005). *Research Methods for Organizational Studies*, 2nd ed. Mahwah: Lawrence Erlbaum Associates.

Stewart, G (1995). Supply chain performance benchmarking study reveals keys to supply chain excellence. *Logistics Information Management*, 8(2), 38−44.

Thomas, DJ and TS Graham (1996). Co-ordinated supply chain management. *European Journal of Operational Research*, 94(3), 1−15.

Vereecke, A and S Muylle (2006). Performance improvement through supply chain collaboration in Europe. *International Journal of Operations & Production Management*, 26(11), 1176−1198.

Voss, C, N Tsikriktsis and M Frohlich (2002). Case research in operations management. *International Journal of Operations & Production Management*, 22(2), 195−219.

Womac, PJ, DT Jones and D Roos (1990). *The Machine that Changed the World*. New York: Harper Perennial.

Yin, RK (1994). *Case Study Research — Design and Methods*. Thousand Oaks: Sage Publications.

Zhou, H and WC Benton Jr (2007). Supply chain practice and information sharing. *Journal of Operations Management*, 25, 1348−1365.

Aron Chibba is a Lecturer at Halmstad University, Sweden, and a faculty member of the Centre for Technology, Innovation and Marketing Management (CTIM2). He holds a LicEng in Industrial Management and an MSc in Total Quality Management. He spent more than ten years as a quality consultant and CEO of both a non-destructive testing firm and a certification organisation before rejoining the academy in 1998. His research interest is in the area of managing the supply chain from a quality management perspective.

Jonas Rundquist is a Lecturer at Halmstad University, Sweden, and a faculty member of the Centre for Technology, Innovation and Marketing Management (CTIM2). He holds a PhD in Industrial Organization and an MSc in Innovation Management. He has spent more than ten years as a project manager and CEO of design-intense firms before rejoining the academy in 1999. His research interest is in the area of organising and leading development projects with a focus on knowledge integration.

Paper 6

Chibba, A. (2015). Measuring supply chain performance: A framework for prioritizing measures. *International Journal of Research in Business and Technology*, 6(2): 782-793.

TECHMIND RESEARCH
ISSN: 2291-2118

International Journal of Research in Business and Technology
Volume 6 No.2 April 2015

Measuring supply chain performance: A framework for prioritizing measures

Aron Chibba
School of Business and Engineering
University of Halmstad
Aron.Chibba@hh.se

Abstract- *One could consider changing the expression "organisations compete on a market" to "supply chains compete on a market". The reason for this is that most organisations are interested in reducing cost and increasing profitability. The need to evaluate the appropriate type of supply chain performance measure is therefore vital, as it can affect the decision-making process. The objective of this paper is to present a framework that identifies which performance measures and metrics should be prioritised in relation to the type of product manufactured and the type of supply chain using the product life cycle (PLC) approach. The framework presented consists of three descriptions of theories, which, when combined, provide valuable guidance for the prioritisation of performance measures. The three theories are: 1) type of supply chain, 2) type of supply chain performance measure; and 3) scope of measurement in the supply chain.*

Keywords- *Supply chain; Performance; Measure and metrics*

1. INTRODUCTION

During the last two decades supply chain management literature has evolved rapidly as a result of global competition and the introduction of information technology. Reducing cost and increasing profitability has always been of interest to organizations that compete on a market. Some researchers claim that it is the supply chain itself that competes on a market and not merely the organizations with their specific strategies and goals e.g. (Christopher, 1997) [8]. All members of the supply chain, both upstream and downstream, are actors who influence its output (e.g. quality, delivery, cost). In a framework that reflects manufacturing strategy issues in corporate decisions, (Hill, 2000) [30] describes how organizations can gain advantage over their competitors. He claims that supply chain strategy is part of the overall manufacturing strategy of an organization, and therefore the manufacturing performance affects the performance of the supply chain. The need to measure the correct metrics of performance within an organization is vital, due to the fact that it may affect the decision process. For example, if the measure fails to provide correct or relevant information about the process being measured, it could lead to a wrong decision followed by counterproductive actions. Several studies e.g. (e.g. Koh et al., 2007 [32]; Saad and Patel, 2006 [50]; Vereecke and Muylle, 2006) highlight the need to measure the efficiency of integrated supply chains. These studies have attempted to outline and describe different performance measures across and between organizations. However, the object of study of most researchers is the organization that operates within the supply chain, which means that the research outcomes do not actually capture the performance of the supply chain itself. (Lambert and Pohlen, 2001) also point out that most articles and discussions about supply chain measures/metrics are, in reality, about internal logistic performance measures. They argue that these measures do not capture the overall supply chain performance (SCP) nor do they indicate opportunities to increase competitiveness, customer value or value for each actor in the supply chain.

This paper focuses on analysing the supply chain performance of manufacturing organizations, i.e. the measures and metrics used to describe it. The result of this paper is relevant for all types of manufacturing organizations, in particular OEMs, Overall Equipment Manufacturers. The empirical data in this paper have mainly been collected from OEMs. This type of manufacturer usually operates downstream the supply chain, near the customer; therefore this paper is relevant for this part of the supply chain. How the supply chain of a manufacturing organization competes and develops in order to remain competitive is also focused upon and supply chain performance measures and metrics are analyzed. The unit of analysis is the supply chain type and its measures, sub measures and metrics. The main research question is: *What type of supply chain performance measures should be prioritised in different types of supply chains?*

The objective of this paper is to present a framework that indicates which performance measures/metrics should be prioritized depending on the type of supply chain operated by the organization, e.g. efficient, quick, agile, market responsive, lean, or hybrid. The objective is also to apply the life cycle (PLC) approach (Hill, 1993) to the market, in particular in the introduction, growth, maturity and decline

phases, and combine it with the different supply chain measures and the scope inherent in the measurement situation. Some parts, involving the PLC and the type of supply chain, have already been described and presented by other researchers i.e. (Cigolini Cozzi, *et al*., 2004) [13]; (Aitken, Childerhouse *et al*., 2003) [1]; (Childerhouse and Towill, 2000) [7]; (Christoper and Towill, 2000) [10]. The "theory" about the measurement and metrics of supply chain performance in terms of what it is, how to measure it and, finally, how to choose the most suitable measures and metrics for different types of supply chains, will be presented. If, for example, the market is mature, cost is the right measure, or if the market is growing, delivery (time) could be the most suitable measure, or if the market is niche based or innovative, perhaps product characteristics, i.e. quality, are of great importance. The aim of this paper is to provide knowledge which can be used by organizations for developing and improving their supply chain, both upstream and downstream. The major contribution is the framework for determining and prioritizing which supply chain performance measures and metrics should be assessed. The framework can be used as a guideline to show manufacturing organizations e.g. OEMs, what aspects of supply chain performance are important to measure. The OEM can then monitor and evaluate the performance of the supply chain and use this information to introduce improvements.

The framework presented in this paper is based on previous research and empirical studies of two large multinational manufacturers of heavy vehicles. Delivery, quality, price, cost and flexibility are the measures particularly focused upon in this paper. The empirical work mainly focuses on overall equipment manufacturers i.e. OEMs and the appended papers consist of interviews with OEM managers for the most part from large enterprises (LE). The framework is therefore limited to these types of organizations, while the empirical work is mainly valid for downstream in the supply chain, i.e. near the end customer. The research takes an OEM perspective and does not include any interviews with suppliers and/or customers. Before including both suppliers and customers, more research is required about how a manufacturing organization such as an OEM measures and defines their type of supply chain. However, the theory presented does not solely focus on manufacturing but is relevant for all types of organizations.

2. METHOD USED TO DEVELOP THE FRAMEWORK

This paper has a descriptive rather than an explanatory approach. Case studies are often associated with descriptive and exploratory research. The method used to develop the framework in this paper is based on the scientific principle of adding small pieces of theory to well known existing theories i.e. deductive. The point of departure is the famous product life cycle (PLC) model with its four phases: introduction, growth, maturity and decline. This model served as a base for adding both old and new theory i.e. which types of products and supply chain are connected to each phase of the product life cycle and which types of performance measures and metrics are suitable as a means of assessment for manufacturing organizations and, finally, the point in the supply chain at which each performance measure should be applied. The first contribution is the connection of different types of supply chain to the product life cycle model. The theory of supply chain types e.g. efficient supply chain (ESC), quick supply chain (QSC), market responsive supply chain (RSC), agile supply chain (ASC), lean supply chain (LSC) and finally hybrid supply chain (HSC) is then added to the model and discussed. The types of products which can be connected to each type of supply chain are also presented and discussed. This provides the first input to the framework, *"type of supply chain"* e.g. efficient supply chain (grocery, newspapers*)* and lean supply chain (automobiles). The types of supply chain performance measures and metrics that can be associated with each "type of supply chain" are then discussed and the outcome is the second input to the framework i.e. *"type of supply chain performance measure and metrics"* i.e. what type of performance measure and metrics should be measured. For example: an agile/quick supply chain requires speedy delivery, while a lean supply chain is more focused on cost reduction. The third and final input to the framework deals with the "*scope of measurement in the supply chain"* i.e. the most appropriate point in the supply chain for measuring performance. It could be between the organization and customer, the supplier or even internal measures within the organization or over the whole supply chain. These three parts of the framework provide an understanding of the need to choose the right type of performance to measure and where in the supply chain it should be measured.

Theory supporting the development of the framework is mainly collect from existing well known theory and the empirical work conducted in two large multinational manufacturers of heavy vehicles. It begins with an overview of the product life cycle (PLC) as a concept and proceeds by connecting different types of products with individual PLC phases. Supply chain theory is then described and linked to the PLC, together with supply chain performance measures and metrics and where in the supply chain an organization should measure performance.

The empirical work supporting the development of the framework is collected from a case study from two large multinational manufacturers of heavy vehicles. The two heavy vehicle manufacturers are part of a "heavy vehicles" group and also support CIL, Centrum for Information logistics, Ljungby, Sweden. The manager of CIL first contacted these two manufacturers to invite them to take part in the research project, after which we contacted them and described the project. The companies that we were about to study gave us their full support. Top executives allowed us access to required data i.e. personnel and meetings. We employed a qualitative research process, as

our aim was to present the supply chain performance measures and metrics focused on by these two Heavy Vehicle manufacturers as a result of their position in the supply chain. We limited our interviews with managers to 2-3 hours per interview. At an early stage we made it clear that we wanted to interview the "owners" of the performance measure i.e. those who were responsible for measuring the supply chain performance, e.g. quality, delivery, cost (price) and flexibility. Together with the two manufacturers, we then defined our respondents as follows: Company As' Quality Assurance Purchasing Manager, Production Manager and Purchasing Manager and Company Bs' Quality Manager (also production manager at site 1, Production Manager site 1 and Production Manager site 2, Purchasing Manager (site 1 and 2) and finally Operating Purchasing Manager (site 1). The total number of respondents was seven. The interview questions were related to the supply chain, to performance, measures and metrics. The issues addressed in the interviews were based on earlier supply chain performance research and supply chain performance theories e.g. (Robson, 2004 [48]; Cigolini, Cossi *et al*., 2004 [13]). Staff interviewed included the managers from each company responsible for supply chain performance. The empirical content of the in this paper is mainly based on case studies, which seems to be the most appropriate data collection method when concepts and variables are difficult to quantify. One alternative approach could be to use a more quantitative method as well as a broader sample in order to be able to generalize the conclusions. The reasons for only choosing four metrics are that the measures chosen are the ones most frequently referred to by purchasing managers when selecting suppliers. Moreover, the presented work mainly focuses on large manufacturing organizations, especially OEMs.

3. THEORY SUPPORTING THE DEVELOPMENT OF THE FRAMEWORK

The concept of product life cycle (PLC) was first introduced in the 1950s by (Dean, 1950) [16], who used the concept in relation to the marketing role of the life cycle. It has since been widely discussed and reviewed by researchers including (Gardner, 1987) [19] and (Rink and Swan, 1979) [47], who presented surveys of the literature. However, the validity of the PLC concept has been questioned. According to (Pesonen, 2001) [45], most criticism of the life cycle concept was related to marketing issues. He argues that opponents mainly criticize the use of the bellshaped sales curve as default or self-evident product sales behavior. These researchers provide their point by illustrating the poor fit of the curves by means of empirical examples of product class, product form or brand. For example, (Cox, 1967) [14] who identified six different shapes of the product life cycle graph in a study of 256 pharmaceutical products, thus revealing that there are many products that do not follow the usual shape of the product life cycle presented in figure 3. However, other researchers (Barksdale and Harris, 1984) later presented evidence showing that the bell-shaped curve is a reasonable model of the sales record for many types of products. The concept of PLC is based on the fact that every product has a life in the market with respect to business, cost and sales measures. When a product is developed, it sooner or later enters the market. Sales grow slowly at first, until a critical mass of consumer awareness is achieved, after which sales grow rapidly until the demand cools off and the product enters a sustained period of slower growth. Later, the sales decrease gradually and then perhaps more rapidly. When sales reach a certain level, the organization has to consider ending the life of the product. The PLC is typically divided into four phases (Hayes and Wheelwright, 1984): introduction, growth, maturity and decline. However, some researchers add an initial phase of development, while others include a final cancellation phase or a saturation phase between maturity and decline. All types of products can be fitted into the PLC model, although different types of products, e.g. complex or simple, have a particular curve in the PLC. For example, an organization that manufactures white products, automobiles or forklifts is in a mature market (Selldin & Olhager, 2007 [51]; Cigolini, Cozzi *et al*. 2004 [13]; Huang, Uppal *et al*., 2002 [31]; Fisher, 1997 [17];).

3.1 Type of product characteristics in each stage of the PLC model

A product can either be functional or innovative, primarily depending on its demand characteristics in terms of the life cycle length, demand predictability, product variety, as well as market standards for lead times and service (Fischer, 1997). Some researchers (Huang, Uppal *et al*., 2002) also hold that products can be categorized into functional and innovative but add one more category i.e. hybrid products. *Functional products* are defined as simple products, synonymous with standard and commodity products i.e. grocery, pharmaceuticals, basic apparel (jeans and underwear), classic books. Their demand can be accurately forecast and their market share remains fairly constant. They also enjoy a long life-cycle with superficial design modification leading to different product types. Such products have a well defined process and it is reasonable to state that the organization has a long-term relationship with its suppliers in terms of material quality, delivery times and quantity discounts. *Innovative products* are defined as new products developed by organizations to capture new markets and designed to be acceptable to changing customer demands or derivative products for capturing a wider share of the market. Huang, Uppal *et al*. conclude that *hybrid products* consist of either different combinations of standard components, or a mix of standard and innovative components (Huang, Uppal *et al*., 2002) [31]. (Cigolini, Cozzi *et al*., 2004) [13] also categorized products and presented two distinct groups; complex products and simple products. Their description of "simple products" matches Huang, Uppal *et al*.'s description of

functional products. However, their description of complex products does not fully agree with the descriptions of innovative or hybrid products. "Complex products" indicates the structural complexity of the end product i.e. number of parts, subassemblies and level in the bill of materials, which determines the number of manufacturing processes, suppliers and technologies that have to be managed and co-ordinated. However, a complex product can also be a functional one. Functional products are either simple (grocery, basic apparel) or complex (white goods, automobiles) and are described in the literature (Selldin & Olhager, 2007 [51]; Cigolini, Cozzi *et al*. 2004 [13]; Huang, Uppal *et al*., 2002 [31]; Fisher, 1997 [17]) as being in the maturity phase of the PLC. Innovative products are said to be in the introduction and growth phase (Selldin & Olhager, 2007 [51]; Huang, Uppal *et al*., 2002 [31]; Fisher, 1997 [17]). However, innovative products are described by (Cigolini, Cozzi *et al*., 2004 [13]) as being in both the introduction and decline phase. The reason for this is that innovative products have a short PLC e.g. three months to one year (Fischer, 1997) [17]. This means that the maturity phase is so short that it almost immediately goes from introduction and growth to decline with no time for the maturity phase. Hybrid products are described by (Huang, Uppal *et al*., 2002) [31] as consisting of either different combinations of standard components (functional products) or a mix of standard and innovative products, such as an automobile. Researchers seem to have a similar view and way of presenting product characteristics within the phases of the PLC (Selldin & Olhager, 2007 [51]; Cigolini, Cozi *et al*., 2004 [13]; Huang, Uppal *et al*., 2002 [31]; Fisher, 1997 [17]).

3.2 The type of supply chain connected to products within the PLC

This section gives a deeper understanding of how various products require different types of supply chains, in order to ensure effective manufacture. The types of supply chains presented are then connected to the PLC model. (Fisher, 1997) [17] has developed a model that can be considered a prescription for choosing the right supply chain i.e. efficient supply chain or a market responsive supply chain, for a certain product. A Physically Efficient supply chain is suitable for functional products, while a market responsive supply chain is appropriate for innovative products. Cigolini, Cozzi *et al*. also link product characteristics and type of supply chain, i.e. efficient, quick or lean supply chains, and conclude that:

- Mature and simple products require an efficient supply chain
- Mature and complex products require a lean supply chain
- Complex products in the growth phase require a lean supply chain
- Simple products in the introduction/decline phase require a quick supply chain

There are several types of supply chains described in the literature. (Fischer, 1997) [17] presented a model which links supply chains to products. The model describes two types of supply chains and connects functional and innovative products to them i.e. efficient supply chains (ESC) are matched to functional products while *market responsive supply chains* (RSC) are linked to innovative products. Market Responsive supply chains (RSC) have similar characteristics to agile supply chains (Selldin & Olhager, 2007). An *efficient supply chain, ESC,* brings products to the market that can broadly be considered as commodities and are often sold in high volumes (e.g. grocery, newspapers …). Because of the stability of their product flows, such organizations can invest in large and financial-intensive facilities, and improvement initiatives are focused on operations rather than product innovation. These types of products are in the maturity phase of the PLC. A *quick supply chain, QSC* (e.g. fashion apparel, white products) can be defined as "products whose demand is difficult to forecast". These types of organisations invest in manufacturing systems with a high variable vs. fixed cost ratio due to the fact that manufacturing flexibility is very important. These types of organisations are in the introduction (and decline) phase of the PLC. A *lean supply chain*, LSC, (e.g. automobiles) deals with a functional product, the demand for which can be forecast. LSCs also have intermediate characteristics: firms do not only compete on product price or novelty, but simultaneously on price, novelty, quality and customer service. An LSC employs continuous improvement processes in order to eliminate waste or non-value stops across the chain (Turkett, 2001; Christopher and Towill, 2000 [10]). The LSC employs both lean production and time compression to ensure economical, flexible and responsive operation. (Naylor *et al*., 1999) [41] presented a definition of leanness: to develop a value stream to eliminate all waste, including time and to enable a level schedule. Innovative products focus on capturing new markets and are designed to be acceptable to changing customer demands. (Huang, Uppal *et al*., 2002) argue that this type of product usually has uncertain demand and its design may be unstable; such products are in the introduction or growth stages of the product life-cycle. Huang, Uppal *et al*. claim that this justifies the use of an *agile supply chain* (ASG), the paradigm of which was presented by (Christopher and Towill, 2000) [10]. According to (Naylor *et al*. 1999), agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. (Huang, Uppal *et al*., 2002) [31] presented a *hybrid supply chain* i.e. a combination of an LSC and ASC, which they claim might be the best choice for car manufacturers. In the example provided, they demonstrate that some automobile components may contain innovative features. As a result, these components may be produced using either lean or agile techniques. A hybrid supply chain may therefore be appropriate, as it consists of a mix of both lean and agile techniques. These products e.g. automobiles forklifts, rollers, pavers are in the introduction, growth and maturity phases of the PLC. (Naylor *et al*., 1999) also presented a

supply chain which is a combination of LSC and ASC i.e. *Leagile supply chain*. This type of supply chain is described by (Christoher and Towill, 2000) [11] as both lean and agile i.e. agile enough to respond to what is actually selling (market driven) with availability as the market winner. (Christopher and Towill, 2000) [11] also presented a "customized leagile supply chain" which has a more customer driven approach where the market winner is lead-time, and an example of a product could be a personal computer. Dell supplies products that accord exactly with individual customer specifications.

3.3 Performance measures connected to the type of supply chain

As mentioned before the performance of the supply chain has been widely covered in the literature These studies highlight the need to measure the efficiency of the integrated supply chain. The efficiency can best be described by customers. (Petroni and Panciroli, 2002) [46] argue that customers usually retain suppliers who achieve the highest aggregate score on price, quality, flexibility of production and delivery times. (De Toni, Nassimbeni *et al*., 1994) [15] claim that an efficient high quality supply chain is dependent on the achievement of a high-level performance in terms of cost, quality and time-to-market. (Hayes and Wheelwright, 1984) [24] were the first to present methods for addressing operational strategy by means of four generic competitive priorities; quality, cost, flexibility and delivery, which are the dimensions on which a company chooses to compete within a target market. Their original formulation was applicable to all functions. (Hill, 2000) [30] also addresses competitive priorities such as price, cost reduction, delivery reliability, delivery speed, quality conformance, flexibility - increased demand, product range and design, which he terms order-winners or qualifiers. Since the beginning of the manufacturing era, performance measures have been important for organizations as a way of obtaining knowledge about what is happening around them. (Lambert & Pohlen, 2001) [34] argue that a well crafted system of supply chain metrics can lead to competitive advantage through differentiated services and lower costs. The performance of a supply chain can be viewed as a system of measures such as quality, delivery, flexibility and cost/price. Traditional performance measures such as profitability are less relevant for measuring supply chain performance.

A well known framework for benchmarking performance in the supply chain is that of the Supply Chain Council, which is a cross-industry association. Their model, known as SCOR (Supply Chain Operations Reference), is built around four major processes, namely: plan, source, make and deliver. These processes cover the key supply chain activities from the point of identifying customer demand to delivering the product. The main aim of this reference model is to provide a standard way of measuring supply chain performance and to use fixed metrics for benchmarking against other organizations (Christopher, 1998) [9]. The framework describes metric type, the expected outcomes and the diagnostics that can be predicted. However, the Supply Chain Council's integrated supply chain metric framework does not fully take an organization's type of product, type of supply chain or measurement situation into account.

An example of a supply chain performance measure could be delivery, sub measure could be "the ability to consistently deliver on the agreed due date", the metrics could then be presented as "% of on time delivery". Metrics is thus the system of parameters or methods for the quantitative assessment of a process to be measured, as well as the procedure involved in carrying out such a measurement. Metrics defines the items to be measured and is usually specifically related to a given subject area, in which case it is only valid within a certain domain and cannot be directly benchmarked or interpreted outside it. Generic metrics can, however, be aggregated across subject areas or business units of an enterprise.

The main idea behind measuring performance is to obtain information about what needs to be improved. Organizations today try to measure their overall customer service performance, and while the criteria considered vary, they usually include quality (of the product) and delivery time. However, the establishment of a measurement system requires knowledge about the processes within the organization and between customers and suppliers. To generate this knowledge the organization has to decide what performance metric to measure. As (Robson, 2004) [48] stated "without the knowledge of the exact circumstances under which a measurement system either will or will not improve the performance, it is difficult to genuinely justify the additional cost of implementing a measurement system". (Krausse & Pagell, 2002) [33] presented a table of performance items for assessing organizational strategy, the main idea being to describe "priority" e.g. quality (e.g. reliability, durability, and conformance), delivery (e.g speed, reliability), flexibility (e.g. volume, mix), cost (e.g. price, total cost) and innovation (e.g. process, product) as well as the focus of the manufacturing and purchasing items. For example, quality (reliability) in manufacturing is defined as "the ability to maximize the time to product failure or malfunction" while in purchasing the "supplier selection and retention decisions are based on the ability of a supplier to provide reliable inputs". However, there are several supply chain performance measures and metrics that can be assessed. Those most commonly used by practitioners i.e. purchasing managers as well as the most cited in research are: quality, delivery, cost and flexibility, which will be described in more detail below.

Quality has according to (Hill, 2000) [30], been thrust onto centre stage since the late 1970s. However, several companies have failed to compete in this domain. Hill holds that the definition of the term quality has been broadened to encompass many dimensions, resulting in a lack of understanding and subsequent lack of direction. One reason why companies do not compete in the quality

domain is due to failure to clarify which dimension(s) of quality will provide the best result in given markets. One of the cited researcher who presented eight dimensions of quality is (Garwin, 1988) [20], e.g. Performance – a product'sprimary operating characteristics, Perceived quality – how a customer views the product. The dimensions of quality are generic dimensions that can apply to all types of products and services in all types of markets. These quality dimensions are well known and much cited. However, the term product quality, which is not mentioned, can be classified according to perceived quality i.e. how a customer views the product. Product quality is focused on the user of the product (or service, service quality). The user can be an organization or an individual, not necessarily the end customer but a customer within the supply chain i.e. an internal customer. The supply chain performance measure "quality" has several sub measures e.g. conformance quality, quality reliability and end product quality. In the literature, quality and delivery are described as important measures for monitoring the supply chain (Christopher and Towill, 2001 [11]; Aitken, Childerhouse *et al*., 2003 [1]; Hill, 1993 [29]).

Delivery performance has several sub-measures e.g. on time delivery, delivery reliability, faster delivery times, delivery service, delivery frequencies, delivery synchronization, delivery speed etc. Delivery reliability concerns supplying the ordered products on the agreed date. On-time delivery (OTD) is therefore a major concern of the manufacturing as well as the distribution function. (Hill, 2000) argues that in many businesses this criterion constitutes a qualifier. A study of the Indian automobile industry (Saad and Patel, 2006) [50] showed that the key supplier selection factors identified by most of the respondents were supply delivery lead time, historical rejection rate, geographical proximity and reliability. If organizations frequently miss the OTD date, they usually end up with a problem and have to improve quickly before customers change to a different supplier. OTD is a competitive factor and customers tend to measure this performance metric. Hill argues that a company wins orders through its ability to deliver more quickly than competitors or to meet the required delivery date when few or none of the competition can do so. He holds that there are two perspectives on the issue of delivery speed. One is when the process lead time, although shorter than the delivery time required by customers, is difficult to meet as a result of the current forward order load, i.e. the order backlog on the manufacturing capacity, which means that the process lead time to complete the order is greater than the delivery time required. The second perspective is when the process lead time is greater than the customer delivery requirement. Delivery has several sub metrics, and organizations decide which sub-measures are most appropriate to measure, e.g. delivery from suppliers, delivery within their own organization or delivery to customers.

Cost reduction both externally and internally in the supply chain is vital for improving productivity. Hill claims that many organizations do not concentrate their efforts in the area of greatest cost. Instead, they concentrate on reducing the cost of direct labour. (Gadde and Håkansson, 2001) [18] provided examples of what is usually known as indirect purchasing costs. These costs can be defined as: purchasing costs, goods handling costs, storage costs, financial costs, supplier handling costs, administration costs and development costs. Cost is strongly connected to the performance measure price. (Hill, 2000) [30] states that price is an increasingly important order-winning criterion, especially in the growth, maturity and saturation phases of the product life cycle. The task of manufacturing is to achieve the low costs necessary for price-sensitivity in the market-place. This measure is strongly connected to suppliers i.e. purchased items, as well as the manufacturing organization's own workforce.

Flexibility can be defined as "the extent to which a company intends to respond to market changes e.g. significant increases in demand" (Beamon, 1999 [4]; Hill, 2000 [30]). Or as (Harrison, 2001) states: "flexibility is the management of reacting to changes in demand by preserving the resources of time, money, materials, people, plants and suppliers until they are specifically required". Both definitions characterise flexibility as the capability to respond to individual customer requirements. This is a broad performance measure that includes: demand increases (volume), product range (mix), order handling (time), order size etc. Hill argues that, in some markets, a company's ability to respond to increases in demand is an important factor in winning orders. Japanese car manufacturers provide a good example of flexibility; they have established and continue to develop a production system capable of responding to individual customer requirements (Hill, 2000) [30]. (Slack, 1991) identified four types of system flexibility where each type can be measured in terms of range and response: volume flexibility (the ability to change the output level of products produced), delivery flexibility (the ability to change planned delivery dates), mix flexibility (the ability to change the variety of products produced) and new product flexibility (the ability to introduce and produce new products).

3.4 Appropriate supply chain performance measures

There are several types of supply chains described in the literature, i.e. efficient, quick, agile, lean and hybrid, all of which have different characteristics. Several researchers claim that the different types of supply chain require an individual focus in order to achieve optimal performance (Saad and Patel, 2006 [50]; Christopher, Peck *et al*., 2006 [12]; Mason *et al*., 2002 [39]; Christopher and Towill, 2000 [7]; Hoek, R. I., A. Harrisson, *et al*., 2001 [27]; Beamon, 1999 [4]). One could say that certain supply chain performance measures should be prioritized depending on the supply chain type. (Christopher and

Towill, 2000) [10], presented a model summarizing the transition in PC supply chain operations. The model shows the market winners or qualifiers e.g. quality, cost, lead time and availability and how these changed over a 20 years period from the early 1980s to the late '90s.

A primary efficient supply chain measure is cost e.g. total cost from suppliers through the internal supply chain to customer, or all types of cost that have a bearing on the cost of manufacture. The primary supply chain metric can be expressed as e.g. cost/purchased item. A quick, agile or market responsive supply chain (which has similar characteristics) has shorter lead times i.e. delivery as a primary measure, while flexibility (mix) of production and product quality are also primary measures. A shorter lead time from order to delivery is another important Lean supply chain measure, but not but not to the same degree as cost i.e. cost is more important than delivery. A hybrid (lean & quick/agile/market responsive) supply chain focuses on shortening the lead times at component level but without incurring cost, while in order to accommodate customer requirements, it follows the agile (quick/market responsive) supply chain performance measures at product level i.e. delivery, flexibility and quality. In figure 1, the PLC model has been modified in relation to appropriate measures for each type of supply chain and type of products.

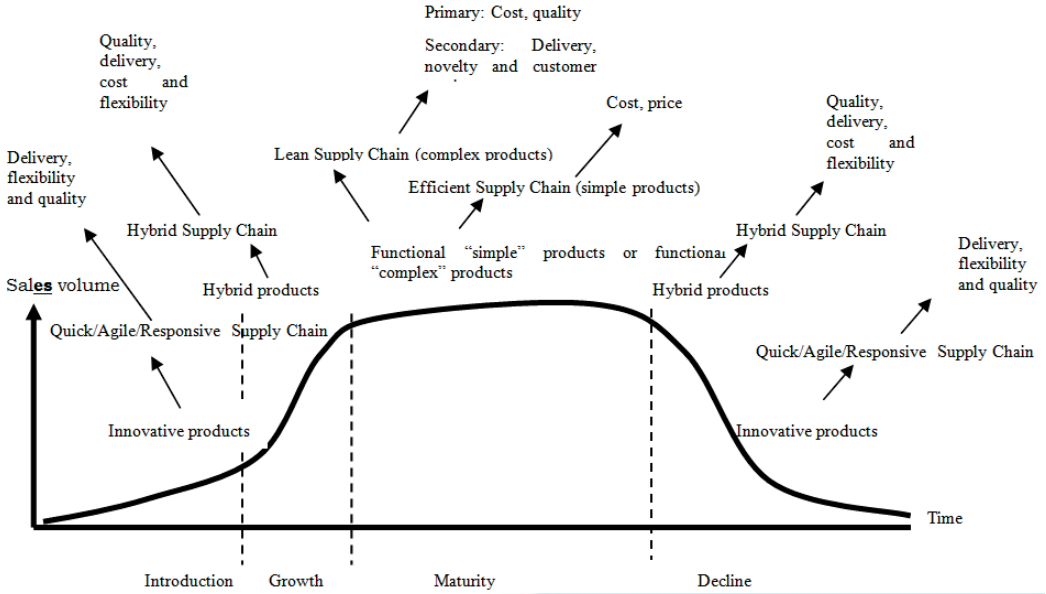


Figure 1. Phases in the product life cycle in relation to different product characteristics and their supply chains, measures and metrics

3.5 Scope of supply chain measurements

The production process in manufacturing organizations is often an activity that has a major impact on production cost, quality and speed of delivery. Therefore, the production process needs to be measured, managed and improved and suitable metrics established under the following three headings (Gunasekaran, Patel *et al*. 2001) [22]: range of products and services, capacity utilization and effectiveness of scheduling techniques. These types of measures are known as functional measures. *Functional measures* (type 1) depict the performance of a separate activity/function of the chain, e.g. flexibility (mix) of production – the ability to effectively produce a wide variety of different products, although they are not supply chain measures as such. However, Holmberg (2000) [28] claims that implementation of SCMs within an organization requires that the internal perspective on performance measures be expanded to include both "interfunctional" and "partnership" perspectives as well as the avoidance of an inward-looking and self focused management approach. There are also measures that show the performance of several interconnected functions i.e. head-processes. Metrics, such as cost (total cost), quality (part per million defects, PPM), non-conformities and delivery lead-time, is suitable for measurement. These types of measures are called *Internal integrated measures* (type 2) and depict performance across functional boundaries within the firm, e.g. quality (conformance) – the ability to manufacture a product whose operating characteristics meet established performance standards; Cost (total cost) – the ability to minimize the total cost of production (labour, materials, and operating costs) by means of efficient operations, process technology and/or scale economies; Delivery (speed) – the ability to minimize the time between the receipt of a customer order

and final delivery, although it can be argued whether this is a supply chain performance measure. These measures shed light on organizational performance and are included in our study as (internal) supply chain performance measures. A study of the US food industry reported that poor co-ordination among supply chain partners wastes an estimated $30 billion annually (Fisher, 1997) [17], which highlights the importance of establishing partnerships in a supply chain. There is a set of criteria/parameters that should be considered when evaluating a partnership (Gunasekaran, Patel *et al*., 2001) [22]. For example, the level of assistance in mutual problem solving supports buyer-supplier partnership development. Several researchers have suggested the following supply chain partnership evaluation criteria: level and degree of information sharing, the entity and stage at which the supplier is involved (Toni, Nassimbeni *et al*., 1994), buyer-vendor cost saving initiatives (Thomas and Graham, 1996) [55], extent of mutual co-operation leading to improved quality (Graham, Dougherty *et al*., 1994) [21] and the extent of mutual assistance in problem solving (Maloni and Benton, 1997) [38]. Other measures that merit consideration are quality (conformance, reliability), delivery performance (reliability), product price and flexibility of scheduling and production. These types of measures are known as *One sided integrated measures* (type 3) and depict performance across organizational boundaries as well as measuring chain performance across supplier or customer boundaries, e.g. total cost, total lead-time and delivery (speed) – the ability to respond in a timely manner to customer needs. Some researchers (Rushton and Oaxly, 1991 [49]; Thomas and Graham, 1996 [55]) claim that the largest cost component of logistics is transportation costs in the total chain. They state that the trucking cost is always the largest part of the total distribution cost. Therefore, it appears important to treat delivery and cost as a high priority metric. (Stewart, 1995) identified the following measures of delivery performance: delivery-to-request date, delivery-to-commit date, and order fill lead-time. These types of measures are known as *Total chain measures* (type 4), as they depict performance across organizational boundaries and measure the performance of the entire supply chain, including links to suppliers and customers, e.g. total chain costs – and provide an opportunity to minimize the total cost from supplier to end customer. The above measurement situations (type 1-type 4) can be linked to a model developed by the Supply-Chain Council (SCC) e.g. PLAN, SOURCE, MAKE and DELIVER. (Lockamy III and McCormack, 2004) [37] describe these four processes as follows: PLANNING deals with the decision-making area, e.g. demand planning, which includes forecasting development activities has a significant impact on supply chain performance. SOURCING handles supplier transactional collaboration activities and has a significant impact on supply chain performance within the Source decision area. MAKING planning process activities have a significant impact on supply chain performance within the Make decision area. Activities include: collaboration among the sales, manufacturing and distribution functions. (Lockamy III and McCormack, 2004) [37] argue that to ensure its effectiveness, the process must be integrated and coordinated across functional and organizational boundaries. In the DELIVERY decision-making area, delivery process measures have a significant impact on supply chain performance. According to (Lockamy III and McCormack, 2004) [37], these measures and metrics should document the supply chain inter-relationships in a manner that can be understood by the supply chain trading partners. Figure 8 shows the SCOR model combined with different supply chain performance measure situations.

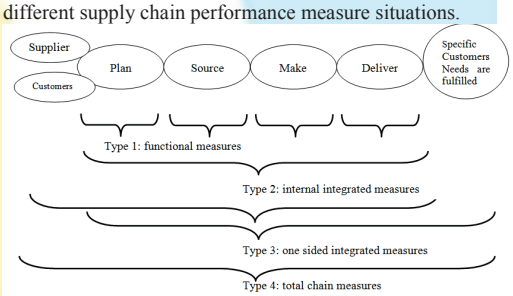


Figure 2. Four different types of supply chain performance measurement situations

This way of depicting the measurement situation provides a more concrete picture of where in the supply chain the performance measurement should be performed i.e. internally, customer side, supplier side or the whole supply chain. To find support from theory, the measurement situations presented above could be linked to (Hill, 2000) [30]description of the four phases i.e. Integrating the steps within the internal supply chain (phase1), procurement through finished goods (phase 2), coordinate activities between businesses (phase 3), and planning and executions of activities across the supply chain (phase 4). If we combine the model presented in figure 1 "Phases in the product life cycle in relation to different product characteristics and their supply chains, measures and metrics", with figure 2, "Four different types of supply chain performance measurement situations" we obtain a picture that can explain what types of supply chain performance measure are important and should be prioritized as well as where to measure a certain type of performance e.g. delivery (on time) from customer (type 3), in relation to e.g. types of products manufactured and types of supply chain.

4. EMPIRICAL WORK SUPPORTING THE DEVELOPMENT OF THE FRAMEWORK

Manufacturers of heavy vehicles e.g. forklifts, pavers, rollers etc produce products which are classified in the literature, e.g. (Fischer, 1997) [17]; Cigolini, Cozzi *et al*., 2004[13]; and Huang, Uppal *et al*., 2002 [31]) as functional products with innovative characteristics. This in

turn indicates the type of supply chain in which the organization operates, (Cigolini, Cozzi *et al*., 2004[13] ; and Huang, Uppal *et al*., 2002), i.e. a hybrid supply chain as well as the phase of the product life-cycle in the market, i.e. introduction, growth and mature, (Cigolini, Cozzi *et al*., 2004 [13]; Hill, 2002 [30]). A Hybrid (lean & quick/agile/market responsive) supply chain focuses on shortening lead times, without incurring cost. Taken together, this indicates the types of performance measures and metrics that should be evaluated i.e. quality, delivery, cost and flexibility, (Cigolini, Cozzi *et al*., 2004 [13]; Hill, 2000 [30]). And finally we can also predict the scope of measurement situation type 1 – type 4 and combine it with our knowledge of which performance measures and metrics are appropriate for measurement. The data presented below (table P) are the results from the empirical work.

Table 1. The supply chain performance measures of two heavy vehicle manufacturers

	Performance measure	Sub measure	Metric
Type 1			
Functional measures	Quality	Quality conformance	PPM
	Cost	Productivity	Man hour/machine
Type 2			
Internal supply chain measures	Delivery	Lead time	Days
	Cost	Direct labour cost	SEK/machine
Type 3	**Supplier**	**Supplier**	**Supplier**
One sided integrated measures i.e. supplier or customer	Quality	Quality conformance	PPM
	Delivery	Reliability	%
	Price	Price/purchased item	SEK/item
	Customer	**Customer**	**Customer**
	Delivery	Reliability	%
	Quality	Quality conformance	PPM
	Service after delivery	Time to establish customer services	Hours
Type 4			
Total chain measures	Total cost	-	SEK
	Total lead time	-	Weeks

The presented empirical work of how two large multinational heavy vehicle manufacturers measure their supply chain seems to agree with the theory presented in this paper. These two OEMs have developed their supply chain for over 50 years and their products are in a mature marketplace. They operate downstream in the supply chain i.e. close to the end customer. The supply chain type can be classified as a hybrid, in which they try to achieve mass customization by postponing product differentiation until the final assembly by adding innovative components to existing products. When choosing suppliers they focus on low cost and high quality, along with delivery speed and flexibility of production. Both manufacturers focus on quality and shorter lead-times, but without leading to increased costs. Their supply chain measures and metrics indicate that they are in a mature market and that their products can be classified as functional with innovative characteristics and their supply chain as hybrid (between a lean and an agile/quick supply chain). They only work with a 1st tier supplier and they are near the end customer. We found evidence that these two organizations primarily focus on product quality, on-time delivery to customers and total cost from the point of order to payment from the customer. The product quality aspects of suppliers seem to be highly important i.e. should be prioritized, which also applies to the lead time from suppliers. The example reveals that these two heavy vehicle manufacturers should prioritise a greater level of interaction with 2nd and 3rd tier suppliers in order to decrease the total cost, shorten lead times and improve quality.

5. CONCLUSION

The purpose of this paper is to describe a framework for prioritizing the supply chain performance measures and metrics to be evaluated. The framework was developed on the basis of the empirical work carried out in this paper and knowledge from previous research. It describes several aspects that should be taken into account: The life-cycle stage of the manufactured products i.e. introduction, growth, maturity or decline. Furthermore, the characteristics of products in the supply chain i.e. can they be classified as functional, innovative or hybrid. What type of supply chain is considered i.e. efficient, quick, agile, market responsive, lean, or hybrid? Which type of supply chain performance measure and metric is important i.e. quality, delivery, cost or flexibility. And finally, what type of supply chain measurement situation is preferable. These measurement situations are described as type 1 – type 4. Type 1: functional measures depicting functional level performance, type 2: an internally integrated supply chain which shows the performance within the organization and between functions (cross functional), type 3, one sided integrated measures that depict the performance in relation to suppliers and/or customers, and finally type 4, which

depicts performance over organizational boundaries (total chain) i.e. from raw material suppliers to the end customer and/or user. The framework presented in figure 3 has its base in previously presented literature and research i.e. well known theory and the empirical work in this paper.

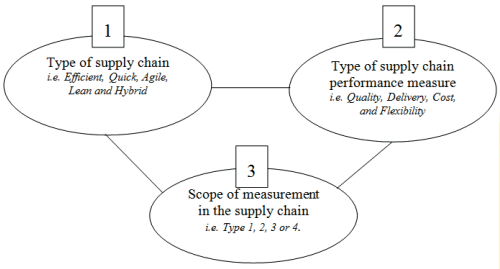


Figure 3. Framework for prioritizing supply chain performance measures

The above framework consists of three different descriptions of theories, which, when combined, provide valuable guidance for which performance measures a manufacturing organization should prioritize. These descriptions are supported by theory to varying degrees, as described below.

The type of supply chain (1) i.e. efficient, quick, agile, market responsive, lean and hybrid, is fully supported by theory. Also the empirical work seems to match. The type of products manufactured defined by (Fischer, 1997) [17] i.e. functional, innovative or hybrid, indicates, according to (Cigolini *et al*., 2004 [13]; Huang, Uppal *et al*., 2002 [31]), the phase in the product life-cycle into which the product can be classified i.e. introduction, growth, maturity, or decline. The product life-cycle phase in turn indicates the type of supply chain i.e. efficient, quick, agile, market responsive, lean or hybrid (Cigolini *et al*., 2004; Huang, Uppal *et al*., 2002 [31]; Aitken, Childerhouse *et al*., 2003 [1]; Christopher and Towill, 2001 [11]; Fisher, 1997 [17]). The number of supply chain types can be limited to 4, due to the fact that several types of supply chains have similar characteristics. Figure 1, seems to be a contribution to theory.

The type of supply chain performance measure (2) is also supported by the empirical work and by theory e.g. (Saad & Paatel, 2006 [50]; Krausse & Pagell, 2002 [33]; Gadde & Håkansson, 2001 [18]; Lambert & Pohlen 2001[34]; Stewart, 1995 [53]; De Toni and Nassimbeni, *et al*., 1994 ; Hayes and Wheelwright, 1984 [24]). However, the three level classification of the performance seems to be new: supply chain performance measures, sub-measures and metrics appear to be contributions to theory.

The scope of the measurement situation (3) is firmly grounded in theory e.g. (Hill, 2000 [30]; Stewart (1995) [53] and the SCOR (Supply Chain Operations Reference) model, which was further developed by the researcher. Measurement scope is presented for type 1 to type 4, see figure 2, which is, to the best of our knowledge, a contribution to theory.

These three descriptions of theory relate to each other. The type of supply chain (1) and the type of supply chain performance measure (2) are strongly linked; theory reveals that they are dependent on each other. Theory indicates which types of supply chain performance measures could be connected to each supply chain type. The connection between (1) and (2) is quite clear. The scope of the measurement situation (3) is also obvious due to the fact that the supply chain performance must be measured at some level or phase, i.e. type 1 – type 4. The type of supply chain performance measure (2) dependent on the type of supply chain (1) is also quite clear. This provides a picture of what an organization should focus upon i.e. which supply chain performance measure and metrics and at what point in the supply chain they should be measured.

REFERENCES

[1] Aitken, J. and Childerhouse, P. *et al.,* (2003), "The impact of product life cycle on supply chain strategy", *International Journal of Production Economics*, Vol. 85, saknas pp. 127-140.

[2] Barksdale, H.C. and Harris, C.E., (1982), "Portfolio analysis and the product life cycle". *Ong Range Planning*, Vol. 15, nr saknas pp. 74-83.

[3] Basu, R., (2001), "New criteria of performance management - A transition from enterprise to collaborative supply chain", *Measuring Business Excellence*, Vol. 5, No. 4, pp. 5-12.

[4] Beamon, M. B., (1999), "Measuring supply chain performance", *International Journal of Operations and Production Management*, Vol. 19, No. 3, pp. 275-292.

[5] Chan, F. T.S., Qi, H. J., *et al*., (2003), "A conceptual model of performance measurement of supply chains", *Management Decision*, Vol. 41, No. 7, pp. 653-642.

[6] Chan, F. T.S. and QI, H, J, (2003), "An innovative performance measurement method for supply chain management", *Supply chain Management – An International Journal*, Vol. 8, No. 3, pp. 209-223.

[7] Childerouse, P. and Towill, D., (2000), "Engineering supply chains to match customer requirements", *Logistics Information Management*, Vol. 13, No. 6, pp. 337-345.

[8] Christopher, M., (1997), *Marketing Logistics*, Butterworth-Heinemann, Oxford.

[9] Christopher, M., (1998), *Logistics and Supply Chain Management: Strategies for Reducing Cost and Improving Service*, Harlow, Financial Times - Prentice Hall.

[10] Christopher, M. and Towill, D., (2000), "Supply chain migration from lean and functional to agile and customised", *Supply Chain Management: An International Journal*, Vol. 5, No. 4, pp. 206-213.

[11] Christopher, M. and Towill, D., (2001), "An integrated model for the design of agile supply chains", *International Journal of Physical Distribution and Logistics Management*, Vol. 31, No. 4, pp. 235-246.
[12] Christopher, M, H, Peck, *et al.,* (2006), "A taxonomy for selecting global supply chain strategies", *The International Journal of Logistics Management*, Vol. 17. No. 2, pp. 277-287.
[13] Cigolini, R., M., Cozzi, *et al.,* (2004), "A new framework for supply chain management" *International Journal of Operations & Production Management*, Vol. 24, No. 1, pp 7-41.
[14] Cox, D. L., (1967), "Product life cycles as Marketing Models", *The Journal of Business*, Vol. 40, No 4. pp. 375-384.
[15] De Toni, A, G. Nassimbeni, *et al.*, (1994), "Service Dimensions in the Buyer-Supplier Relationship: A Case Study" *International Journal of Physical Distribution & Logistics Management*, Vol. 24, No. 8, pp. 4-14.
[16] Dean, J., (1950), "Pricing policies for new products", *Harvard Business Review*, November, Vol. 28, No. 6, pp. 45-53.
[17] Fisher, M. L., (1997), "What is the Right Supply Chain for your Product?" *Harvard Business Review*: 105-116.
[18] Gadde, L. E., and Håkansson, H., (2001), *Supply Network Strategies*, John Wiley and Sons, UK
[19] Gardner, D., (1987), "The product life cycle: a critical look at the literature", *Review of Marketing*, pp. 162-194.
[20] Garwin, A. D., (1988), *Managing Quality*, The Free Press, New York.
[21] Graham, T. S, P. J. Dougherty, *et al*., (2001), "Performance measures and metrics in a supply chain environment", *International Journal of Purchasing and Materials Management*, Vol. 30, No. 4, pp. 13-18.
[22] Gunasekaran, A, C. Patel, *et al.,* (2001), "Performance measures and metrics in a supply chain environment", *International Journal of Operations & Production Management* , Vol. 21, No. 1/2, pp. 71-78.
[23] Gunasekaran, A., Patel, C. and McGaughey, E., (2004), "A framework for supply chain performance measurement", *International Journal of Production Economics,* Vol. 87, pp. 333-347.
[24] Hayes, R. H., and S. C., Wheelwright, (1984), *Restoring our Competitive Advantage*, New York, Wiley.
[25] Hoek van, R.I., (1998), "Measuring the unmesurable" – Measuring and improving the performance in the supply chain", *Supply Chain Management*, Vol. 3, No. 4, pp. 187-192.
[26] Hoek van, R. I., (2001), "The contribution of performance measurement to the expansion of third party logistics alliances in the supply chain", *International Journal of Operations & Production Management,* Vol. 21, No. 1/2, pp. 15-29.
[27] Hoek van, R. I, A. Harrison, *et al.*, (2001), "Measuring agile capabilities in the supply chain", *International Journal of Operations and Production Management*, Vol. 21, No. 1/2, pp. 126-147.
[28] Holmberg, S., (2000), "A systems perspective on supply chain measurements", *International Journal of Physical Distribution & Logistics Management*, Vol. 30. No. 10, pp. 847-868.
[29] Hill, T., (1993), *Manufacturing strategy*, first edition, Palgrave, New York.
[30] Hill, T., (2000), *Manufacturing strategy*, second edition, Palgrave, New York.
[31] Huang, S.H. and Uppal, M., (2002). "A product driven approach to manufacturing supply chain selection", *Supply Chain Management: An International Journal*, Vol. 7, No. 4, pp. 189-199.
[32] Koh, L. S.C and Demirbag, M. *et al*., (2007), "The impact of supply chain management practices on performance of SMEs", *Industrial Management and Data Systems*, Vol. 107, No. 1,pp. 103-124.
[33] Krause, D. R. and Pagell, M., (2002), "Strategic consensus in the internal supply chain: exploring the manufacturing purchasing link", *International Journal of Production Research* Vol. 4, pp. 3075-3092.
[34] Lambert, D.M. and Pohlen, T.L., (2001), "Supply chain metrics", *The International Journal of Logistics Management*, Vol. 12, No. 1, pp. 1-19.
[35] Landeghem van, R. and Persoons, K., (2001), "Benchmarking of logistical operations based on a casual model", *International Journal of Operations & Production Management*, Vol. 21, No. 1/2, pp. 254-266.
[36] Lai, K., Ngai E., *et al.*, (2001), "Measures for evaluating supply chain performance in transport logistics", *Transportation Research*, Vol. 38, pp. 439-456.
[37] Lockamy III, A. and McCormack, K., (2004), "Linking SCOR planning practices to supply chain performance", *International Journal of Operations & Production Management*, Vol. 24, No. 12, pp. 1192-1218.
[38] Maloni, M. J. and Benton, W. C., (1997), "Supply chain partnerships: opportunities for operations research", *European Journal of Operations Research*, Vol. 10, No. 10, pp. 1020.
[39] Mason-Jones, R. and Towill, R. D., (1998), "Time compression in the supply chain: information management is the vital ingredient", *Logistics Information Management*, Vol. 11, No. 2, pp. 93-104.

[40] Morgan, C., (2004), "Structure, speed and salience: performance measurement in the supply chain", *Business Process Management Journal*, Vol. 10, No. 5, pp. 522-536.

[41] Naylor, R. and Dove, R., (1997), "Leagility: interfacing the lean and agile manufacturing paradigm in the total supply chain", *International Journal of Production Economics*, Vol. 62, pp. 107-118.

[42] Novac, R.A., and Simco, S.W., (1991), "The industrial procurement process: a supply chain perspective", *Journal of Business Logistics*, Vol. 12, No. 1, pp. 145-167.

[43] Oliver, R.K., & Webber, M. D., (1982), "Supply-chain Management: logistics catches up with strategy", in Christopher M (1982*) Logistics: The strategic issues*, Chapman & Hall, London, pp. 63-75.

[44] Otto, A. and Kotzab, H., (2001), Does Supply Chain Management really pay? - Six perspectives to measure the performance of managing a supply chain. Nurnberg, *Lehrstuhl fur Logistik*, Friedrich-Alexander-Universiteät**:** p. 17

[45] Pesonen, T. L., (2001), *Implementation of design to profit in a complex and dynamic business context,* University of Oulu, Finland.

[46] Petroni, A. and Panciroli, B., (2002), "Innovation as a determinant of suppliers' roles and performances: an empirical study in the food machinery industry", *European Journal of Purchasing & Supply Management*, Vol. 8, pp. 135-149.

[47] Rink, D. and Swan, J., (1979), "Product life cycle research: a literature review", *Journal of Business Research*, Vol. 7, No. 3, pp. 219-242.

[48] Robson, I., (2004), "From process measurement to performance improvement." *Business Process Management Journal*, Vol. 10, No. 5, pp 510-521.

[49] Rushton, A. and Oaxly J., (1991), "*Handbook of Logistics and Distribution Management*, Kogan Page, London.

[50] Saad, M. and Patel, B., (2006), "An Investigation of supply chain performance measurement in the Indian automotive sector", *Benchmarking: An International Journal,* Vol. 13, No.1/2, pp. 36-53.

[51] Selldin, E. and Olhager. J., (2007), "Linking products with supply chains testing Fischer´s model", *Supply Chain Management: An international Journal*, Vol. 12, No. 1, pp. 42-51.

[52] Shepherd, C. and Gunter, H., (2006), "Measuring supply chain performance: current research and future directions", *International Journal of Productivity and Performance Management,* Vol. 55, No. ¾, pp. 242-258.

[53] Stewart, G., (1995), "Supply chain performance benchmarking study reveals keys to supply chain excellence." *Logistics Information Management*, Vol. 8, No. 2, pp. 38-44.

[54] Towill, R. M. Naim, *et al.,* (1992), "Industrial Dynamics Simulation Models in the Design of Supply Chains", *International Journal of Physical Distribution & Logistics Management*, Vol. 22, No. 5.

[55] Thomas, D. J. and Graham, T. S., (1996), " Co-ordinate supply chain management", *European Journal of Operational Research*, Vol. 94, No. 3, pp. 1-15.

[56] Tracey, M. and Tan C. L., (2001), "Empirical analysis of supplier selection and involvement, customer satisfaction, and firm performance", *Supply Chain Management: An International Journal*, Vol. 6, No. 4, pp. 174-188.

Paper 7

Chibba, A. and Garvare, R. (2011). Supply Chain Quality Management in Wind Turbine Industry - A Case Study. *Conference proceedings, 18th International Annual EUROMA conference* in Delft, Netherlands.

Supply Chain Quality Management in Wind Turbine Industry - A Case Study

Aron Chibba
Centre for Technology, Innovation, and Marketing Management (CTIM2),
Halmstad University, Sweden, arch@hh.se

Rickard Garvare
Division of Quality Management
Luleå University of Technology, Sweden,

Abstract. *The wind power industry has gone through a rapid development in recent years and wind power exploration is a fast growing market. However, low prices have pushed the production of poor quality products and there is a need to secure the quality of wind turbine goods and services in order to reach a satisfactory return rate on investment. In Sweden the development of wind turbine industry has increased during the last 10 years. However, industrial wind exploration in Sweden, especially in forest environment, is still underdeveloped when it comes to aspects of quality assurance. The knowledge that has been developed regarding manufacturing, installation and service in other sectors has only to small extent been diffused or disseminated to the wind turbine industry. The purpose of this article is to examine how quality performance in the supply chain of wind turbines could be improved without violating strategic imperatives of affected stakeholders. A case study approach is used and the results indicates that the Customer use supply chain performance measures that could expressed as quality, delivery, cost and flexibility. Also, the relationship with the supplier has gone through a phase which leads to a changed business model for the supplier i.e. vertical integration.*

Introduction

China and US are the worlds largest turbine manufacturer and the wind power exploration in China is a fast growing market. Some researchers (Yu, Ji et al, 2009) predict that wind power in China will be able to compete with coal generation as early as 2015 or 2020. However, within this market the Investment Return Rate (IRR) of most projects is less than 8 percent. Low prices and pressing deadlines have pushed the manufacturing sector to produce poor quality products (Yu, Ji et al. 2009).

In Sweden the wind power industry is currently a mixture of individual farm use; small scale companies with a few turbines; individual scattered farms selling power to the grid; and large and growing corporations with electrical power production as its core business. The investment in wind power is about 1 USD per produced kWh and year (Swedish energy government). Some indicators of the development of wind power industry from the early 1980 to 2010 is presented in Table 1. In 2010 the branch association Swedish Windenergy found that installed effect had increased by 40 percent in one year alone. However, in comparison with process industry, car industry, telecom industry and other more developed markets the wind turbine industry is far from mature with regard to product quality.

There are several principal positions where wind turbines can be placed, for instance at sea, in landscape, in mountains or in forest. Different types of issues have to be dealt with depending on where the turbines are situated, e.g. a wind turbine in a forest environment where high wind shear could be expected.

Table 1. Some indicators of the development of wind power in Sweden.

The development of wind power industry in Sweden 1980-2010			
	1982	2000	2010
Diameter rotor	<15m	80m	128m
Mark power	30 kW	2,5 MW	6 MW
Number of wind turbines	1	527	1663
Installed power	3 MW	241MW	2052MW
Production (year)	0 GWh	447 GWh	3481,4 GWh

According to Yu, Ji et al. (2009) there is a need to improve the quality assurance of wind turbine products used for industrial wind exploration. Sweden has a highly developed process industry and manufacturing industry. The knowledge regarding manufacturing, installation and service has only to a small extent been diffused and disseminated to the wind turbine industry, including wind turbines in forest environment. One can argue that the wind turbine industry in forest environment is still in an early phase. A search in the database Emerald (scientific articles within management, quality etc.) gave the following results, see table 2.

Search	**Number of hits**
Wind power/industry	4092/2122
Wind turbine/s	752/414
Wind turbine/s and quality	249/163
Wind turbine/s and quality assurance	23/13

Search	**Number of hits**
Car industry	10286
Car/s	16111/7641
Car/s and quality	9802/4794
Car/s and quality assurance	1206/556

Table 2. A comparison between wind power industry and car industry regarding publications (hits) about quality and quality assurance.

Although much important work has been carried out a number of questions remain regarding quality assurance of goods and services of wind turbines. The articles found in the search do not deal explicitly with wind power and turbines but rather aerospace and space technology (Aircraft engineering and aerospace technology). These industries are related through the use of blades and propellers. The area of wind exploration within a forest environment is relatively new and requires research about quality assurance of products and related services.

The wind turbine industry in Sweden has a variety of stakeholders that have or can have a significant impact on aspects in manufacturing, installation and service of wind turbines in a forest environment, for instance quality, delivery, costs and flexibility of the product. Therefore research about quality assurance of wind turbine exploration in a forest environment is of great importance. Important questions like, what are the measures and units that have to be identified and how could these be generally accepted within the wind turbine industry i.e. standardization, has to be secured on scientific base.

The objective of this study is to examine relationships between different stakeholders, the supply chain and quality performance, also aspects of quality assurance over the supply chain, i.e. manufacturing, installation and service of wind turbines in a forest environment. In particular, the aim is to explore how important and critical goods and service characteristics can be affected by different types of stakeholders or actors like suppliers, customers, community, state, neighbours, land owners, members of various pressure groups etc. Specifically the following research questions will be addressed:

- Is there a relationship (degree of importance) between stakeholders' requirements, wants and expectations connected to quality performance in the wind turbine supply chain?
- What influence have different stakeholders' interests on quality and supply chain performance i.e. delivery, quality of product, cost, flexibility, related to the total supply chain i.e. purchasing, manufacturing, installation and service of wind turbines in a forest environment?
- What are the product characteristics that stakeholders find relevant and that therefore have to be measured, controlled and improved?

Theory supporting the study will be gathered from the research fields of Quality Management, Supply Chain Management, wind turbine exploration and eco innovation. In the section below theory supporting the research is described and discussed. We make use of a model which indicate stakeholder influence on the supply chain and its performance measures and how this may effect quality performance in wind turbine parks placed in a forest environment, see figure 1.

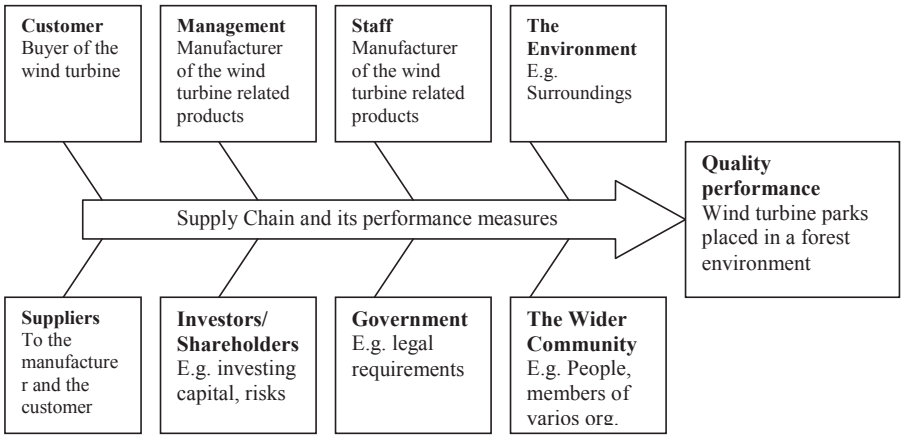


Figure 1. Some relationships between stakeholders within a supply chain, based on the stakeholder model of the business enterprise by Foley (2001).

THEORETICAL FRAMEWORK

Quality performance

Performance in terms of wind speed, turbulence and noise are significant quality characteristics that need to be assured before installation of wind turbines in a forest environment. Such characteristics often form a base for the specification provided to the wind turbine manufacturers. These, together with how well they fulfill the requirements in the specification, are important information for investors.

In our view there might be a great potential for improvement in finding a widely accepted certification of methods and procedures regarding wind production supply chain performance. In order for manufacturers to meet significant quality characteristics, a well defined process covering input, transformation, output, control and improvement is needed. Wind turbine investors are mainly interested in the output, i.e. energy production. In this study we regard quality performance to include manufacturing, transportation, assembly, installation, production and maintenance.

One of the most widely used standards for management systems intended to assure product quality is ISO 9001. A certificate of appliance to this standard is more or less mandatory in many markets and could be described as a qualifier to market entry, Hill (2001). The latest version, ISO 9001:2008, requires that all key processes within an organization are identified, described, monitored, measured and improved. Organizations certified according to ISO 9001 are required to work according to a process concept, in order to achieve a process-oriented organization. According to Palmberg (2009) there are no single definition of a process standing out to be the most broadly spread or most widely used. However, she found that there are six components that can be seen in a

majority of the definitions: 1) input and output, 2) interrelated activities, 3) horizontal: intra-functional or cross-functional, 4) purpose or value for customer, 5) the use of resources and 6) repeatability. These components could also be found as a requirement in the latest version of ISO 9001:2008. An organization searching for an ISO 9001:2008 certification has to describe, monitor and improve its processes. Clearly defined processes within a business could make it easier to improve the overall performance of the business; however it is still dependent of the performance of the other actors within the supply chain.

Supply chain and its performance measures

Aspects of supply chain performance have been widely covered in the literature. Several studies (e.g. Koh *et al.*, 2007; Saad and Patel, 2006; Vereecke and Muylle, 2006) highlight the need to measure the efficiency of integrated supply chains. Petroni and Panciroli (2002) argue that customers usually retain suppliers who achieve the highest aggregate score on price, quality, flexibility of production, and delivery times. Hayes and Wheelwright (1984) were among the first to present methods for addressing operational strategy by means of generic competitive priorities: quality, cost, flexibility and delivery, which are some dimensions on which a company might choose to compete within a target market. Their original formulation was described as applicable to all functions. Hill (2000) addresses competitive priorities such as price, cost reduction, delivery reliability, delivery speed, quality conformance, flexibility, increased demand, product range and design, which he terms order-winners or qualifiers.

In order to improve and make use of corrective actions, e.g. reduce distortions within integrated supply chains, appropriate measures are essential. To measure the information flow and the physical material flow over a supply chain could provide a valuable support when identifying improvement opportunities and developing an improvement plan Chibba and Rundquist (2009). As in most business the supply chain consists of actors that have a direct impact on the organization through goods or services. However, there are also other stakeholders, with other needs and expectations, that may have an impact on the organization.

Stakeholders and the business enterprise

Foley (2005) introduced a theory where stakeholders are defined as entities that in the opinion of business could threaten enterprise viability and/or inflict unacceptably high cost, if their needs and expectations are not met. According to Foley (2009) organization achieve sustainable success if they behave in such a way that the wants and expectations of interested/affected parties identified as imperatives are satisfied, at least cost over the long term.

Foley (2009) defines stakeholders as those entities and/or issues, which a business identifies from the universe of all who are interested in and/or affected by the activities, or existence of that business, and are capable of causing the enterprise to fail, or could cause unacceptable levels of damage, if their needs are not met, e.g. customers ceasing to by product. Foley states that identifying a stakeholder and to respond to this is complex, multi-layered and evolving, rather than simple, fixed and episodic. This will also be

influenced by the organization's historically created assumptions and interpretations of itself and its environment.

Garvare & Johansson (2010) claim that for long term survival in a violent and uncertain environment, i.e. to achieve organizational sustainability, contemporary organizations must satisfy a variety of stakeholders, who are all capable of inflicting unacceptable levels of damage on the viability of the organization if their interests are not met. Garvare & Johansson presents a categorization of stakeholders and interested parties, and suggest a description of differences between stakeholders and interested parties. In short, primary stakeholders have a direct influence on business performance, e.g. customers, suppliers, government, co-workers, management and latent stakeholders. Meanwhile, secondary stakeholders have indirect influence, e.g. media or members of various pressure groups. The interested parties however are those that have a week influence, little or no power to affect the sustainability of the organization.

The Wider community

Juran (1988), stretches the term customers to include all who are impacted by an organizations processes and products. He mentions clients, owners, media, local communities, governments' regulatory bodies and also the public. Juran refers to the most obvious impact related to product safety or damage to the environment. In this paper we use the term interested parties to denote the wider community, i.e. all who are impacted by an organizations processes, products and business overall but lack direct influence on the organization.

The Investors/shareholders

The investment costs for wind turbines are high in comparison with many other businesses, e.g. manufacturing industry; however the running costs are low and proportional to the production. The production cost might be calculated, however the high capital investment cost can be difficult to predict. Therefore aspects of quality assurance over the energy production process, i.e. the predicted energy output, are important. Financial investors and shareholders need to be assured about the energy output performance. However these do not directly impact the supply chain quality performance. Therefore, the investors/shareholders will be discussed using research findings i.e. results from interviews.

The management and staff

Managers have directed and shaped the growth of the modern enterprise, in particular those established to sell goods and services (Foley, 2001). During the last two decades the development and refinement of the behavioral and managerial theories of the business enterprise has evolved in terms of how the business environment shape the needs and expectations of a manager, Foley (2001). Managers now seem to face not only a business environment but also the physical environment. In this paper, we will focus on how the managers handle the different types of stakeholders of the business to assure quality performance throughout the whole supply chain. Also how these managers communicates this to all staff.

The environment

Organizations have relationships to both the business environment and the physical environment. There are several definitions of the Business environment. One recent definition made by Vernon Prior (2009) is: *"Business environment, encompasses all those factors that affect a company's operations; including customers, competitors, suppliers, distributors, industry trends, substitutes, regulations, government activities, the economy, demographics, social and cultural factors, innovations, and technological developments".* The physical environment could be described using the definition in ISO 14001 *"Surroundings in which an organisations operates which including air, water, land natural resources, flora, fauna, humans ant their interrelation*". These definitions may give an understanding how much the operating environment and the environment affects organizations. When an organization plans to explore a wind turbine park, several stakeholders can be affected, e.g. landowners and neighbours. The term NIMBY (not in my back yard), is, according to Wolsink (2007), referring to a situation in which someone has a positive attitude towards something in general but accompanies this with a motivation to oppose its installation locally, due to reasons of self-interest. The Secretary of Energy Advisory Board recognized NIMBY as a significant problem for hazardous waste facilities (SEAB, 1993). This leads to a recommendation that the US department of Energy should address this by increasing public participation. Yu, Ji et al, 2009 find that NIMBY has become a problem for large scale wind exploration. Also Jones and Eiser (2009) conclude that NIMBY could be used, at a basic level, as a sole explanation of local resistance to wind development. They point out two gaps in specific and general attitudes, 1) fear of change and the unknown (e.g. concerns over landscape damage) in combination with, 2) lack of trust in the council and uncertainty of the levels of support within the local community. The term NIMBY might be relevant to explore for all actors within the turbine industry. Both the business environment and the physical environment will be discussed in the context of wind turbine exploration.

Government

An obvious instrument available to government is legislation. Political discussions and different environmental organizations may affect the government to act, i.e. legislation, and thereby directly affect actors within the wind turbine industry. In Sweden the environmental legislation is progressively developed to secure a healthy environment. As wind turbine industry is developing the legislation will continue to affect the business environment. In this paper we will not try to explore legislation connected to wind turbine exploration. However we will discuss how the organizations in this study handle the government as a stakeholder.

Customers, staff and suppliers

We use the term customer to denote those organizations who buy goods or services, for instance wind turbines. Several researchers e.g. Mayo (1945), Herzberg (1966) have described, discussed and concluded that managers often saw their staff as being averse to work, and treated them as an inexhaustible resource. However, today this has changed and could be described as the rise and subsequent dominance of intellectual capital over physical capital. It's obvious that in a Swedish context staff is often a stakeholder.

Suppliers are those who supply non-human inputs to the business. Until quite recently the suppliers have been differentiated in ways that are important to the business purchasing enterprise, e.g. on time delivery and quality of product (Foley, 2001). In this paper we use the term suppliers for those organizations that supply products or services or both e.g. the manufacturer of the wind turbines and its suppliers, services provided both to the manufacturer and the customer i.e. transportation, assembly, installation, production and service.

METHODOLOGY

A case study approach was used; including interviews with different stakeholders, i.e. actors upstream and downstream the supply chain. We used directed content analysis, see Hsieh & Shannon (2010), as a qualitative approach to interpret meaning from the content of text data and, hence, adhere to the naturalistic paradigm. The reason for using direct content analysis was to use the theory or relevant research findings as guidance for initial codes. The codes were defined before and during data analysis. The sources of codes or keywords were derived from theory or relevant research findings. We constructed a set of operational measures (codes) that served as a base for the interviews, see appendix 1.

The stakeholders identified in the examined supply chain were: Customers, suppliers, sub suppliers and the government.

Empirical data was gathered via interviews with representatives for stakeholders within the particular supply chain under study. The customer is the organization that owns the wind turbines and sells electrical energy on the market. The supplier is a producer of wind turbines for the global market, and the sub supplier provides goods and services to manufacturers of wind turbines. In total weight respondents were interviewed. Each organization represents a case, see Figure 2.

Case 1	**Case 2**	**Case 3**
Customer (SME)	**Supplier (LE)**	**Sub supplier (SME)**
R1: Managing Director	R6: Quality manager	R9: Managing Director
R2: Executive Vice President	R7: Customer responsible	-
R3: Product development	R8: Supplier Development	-
R4: Responsible Permits	-	-
R5: Technical Manager	-	-

Figure 2. The studied cases and the respondents interviewed.

Semi-structured interviews were used. First, we identified and coded different key concepts and variables with support from theory. Secondly, we deducted operational definitions for each category, using theory. Finally, all highlighted passages were marked using the predetermined codes. To increase reliability we used respondents from the

customers supply chain, this to strengthen the data. All but one of the interviews were recorded. The interviews were analyzed for themes using QRS N9 software.

RESULTS

The Customer

In this case, the customer is a small and young organization, in contrast to its suppliers. To have in mind, it is usually the "dominate player that dictates the rules within the supply chain". However, in this case the Customer has made considerable progress regarding the development of its supply chain, i.e. vertical integration to secure quality, delivery, cost and flexibility. These changes have affected one of the suppliers, that it actually sees this customer as contributing to the development of its business, for instance regarding changes the business model. The Customer, has documented the managed internal processes. The organization do not have a third party certification to any management standard, e.g. quality (ISO 9001), environmental (ISO 14001) or work safety (OHSAS 18001), however they have defined and to all employees, well known (internal) process descriptions of how to work. The Customer has four main processes: permit, construction, production and maintenance and finally research and development. Several support processes have also been identified, such as purchasing, administration and finances. The organization also has procedures for controlling the construction process which contains: responsible person, procedures in how to perform actions, e.g. meetings, daily operations, and health and safety aspects. The company also makes use of checklists to document its actions and key performance indicators (KPIs) to make sure it follows the path that management has decided upon. The management team meets on a regular basis, at least every other week.

The development of new products within the wind turbine industry is fast and new areas of exploration has already emerged wind turbine parks in forest, at sea and mountains. In an attempt to secure the deliveries the organization has chosen to work with global actors. Communications are handled on different levels 1) daily contact, 2) meetings quarterly and 3) commercial contracts. Technical related improvements are discussed through these meetings. The organization makes use of supplier agreement/contract with its suppliers of wind turbines and other related services. It also has a number of other suppliers, e.g. field and plant, cranes, transportation, service, construction. The Customer works close to its suppliers and share information with them, e.g regarding R&D. They also stress the importance of their needs, wants and expectations to the Customer, for instance regarding lead time, cost for service, accessibility of service data from the wind turbines, and the time to deliver spare parts.

The Customer has several stakeholders that it has to consider, e.g. government, investors, customers, suppliers. The environment and the wider community are among its interested parties that may make their voices heard via the use of secondary stakeholders such as media and NGOs. Some of the governmental departments are: Environmental Protection Agency, Traffic Board, Swedish National Grid and Swedish Contingency Agency. These stakeholders do not decide if it is a "yes or "no", however, they give restrictions that must be fulfilled before the Customer can set up wind power turbines in the forest.

Local communities may have influence on the Customer, most often due to the power to place veto on exploration. This is handled by local politicians, which in some cases do not have the same agenda as the national government. The government has put up challenging long term targets for energy generated by wind turbines (30 TWh in year 2020) and encourages wind power exploration. Local communities are often positive to wind power exploration in general.

The branch associations which are against wind power exploration can be seen as a secondary stakeholder with the power to affect the business environment. It can provide information to decision makers that may affect permissions, whether it is a go or not. There are other branch associations as well, with other agendas, e.g. that wind power exploration is a positive and growing area of energy production.

The competitors can be viewed as interested party. The reason for this is the facts that there is limited space left for exploration of wind power and they compete to get permits in attractive areas. Also in some cases these competitors, collaborates to make the exploration possible for both of them. However, in this case, the local community, government legislation and the Swedish military are those that could affect the business the most.

Those respondents that had an overview of the organization describe that the improvement potential is mainly found in two areas 1) Micro siting, where to put the wind turbines and 2) wind analysis, i.e. the ability to predict potential levels of power production. The organization has tried several models in order to improve its predictions. Production and maintenance of the wind turbines also has a great improvement potential, together with construction efficiency and finance.

The Supplier

The Supplier of the case study is a large enterprise (LE) with several years in wind turbine industry. The organization has a third party certification according to ISO 9001, 14001 and OHSAS 18001. The descriptions of the company's main process, sub processes and supporting processes are clear. Being a LE, its business is divided into several units that share some processes which are general for all units.

At the time of the study the Supplier worked closer to the Customer than it had ever done before. A reason for this was that the Customers needs, wants and expectations were in some cases completely new to the Supplier. The Customer had needs, wants and expectations that differed to those of other customers in the same branch. The company was described as a "demanding" customer, however the Supplier could not afford not to listen to the Customer and therefore wanted to fulfill its needs, wants and expectations. The Customer were about to change the local wind turbine industry, using its new business model. This model affected the Suppliers business model. The underlying details was based on performance, e.g. delivery (on time spear parts, lead time wind turbines), cost (services of wind turbines), flexibility (to have access for service data from wind turbines). Other customers had not stated these types of needs, wants and expectations

previously because they were not the same type of customers. Modern wind turbine exploration organizations often own parks with several wind turbines, with a focus on high output. To achieve this they have a strong business focus and business model, in contrast to e.g. farmers who only own one wind turbine or wind turbine cooperative, that use the output themselves.

The Supplier makes use of sub suppliers which range from large and world marked leading companies to small specialized companies with only few employees. The Supplier prefers sub suppliers that have a third party certification and requires that some aspects of social responsibility, e.g. child labor, is fulfilled. The Supplier has developed a guideline that points out requirements that have to be fulfilled by the sub suppliers. This guideline includes improvement programs intended for organizational development of strategic sub suppliers (and in some cases also their suppliers, TIER 2). The use of different methods, tools and frameworks, e.g. Critical To Quality, Production Part Approval Process, Six Sigma, Lean Production and Balanced Scorecard, is mandatory. The Supplier has also developed a reporting system which measures all KPIs of the sub suppliers, e.g. quality (conformity), delivery (on time), cost (development), process capability performance and part reliance.

The Supplier has several secondary stakeholders that it has to consider. The respondents mention wider community, different member associations i.e. pressure organizations, and some scientists' organizations. They described a need for a deeper dialog with government and better communication with member associations. However, there were some member organizations that the Supplier had difficulties communicating with, so they shared information through the local community or government, because this seemed to be the best way. The Supplier respondents argued that they needed to develop closer collaboration and dialogue with some of the stakeholders, both primary and secondary, i.e. national government, investors and member associations. The Supplier ranked its primary stakeholders due to importance of fulfilling their needs, wants and expectations as follows: customers, investors (banks) and government. The secondary stakeholders were ranked as: wider community, customers' investors and customers' government regulations e.g. military.

At the time of the study several actors had recently entered the wind turbine industry, and the Supplier was facing a hard competition. Several improvement areas were identified, the most important being shortening of lead times from receiving the wind turbine (from another site) to the wind turbine in production. Also, to optimize the output of the wind turbines, at site seemed to be an improvement area that could generate ROI for the Customer.

The Sub supplier

The Sub suppliers in this case study are small enterprises with a main business in areas such as transportation and service of wind turbines. At the time of the study they did not have a registration to any management standard. However one of the sub suppliers had a certification set by the European Aviation Safety Agency, which means that it had to fulfill requirements and legislation connected to its business. The management had

regular meetings with all employees to secure that quality, environmental and health and safety issues were addressed.

The Sub suppliers saw quality, expertise, reliability and flexibility as their most important order winners. They worked close to the Supplier and shared a long term cooperation and contract.

The Sub suppliers saw on site performance of repairs under changing environmental conditions as their main critical process that could affect the quality of the service. The development of improved access technologies and improvement of service methods were two improvement projects in collaboration with customer.

The Sub suppliers in turn used suppliers that were fixed by "repair manuals", they could not be chosen freely. Some of these were certified according to management standards, e.g. ISO 9001. At the time of the study the Sub supplier did not work in any systematic way to develop its suppliers. Quality, delivery and flexibility were described as the primary needs, wants and expectations.

The Sub supplier performed regular evaluations of its suppliers. All delivery was checked and rated for correct delivery and fulfilling the delivery time. This information was kept as a record and all non conformities were directly communicated with the supplier.

Government was thought as the most important stakeholder due to its power, i.e. the power to remove aviation certifications.

DISCUSSION AND CONCLUSION

In the supply chain studied one actor, the Customer, set most of the rules as far as it came to vertical integration e.g. assembly, transportation and the use of other services e.g. cranes. This was mainly due to the strong focus on output maximization. This new actor had a clear business focus on its processes. The company was able to meet the needs, wants and expectations of its primary stakeholders, e.g. government, suppliers. However, the interaction with secondary stakeholders, e.g. wider community and the environment, could be further developed to secure the sustainability of the organization. The Supplier was not affected in the same way as the Customer regarding secondary stakeholders due to the facts that it delivered the wind turbines and did not own the wind turbine parks placed in a forest environment.

One of the aims of the study was to examine the relationship (degree of importance) between stakeholders' requirements, wants and expectations related to quality performance in the wind turbine supply chain.

As most manufacturers of wind turbines are large enterprises and almost all other suppliers and customers are small, there is an imbalance built within the supply chain. The Customer in this case, tried to minimize cost and increase the possibility to secure high ROI. In order to do this, they cut cost by vertical integration, i.e. by doing some of the suppliers' work, e.g. assembly, transportation and other services such as the use of

cranes. The Supplier and its Sub suppliers delivered the wind turbines including services, if ordered, to the Customer. However, the Customer had taken the decision to go downstream the supply chain, in this case, vertical integration. The Customer's needs, wants and expectations were new to the Supplier in contrast to its other customers.
The customer wanted more e.g. electronically system for handling the service documentation, accessible data generated from the wind park, lower price for service, to faster get access to spare parts.

The Customer had tried to stress its new needs, wants and expectations. Using supply chain performance metrics, some of the improvements that the Supplier could contribute with were: delivery (on time spear parts, lowering the lead time for delivering the wind turbines), cost (lower the service cost of wind turbines), and flexibility (give the customer access for service data generated from wind turbines). Using supply chain performance measures this could, for instance, be expressed as delivery (on time spear parts, lead time wind turbines), cost (services of wind turbines), flexibility (to have access for service data from wind turbines).

Our second question was what influence different stakeholders' interests have on quality and supply chain performance, i.e. delivery, quality of product, cost, flexibility, related to the total supply chain i.e. purchasing, manufacturing, installation and service of wind turbines in a forest environment?

The stakeholders and their influence on quality and supply chain performance related to the total supply chain could be described as follows. The purchasing phase could be controlled by a contract between the customer and the supplier. The supplier sells the wind turbine and other related services e.g. transportation and services. However, due to issues of cost and delivery on time the customer may take over some part of the services of wind turbines. There are several different stakeholders that may affect the possibility for the customer to succeed, i.e. secondary stakeholders that are against wind power exploration, single persons who have media power or even media in general. These can affect primary stakeholders, such as investors, banks, and government to take action.

Our third question was what the product characteristics are that stakeholders find relevant and that therefore have to be measured, controlled and improved?

In our study the Customer had a clear view on how it could improve its processes. Finding reliable and general methods to calculate wind speed was seen as essential. At the time of the study the company made use of several different calculation models to predict wind speed. The Supplier also had a clear view on how to improve its processes. The lead time from a manufactured wind turbine to production was seen as one of the most important issues to address since it affects the delivery time to the Customer, i.e. a central stakeholder interest.

The Supplier did not fully control the products received from the Sub suppliers, e.g. transportation, installation and service. The Customer did not always go via the Supplier but instead often met and cooperated directly with the Sub suppliers. These Sub suppliers

often have a though working environment, something which led to high staff turnover and high demands for effective training of new personnel before entering the sites. Sometimes this was not handled properly, which led to non conformities.

MANAGERIAL IMPLICATIONS

New actors within the wind power exploration in a forest environment has a clear business focus on its processes. They meet the needs, wants and expectations of the primary stakeholders e.g. government, suppliers. However, they could further develop the interaction with the secondary stakeholders this to secure the sustainability of the organisation e.g. to be prepared for the business risks, due to a missed need, wants or expectation from primay or secondary stakeholder or even interested parties.

References

Chibba, A and Rundquist, J (2009). Effective Information Flow in the Internal Supply Chain: Results from a Snowball Method to Map Information Flows. *Journal of Information & Knowledge Management*, 8(4), 331-343.

Foley, K. (2005). *Meta Management: a stakeholder/quality management approach to whole-of-enterprise management*. Sydney: SAI Global.

Foley, K. & Zahner, T. (2009). *Creating and managing the sustainable organisation – the stakeholder way*. Sydney: SAI Global.

Garvare, R and Johansson, P (2010). Management for sustainability – A Stakeholder Theory. *Total Quality Management & Business Excellence*, 21(7), 737-744.

Herzberg, F (1966). Work and the nature of man. World Publishing, Cleveland. OH.

Hill, Terry. (2000). Manufacturing Strategy. Second edition. Plagrave, New York.

Hsieh, Hsiu-Fang and Shannon, Sarah E (2005). Three Approaches to Qualitive Content Analysis. *Qualitative Health Research*, 15(9), 1277-1288.

ISO 9001:2008, Quality Management Standard. International Organisation for Standardisation.

ISO 14001:2004, Environmental Management Standard. International Organisation for Standardisation.

Juran, J. Frank, M. (eds.) (1988), Juran's Quality Control Handbook, New York, NY: McGraw-Hill

Koh, L and Demirbag, M. et al. (2007). The impact of supply chain management practices on performance of SMEs. Industrial Management and Data Systems. 107 (1). 103-124.

Mayo, George Elton. (1948). The Social Problems of an Industrial Civilisation. London: Routledge and Kegan Paul.

Palmberg, K. (2009). Exploring process management: are there any widespread models and definitions? *The TQM Journal*, 21(2), 203-215.

Saad, M and Patel, B. (2006). An investigation of supply chain performance measurement in the Indian automotive sector. Benchmarking: An International Journal, 13(1/2), 36-53.

Vereecke, A and S Muylle (2006). Performance improvement through supply chain collaboration in Europe. International Journal of Operations & Production Management. 26(11), 1176-1198.

Wolsink. M. (2007). Wind power implementation: The nature of public attitudes: equity and fairness instead of "backyard motives". Renewable and Sustainable Energy Review 11. 1188-1207.

Yu, J and Ji, F et al, (2009). An over painted oriental arts: Evaluation of the development of the Chinese renewable energy market using the wind power market as a model. *Energy Policy*, 37, 5221-5225.

Appendix A: Operational measures

1. Questions related to internal processes
1.1. Could you short describe your profession? (title, position, function, process etc)
1.2 How would you describe your organizational processes? (Management process, head process/es, sub processes and supporting processes).
1.3 How would you describe your own working process (input-transformation-output) i.e. what are you processing e.g. information or products?
1.4 Do your organization have a certification/registration to any management standard e.g. quality, environmental, work safety, social accountability? If not, how do you secure the organizational processes i.e. internal, customer, suppliers and stakeholders?
1.5 How are questions regarding quality, environment and work safety, communicated throughout the organization? (formal meetings or informal meetings, appointed member of the management or other ways)
1.6 Have you identified your key customers, key suppliers and key stakeholders? If yes, how have you done this? Is this information documented and communicated?
1.7 Which of your processes has the greatest improvement potential or could be optimized to maximize profit?
1.8 Which of your processes/function handles requirements, wants and expectations that you have to fulfil in order to deliver quality to your customers.
1.9 How you measure the performance of your processes?
1.10 What are your most important performance measures e.g. key performance indicators, KPIs? E.g. quality, delivery, flexibility, price/cost or other.
1.11 Which types of meetings have been established to secure information regarding your business performance (operational and financial); formal (expressed by management) or informal (not expressed by management) or other types of meetings.
1.12 Which process handles the needs, wants, and expectations from customers? (Eg. sales/marketing).
1.13 Perform audit against requirements in ISO 9001: 2008 chapter 4, 5, 6, 7 and 8.

2. Questions related to customers
2.1 How would you describe your customers (size, cooperation, contract etc.)
2.2 How would you describe your customer's marketplace i.e. mature or innovative market, or a combination (hybrid)?
2.3 How would you describe your order winners against your customers? (quality, delivery, flexibility, cost/price)?
2.4 How many key customers do you have? How do you define key customers?
2.5 Could you give examples of reclamation/nonconformancies form customers? (product quality, not meeting specifications, delivery, installation, service, etc.)
2.6 What needs, wants and expectations do your customers have? What are important for them? (quality, delivery, flexibility, price/cost or other)
2.7 In what way do you cooperate with your customers to meet their needs,
wants and expectations?
2.8 Which processes are critical to you (processes that can affect the quality of the service delivered?)

2.9 How do you secure and fulfill the needs, wants and expectations of the product quality to your customer regarding, purchasing, production, transportation, installation and service?
2.10 Do you currently work to improve any part of the supply chain optimize the flow i.e. purchasing, production, transportation, installation and service.

3. Questions related to suppliers
3.1 How would you describe your suppliers? (size, cooperation, market etc.)
3.2 Do they have a certification against a management standard e.g. ISO 9001, ISO 14001 etc?
3.3 Do you currently work to develop your suppliers? If yes, could you describe how this is performed?
3.4 How long have you been cooperating with your suppliers?
3.5 Could you give an example of nonconformancies form suppliers? (product quality, not meeting specifications, delivery, installation, service, etc.)
3.6 What needs, wants and expectations do you have on your suppliers?
3.7 Do you perform evaluations of your suppliers? If yes, how is this performed?
3.8 Do you classify your suppliers after some criteria? If yes, could you describe this?
3.9 Do you measure performance of your suppliers e.g. quality, delivery, flexibility, cost/price etc.
3.10 What are the most important performance measures (quality, delivery, flexibility, cost/price etc) used against suppliers?
3.11. Could you describe a typical or bad project in contrast to optimized project i.e bad vs. good case. Eg. typical or bad case, when you suffered from a quality, delivery, flexibility or cost perspective! Optimized, when your requirements, needs and expectations where highly meet.

4. Questions related to stakeholders (shareholders, staff, government, the environment and the wider community)
4.1 What types of stakeholders do you have except customers and suppliers?
4.2 When do need to develop a dialog with stakeholders in a deeper way? If, yes, could you describe these stakeholders?
4.3 Which of your stakeholders needs more collaboration/dialogue?
4.4 Can you give an example of nonconformities from stakeholders that has or could affect your internal and external processes? E.g. quality, delivery, flexibility, price/cost or other.
4.5 What needs, wants and expectations do your stakeholders have? What could happen if you decide not to meet their needs, wants and expectations?
4.6 What performance measure do these stakeholders have interest in?
4.7 Could you rank your stakeholders regarding how important it is to fulfill their needs, wants and expectations? E.g. governmental legislation, landowners, stockowners, different organizations that could have interest, etc.