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Sindre Bolseth

The Extended Enterprise Operations Model Toolset

Towards information visibility and visualization in integrated, global and responsive value chains

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Norwegian University of Science and Technology
Thesis for the degree of philosophiae doctor
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”Would you tell me, please, which way I ought to go from here? That depends a good deal on where you want to get.”

Conversation between Alice and the Cheshire Cat

Lewis Carroll (1865), Alice’s Adventures in Wonderland

Preface

This PhD thesis has been a long, cumbersome, partly lonesome, and not least an exciting journey. The PhD has in many regards been an integrated part of the last decade of my life. The doctoral thesis has in many ways developed me as a person, taught me to recognize my own capabilities, and how to interrelate and work together with other people in a business context. Furthermore, the research has given me new and thorough insight into the various scientific fields discussed and treated in the thesis, as well as in the current and future business environment, and also educated and shaped me as a researcher.

Even though the PhD has been a solo project, it has not been possible without the assistant of many skilful and resourceful people. Now at the end of the research project, I would like to look back at the whole period and acknowledge the people that have directly, and indirectly, contributed to the process and/or to the outcome.

First of all, I would like to thank Professor Jan Ola Strandhagen, my PhD supervisor, and also manager at SINTEF. In particular I would like to thank him for all the help he gave me to gain access to Stokke, RCT and Hydro, which later became important cases in this thesis. Furthermore, he has taught me the “art” of applied business research, the value of strategic thinking and many other valuable lessons in manufacturing and logistics.

Erlend Alfnes and Perter Falster have been good discussion partners and their efforts, support and feedback have been of invaluable importance to me. Erlend has throughout the whole PhD period been a mentor to me, been an excellent discussion partner and always willing to read various draft versions and provide detailed, useful and constructive feedback. Peter has been a strong contributor the last years, and the discussion and feedback from our meetings have not only helped to improve the thesis but also served as a preparation for the defense of the thesis.

In addition, I would like to thank Astrid Vigtil who has contributed in the final stages of the thesis and Tonje Korina Griffin and Philip Ridgway for proof reading the thesis.

Arne Horten and Kristian Martinsen at RCT and Roy Jakobsen at HAST also deserve a grateful thanks for involving me in their companies, for many challenging discussions and their research contributions to this dissertation.

I would also like to thank former colleagues (in particular Maroc Busi, Ingvar Hagen, Anderas Seim, Marco Semini, Freddy Johnsen and Lars Skjelstad, as well as the rest of the logistic group) at SINTEF/IPK for good discussions and a social dimension to work. It is also appropriate to thank the management and administrative personnel at IPK, in particular Asbjørn Rolstadås, Per Schjølberg, Liv Martha Sødahl, Øyvind Andersen, and the late Hans Bruvik for their assistance. Sincere thanks goes to Elin Tronhus and Åse Normann at the library in Valgrinda, for their patience, their extremely good service and always cheerful mood.

Further, I would like to thank my current employer and manager at Hydro, Elisabeth Holmsen, for the support in finalizing the thesis and preparation towards the defence.

The PhD has been financed by the Productivity 2005 (P2005) research program at NTNU. I would like to thank all my colleagues at P2005, and in particular Britt Dale, Ragnheidur Karlsdottir and Jan Ola Strandhagen.

The PhD period had not been the same without the support from some of my close friends. I would like to thank Henrik, Anders, Bendik, Trond, Hilde, and Vidar, for their patience and their efforts to socialize with me.

I'm not sure how to thank my family and how to apologize for the absent and neglect the last decade. My father (Per Endre), Anne Mari, my sister (Kari) and my two grandmothers (Anna and Rigmor) have always been there for me and I am sincerely grateful for this – thank you very much!!

Oslo, December 2009

Sindre Bolseth

Abstract

Manufacturing companies are subject to tremendous pressure of the ever-changing business environment. They compete in a marketplace where globalization, Information and Communication Technology (ICT), time, cost and customization are important business drivers. As a result, many companies have globally distributed operations (including global suppliers and customers), are struggling with lack of control and limited influence of their own operations (due to among other outsourcing), are experiencing huge demand fluctuations in the value chain, are struggling on one hand to get hold of timely and accurate information and on the other hand are overwhelmed by unimportant, dated and biased information. Further, these companies are experiencing that the vulnerability of business to disturbance or disruption has increased, and finally, are lacking the responsiveness to react to ever increasing levels of volatility in demand. All in all, they compete in a global, complex and highly dynamic business environment, with changing customer expectation, increasing demand for customization and flexibility, shorter time to market, decreasing product life cycles, and extreme cost pressure.

Companies need to respond to these business drivers and the current challenges in the business environment. This doctoral thesis highlights six generic so-called critical response activities:

1. *Developing global integrated value chain systems* - the focus is shifting from competition between firms at the same level in the production process to competition between value chains, from raw materials to end customers.
2. *Exploiting the opportunities offered by ICT* - such as improving productivity, cost reductions, improving decision making, enhancing customer relationships, and developing new strategic applications among others.
3. *Shifting focus from function to processes* – companies need to change their vertical organization structure to a more horizontal structure, and this change draws attention to processes, as opposed to looking at the functional barriers.
4. *Rethinking planning and control of operations* - there needs to be a shift from the conventionally forecast-driven to a more demand-driven and proactive planning and control regime. The planning and control regime needs to be agile, response-based and resilient in order to be able to react rapidly, or even better, in advance to demand requirements.
5. *Shifting focus from products to solutions* - customers are demanding more than just standardized or commodity products.
6. *Focusing on innovation and R&D* - innovations are not only limited to technical innovation (introduction of new products, processes or services into the market), but organizational and marketing innovation are as important as technical innovation to growth and competitiveness

The research in this thesis is grounded on the first four critical response activities, whereas the latter two critical response activities have a product focus, are consequently out of scope and are not debated any further.

The research rationale of the thesis is congruent with the two first critical response activities; the *need to develop value chain systems* and *exploiting the possibilities offered by ICT* (the third and fourth critical response activity may be viewed as the focus area within the research rationale). What has been of particular interest is how ICT can enable value chain system

(especially Extended Enterprise) collaboration and not least improve and support operations within such systems. Within this Extended Enterprise type of value chain system collaborations, the concepts of information visibility and information visualization have been identified as essential to overcome the barriers to establish such a value chain system and perhaps more importantly, as tools to improve, enhance and support operations within the Extended Enterprise. Hence, the Extended Enterprise, information visibility and information visualization are the three main concepts within this thesis, and are defined as:

- **The Extended Enterprise** is a long-term, strategic, and ICT enabled network collaboration between at least two value chain partners (manufacturers, suppliers, transporters, warehouses, etc) which seeks to integrate their operations to secure a superior value creation process (products and/or services) for its customers and a sustainable competitive position for its members.
- **Information visibility** is the ability to "see" (i.e. access) all relevant information, on-line and in real time, in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. This is achieved through a seamless flow of accurate and timely information (e.g. customer demand information and other operational, tactical and strategically information influencing the operations) within and between companies in the value chain.
- **Information visualization** is the use of computer-supported, interactive, visual representations (i.e. models) of abstract and complex data and information for gaining new knowledge, amplify cognition, and rapid and action-oriented understanding.

The overall objective of the doctoral thesis has been to establish requirements, specifications and functionality for an information and visualization toolset, as decision support for planning and control of operations (particularly manufacturing and logistics processes) in the Extended Enterprise. The overall objective can be divided into more specific objectives:

- Create a common understanding of the term/concept Extended Enterprise, and contribute in the scientific development of the Extended Enterprise concept.
- Develop a concept for information visibility in the Extended Enterprise.
- Develop a concept for information visualization of operations, and particular of processes, in the Extended Enterprise.
- Explore the usage of ICT in the Extended Enterprise, and ultimately how ICT can support planning and control of manufacturing and logistics operations in the Extended Enterprise.

As a response to the objectives listed above, a combined and integrated concept (which later is formalized into a system) of ***information visibility and visualization*** is introduced: The ability to visually access (on-line and in real time) all relevant information in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. The visualization of information is enabled through the use of computerized models and other graphical interfaces. These computerized models are supported and linked to a flow of accurate and timely information spanning the value chain.

Hence, an **Extended Enterprise information visibility and visualization system** is a system that enables information visibility and visualization in the Extended Enterprise. Furthermore, it is a system that:

- Supports a seamless flow of accurate and timely information across the Extended Enterprise.
- Enables easy integration, connectivity and interoperability between various and necessary ICT systems in the Extended Enterprise.

- o Enables visualization of the shared information through the use of computer supported models and other graphical interfaces.
- o Supports communication, monitoring, analysis, and decision making within and between members of the Extended Enterprise.
- o Enables automation of operations, and provide alerts prior to events and/or exceptions.

Relating to the Extended Enterprise information visibility and visualization system, the main focus has been on developing functionalities for this type of system, together with information sharing requirements in the Extended Enterprise:

- o **Functionalities** – in total 31 requirements and functionalities for this type of system have been identified and described. These serve as guidelines for selecting and/or developing an information visibility and visualization system for the Extended Enterprise.
- o **Information sharing** – an information sharing cube has been developed specifying what to share, when to share and whom to share with. The information sharing cube is used to identify which kind of information to share, when and to whom in the Extended Enterprise.

The Extended Enterprise information visibility and visualization system is a generic, high-level and theoretical description of how to enable information visibility and visualization in the value chain. In order to fulfill the research objectives of this thesis, an information visibility and visualization toolset, called the **Extended Enterprise Operations Model Toolset**, was developed as a response to the requirements and functionalities of the Extended Enterprise information visibility and visualization system (i.e. functionalities and information sharing requirements).

The objective of the Extended Enterprise Operations Model Toolset is to provide a powerful set of tools as decision support for planning and control of operations in the Extended Enterprise. The toolset has been developed with a particularly focus on the manufacturing and logistics processes in the Extended Enterprise, and the aim has been to develop tools and concepts supporting the development and operation of integrated, global and responsive value chains. The Extended Enterprise Operations Model Toolset seeks to enable communication, monitoring, analysis and decision support within and between the members of the Extended Enterprise. The Extended Enterprise Operations Model Toolset supports short term operational and tactical planning and control of operations, as well as more long term strategic improvements of operations in the Extended Enterprise.

The Extended Enterprise Operations Model Toolset constitutes six different tools:

- o *The Extended Enterprise Operations Model* – is a tool for visualizing, planning and control of information and material flow in the Extended Enterprise. It is computerized and web-based; it ensures efficient and coordinated planning and control; it enables real-time information flow and communication, and functions as an on-line repository for the Extended Enterprise. It has six views/perspectives on the Extended Enterprise and includes information about processes, resources, materials/products, information (flows and systems), organizations, and control.
- o *The Extended Enterprise Process Model* – is a tool that enables Extended Enterprises to build up their operation based on standard processes. The EE Process Model will allow mapping of all actors, processes and activities in the Extended Enterprise, and thereby have a complete and corresponding description of the Extended Enterprise.

- *The Extended Enterprise Modeling Tool* – is a tool for mapping and modeling operations in the Extended Enterprise; i.e. a tool for generating computerized models.
- *The Extended Enterprise Dashboard* – is a tool for measuring, monitoring, analyzing and managing the operations in the Extended Enterprise through visual displays, indicators, reports and alarms. It has access to real-time information regarding operations, and this information is matched up to operational, tactical and strategic objectives for the Extended Enterprise through the use of (key) performance indicators.
- *The Extended Enterprise ICT Infrastructure* – seeks to overcome the (technological) barriers of information sharing in the value chain; thus enabling information visibility. Furthermore, it makes it possible to digest, to understand, and to act on the information by using sophisticated analysis, modeling and decision support capabilities.
- *The Extended Enterprise Studio* – is a collaborative, physical and/or virtual environment where teams of Extended Enterprise representatives mutually and simultaneous plan and control the value chain operations through visual support tools.

Within the Extended Enterprise Operations Model Toolset, the focus has been on developing the Extended Enterprise Process Model, together with a specification and formalization of the Extended Enterprise Operations Model, the Extended Enterprise Dashboard and the Extended Enterprise Modeling Tool. The Extended Enterprise ICT Infrastructure and the Extended Enterprise Studio, on the other hand, are just described on a conceptual level.

The research methods applied in this doctoral thesis hava been a combination of literature review, case studies and action research. A continual literature review has supported all research activities throughout the whole PhD period. Throughout the first three years of the PhD three different case studies were conducted. These case studies help generate knowledge and formulate research rationale, problems and objectives. The majority of research conducted within this doctoral thesis has been action research with a case at Raufoss Chassis Technology (RCT). In addition, the major result from the case at RCT has been tested through an action research case at Hydro Automotive Structure (HAST).

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To my late mother,
Sigrid

PART I

Introduction to the research project

This main objective of Part I is ***to introduce and present the research project****, which this doctoral thesis is based on. The aim is to provide an* ***overall introduction to the topic and context of the research project****, and describe the* ***research rationale, problems, objectives, questions and approach****, together with the* ***structure of the thesis****.*

Chapter 1 *will provide an overall introduction to the research project. The chapter will start with a presentation of the current business environment, with a focus on some important business drivers and critical responses to these drivers. This, together with the research context, affiliation, domain, topic, scope, assumptions and rationale, will pave the way for the formulation of the research problems and objectives of the thesis. Furthermore, attention is given to the chosen research approach for the research project. Finally, the limitations and the structure of the thesis are presented at the end of the chapter.*

Part I

Chapter 1

Introduction

Chapter 1

Introduction

1 Introduction

Chapter 1 will provide an overall introduction to the research project. The chapter will start with a presentation of the current business environment, with a focus on some important business drivers and critical responses to these drivers. This, together with the research context, affiliation, domain, topic, scope, assumptions and rationale, will pave the way for the formulation of the research problems and objectives of the thesis. Furthermore, attention is given to the chosen research approach for the research project. Finally, the limitations and the structure of the thesis are presented at the end of the chapter.

1.1 The business environment

Traditionally a typical business environment can be described by Porter's famous *five forces model* (Porter, 1998a and 1985) (see figure 1). The model recognizes five major forces that could endanger a company's competitive position in a given industry. These five forces are:

1. The threat of entry of new competitors
2. The bargaining power of suppliers
3. The bargaining power of customers (buyers)
4. The threat of substitute products or services
5. The rivalry among existing firms in the industry

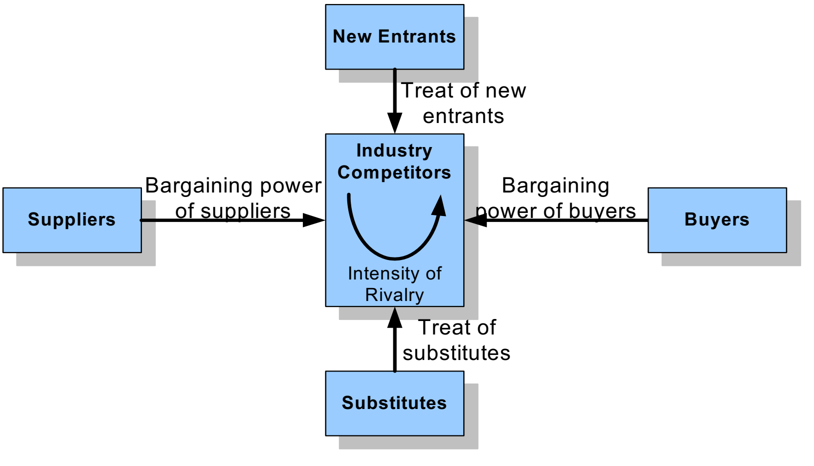

Figure 1 The five competitive forces that determine industry profitability

Source: Porter (1998a)

The collective strength of these five competitive forces determines the ability of companies in an industry to earn, on average, rates of return on investment in excess of the cost of capital. The strength of the forces varies from industry to industry, and can change as an industry evolves (Porter, 1998a). Although the details of the model differ from one industry to another, its general structure is universal (Turban, 2006). Companies need to protect themselves against these forces, or they can use the forces to improve their position, or to challenge the industry leaders.

However, there are many additional forces (e.g. globalization, technology, environmental issues, etc) influencing the business environment. These additional forces are affecting all companies in a given industry, and are therefore on another level than Porter's five forces. All in all this results in a variety of forces influencing the way companies do business.

As a result, manufacturing companies are today subject to tremendous pressure of the ever-changing business environment. They compete in a global marketplace where focus on cost and quality no longer is sufficient. Changing customer expectation, increasing demand for customization and flexibility, shorter time to market, decreasing product life cycles, as well as a complex and dynamic business environment characterize the current global marketplace in which these companies operate.

Companies need to react frequently and quickly to both the problems and the opportunities resulting from this new business environment (Turban, 2006; Arens and Rosenbloom, 2002; Drucker, 2002; and Drucker, 2001). These forces, problems or opportunities can be called ***business pressures or drivers*** (Boyett and Boyett, 1995). The business pressures are forces in the organization's environment that create pressure on (that is, that "drive") the organization's operations Turban (op cit). In order to succeed, or even merely to survive, in this dynamic business environment, companies must not only take traditional actions such as lowering costs, but also undertake innovative activities (such as changing structure or processes) or devise competitive strategy. These reactions to the business drivers can be referred to as ***critical response activities*** (ibid).

Figure 2 illustrates the relationship between business drivers and critical response activities. The figure also indicates that companies need ***support*** in order to establish their response to the business drivers. This support can vary from mapping and analysis techniques, frameworks for strategy formulation and change implementation, to investment in new technology (e.g. Information and Communication Technology (ICT)).

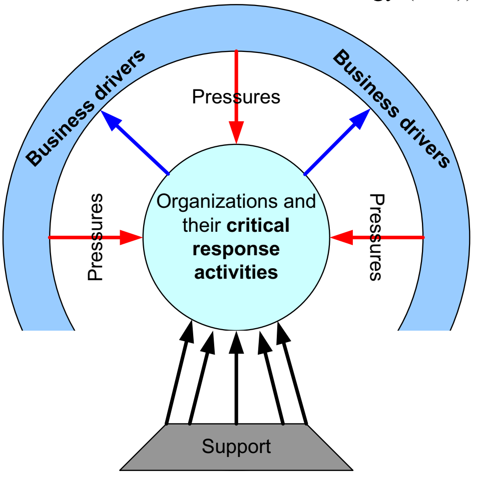

Figure 2 Business drivers and responses

Adapted from Turban (2006)

1.1.1 Business drivers

Several authors have addressed the issue of business drivers (or pressures, trends, etc), see amongst others Christopher (2005, 1998), MANUFUTURE (2004), U.S. Department of Commerce, 2004) and Browne et al. (1995). Common for many of these authors is that they all list 3-6 factors (i.e. drivers) that influence the way business is conducted today. Some examples of highlighted business drivers may be: *Globalization* (Christopher, 2005; MANUFUTURE, op cit; U.S. Department of Commerce, op cit; Christopher, 1998; Browne et al. op cit), *time compression* (Christopher, 1998), *price pressure* (Christopher, 2005) *organizational integration* (Christopher, 1998), *customer power* (Christopher, 2005, 1998), *advances in technology* (MANUFUTURE, op cit; U.S. Department of Commerce, op cit), *removal of trade barriers* (U.S. Department of Commerce, op cit), *environmental issues* (U.S. Department of Commerce, op cit; Browne et al., op cit).

Based on a literature review many different types of business drivers were identified (see above). These business drivers have various degrees of importance for companies, and five business drivers were selected as most important. This selection was rooted in the literature review and supplemented with experienced gained in case studies. These five business drivers will be used to describe the business environment that companies operates in (see figure 3):

1. ***Globalization -*** Two thirds of today's businesses operates globally – global markets, global operations, global financing and global supply chains (Edmonson, 2000). Globalization can take the form of selling in foreign markets, producing in foreign lands, purchasing from foreign suppliers, or partnering with foreign firms. Companies go global to take advantage of favourable costs, to gain access to international markets, to be more responsive to changes in demand, to build reliable sources of supply, and to keep abreast of the latest trends and technologies (Russell and Taylor, 2003).
2. ***Information and Communication Technology (ICT)*** - Perhaps more than any other single factor, ICT has changed the basis of production economics by automating many clerical tasks and greatly improving manufacturing accuracy, reliability, and predictability (Jelinek and Goldhar (1984) and Rondeau and Litteral (2001)). It is important to stress that the benefits of IT have been rich and far-reaching and have not only been limited to the automation of processes. The impact of modern ICT on enterprise systems can be classified into three categories (Huang and Nof, 1999): 1) Speeding up activities, 2) Providing intelligent and autonomous decision-making processes, and 3) enabling distributed operations with collaboration.
3. ***Time focus*** - One of the most visible features of recent years has been the way in which time has become a critical issue in management. Product life cycles are shorter than ever, industrial customers and distributors require just-in-time deliveries, and end users are ever more willing to accept a substitute product if their first choice is not instantly available (Christopher, 1998).
4. ***Cost focus*** - Cost is always a concern for companies. The basic economics of a business is very simple: If you want to improve profitability, you either have to reduce cost or increase income (e.g. sales), or preferably both at the same time. It is therefore not surprising that companies are experiencing an ever more focus on costs, and it is reasonable to assume that this cost focus has existed in industry as long as industry has been around.
5. ***Customization*** - Customers can no longer be thought of as members of a homogeneous market group (Gilmore and Pine II, 1997). Firms are facing an uninterrupted trend towards individualization in all areas of life. In particular, consumers with great purchasing power are increasingly attempting to express their personality by means of an individual product choice (Piller and Müller, 2004). Customization and personalization are about offering individual customers a customized product or service according to their needs (Piller et al., 2005).

These five business drivers describe the business environment in which this research project has its focus (see figure 3). It is important to remember that these business drivers not only represent challenges, but also opportunities.

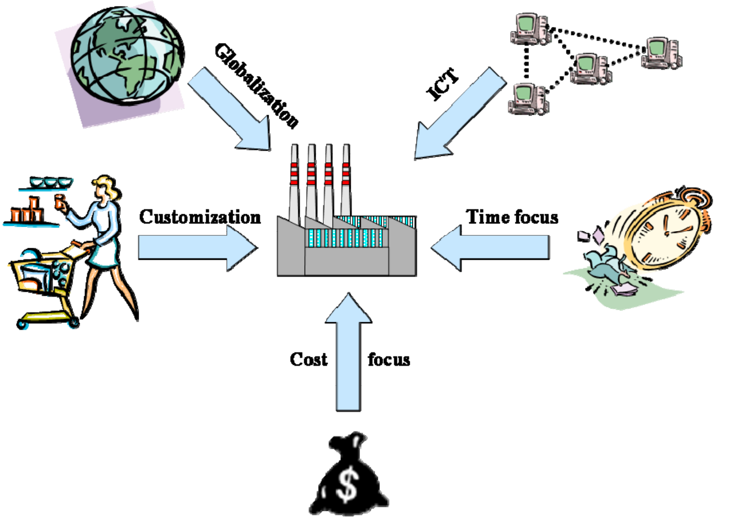

Figure 3 The business environment

It is important to highlight three aspects of the business drivers. Firstly, companies experience these business drivers in various degrees depending on the context. This means that two companies located next to each other operating in different markets and sectors will experience both some identical and particular business drivers. Secondly, the business drivers are in nature different as well. Some drivers are introduced by the customer, by competing companies, suppliers/vendors, others by government, organizations, stakeholders etc. This implies that the business drivers can affect different aspects of the business. Thirdly, variations may steam from the fact that the business environment is extremely complex and the various authors who have conducted these studies have different backgrounds in which they observe the business environment, and may therefore conclude somehow different.

The business drivers in figure 3 are high level pressure on businesses. The direct implications on business from these drivers are not always clear and easy to understand. Some examples of more apparent, tangible and hands-on effects of these drivers can be (from an operations management point of view):

- ***Distributed operations*** – due to among others globalization and cost pressure many companies today have facilities (manufacturing plants, warehouses, etc) geographically distributed (Rudberg and West, 2008; Ferdows, 2003; Ogulin, 2003; Russell and Taylor, 2003; Ferdows, 1997a and 1997b). This requires a new communication (virtual) environment where individuals of globally dispersed companies can communicate, collaborate and coordinate their operations.
- ***Lack of control*** - as companies nowadays focus on their core activities and outsourcing the remaining value chain operations to other business partners and parts suppliers, only a small portion of the operations conducted internally, the visibility and control a company has over these operations has become significantly limited (Peleg and Lee, 2006). Thus, it is important that the companies are able to monitor effectively the activities outside its boundary (Lau and Lee, 2000).

- ***Demand fluctuation*** – many companies are struggling with demand fluctuation in the value chain, where relatively small changes in downstream demand are dramatically amplified upstream (Lee et al. 1997; Forrester, 1958).
- ***Lack of information*** - lack of information or distorted information passed from one end of the value chain to the other can create significant problems, including but not limited to, excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, ineffective transportation, and missed production schedules (Handfield and Nichols Jr., 2002).
- ***Information overload*** – due to the advances within ICT, raw and unfiltered information is produced at a speed and size that exceeds their cognitive capacity (Ho and Tang, 2001). As a result, both individuals and companies are overwhelmed with information; they have access to more information than they are accustomed to managing (Golicic et al., 2002).
- ***Vulnerability*** – The market turbulence has increased due to the business drivers. Furthermore, demand in almost every industrial sector seems to be more volatile than was the case in the past (Christopher and Lee, 2004). At the same time the vulnerability of business to disturbance or disruption has increased (Christopher, 2005). It is not only the effect of external events such as natural disasters, strikes or terrorist attacks but also the impact of changes in business strategy. Many companies have experienced a change in their business risks profile as a result of changes in their business models. For example, the adoption of "lean" practices, the move to outsourcing and a general tendency to reduce the size of the supplier base potentially increases supply chain vulnerability (ibid).
- ***Lack of responsiveness*** – one of the biggest challenges facing organizations today is the need to respond to ever increasing levels of volatility in demand at a low cost (Gunasekaran et al., 2008; Christopher, op cit; Storey et al., 2005). Hence companies need to develop market-responsive processes to quickly respond to unpredictable demand in order to minimize stock-outs, force markdowns and obsolete inventory (Fisher, 1997). Further, companies need to quickly respond to changes in customer demand by adjusting product, mix, volume and delivery (Reichhart and Holweg, 2007).

Lack of information and information overload may seem contradicting, but this is the reality many employees are facing. On one hand they are struggling to get hold of the right information at the right time, and on the other hand they are overwhelmed by outdated and unrelated information.

Other effects of the business drivers clearly exist, but those mentioned above are decisive for the research done in this PhD thesis. The effects will be debated and presented in more detail throughout the thesis.

1.1.2 Companies responses to business drivers

It is clear that companies are under constant pressure of various business drivers. Some of these business drivers, like Porter's five forces, are "universal" and affect all companies in one way or another. Others, like the five business drivers highlighted in this chapter, are more specific and individual and have various effects on the companies. Evidently a company needs to respond to these forces and drivers. Companies' responses can be reactions to a pressure already existing, an initiative intended to defend an organization against future pressures, or an activity that exploits an opportunity created by changing conditions (Turban et al., 2006).

It is no longer sufficient with re-drawing the organization chart and/or small organizational improvements to enable sustainable competitive advantage. In fact, the basic principles that have traditionally guided the company must be challenged and what is required is a shift in the basic paradigms that have underpinned industrial organizations for so long (Christopher, 2005).

Similar to the business drivers in chapter 1.1.1, several authors have addressed how companies should/must respond to the business drivers, see among others Gartner G2 (2004), MANUFUTURE (2004), U.S. Department of Commerce (2004), Porter (1998b, 1980) and Fisher (1997). A key finding from this literature review is that almost all authors launch the idea that ***companies have to work together (collaborate)*** in order to survive, overcome and even better, take advantage of the business drivers. This finding will be one of the cornerstones in the dissertation. Other critical response activities listed are: *Reducing costs* (Gatner G2, op cit; U.S. Department of Commerce, op cit; Porter, 1998b, 1980; Fisher, op cit), focus on *differentiation* (Porter, 1998b, 1980), develop *responsive operations* (Gartner G2, op cit; Fisher, op cit), focus on *innovation* (MANUFUTURE, op cit; U.S. Department of Commerce, op cit).

Based on this literature review, six major business responses were identified as a response to the five business drivers highlighted in chapter 1.1.1, and chosen due to their relevance to this dissertation. The chosen business responses are:

1. ***Develop global integrated value chain systems*** – Traditionally, most organizations view themselves as entities that exist independently from others and indeed need to compete with them in order to survive. However, today the focus is shifting from competition between firms at the same level in the production process to competition between value chains, from raw materials to end customers. A company's ability to create trust-based and long-term business relationships with customers, suppliers, and other strategic partners becomes a crucial competitive parameter (Jespersen and Skjøtt-Larsen, 2003).
2. ***Exploiting the opportunities offered by ICT*** - According to Bowersox et al. (2005) true value chain excellence will only come from making a digital business transformation; meaning exploiting the opportunity offered by ICT to transform the company in to a business where almost every significant process and relationship are digital enabled. ICT is offering alluring opportunities such as improving productivity, cost reductions, improving decision making, enhancing customer relationships, and developing new strategic applications among others (Wreden, 1997).
3. ***From function to process*** – Traditionally, the business has been organized around functions and those functions have provided a convenient mechanism for the allocation of resources and for the promotion of personnel. The classic organization could be described as "vertical" with a multi-layered hierarchical decision-making structure. However, in today's turbulent business environment questions are increasingly being asked about the ability of such organizations to respond rapidly to the fast-changing needs in the market (Christopher, 2005). A number of companies have realized the need to change their vertical organization structure to a more horizontal structure. This change draws attention to processes, as opposed to looking at the functional barriers (Jespersen and Skjøtt-Larsen, 2005). These processes, by definition, are cross-functional and market facing. They are, more likely team-based and they draw their members from the functions whose roles are now transformed to "centres of excellence" (Christopher, op cit).

4. ***Rethinking planning and control of operations*** - The tendency towards increased integration and cooperation between the enterprises in the value chain results in greater complexity in the management and control technology, which requires increased coordination (e.g. planning, control, scheduling, monitoring etc) of resources and activities (Jespersen and Skjøtt-Larsen, 2005). There needs to be a shift from the conventionally forecast-driven to a more demand-driven and proactive planning and control regime. The planning and control regime needs to be agile, response-based and resilient in order to be able to react rapidly, or even better, in advance to demand requirements.
5. ***From product to solution (Extended Products)*** - In the increasingly complex and competitive global marketplace, customers are demanding more than just standardized or commodity products. They increasingly require customized products and a whole array of support for that product (Duesterberg, 2003), i.e. solutions or extended products.
6. ***Focus on innovation and R&D*** – Innovation[1] has become the central pillar of competitiveness (Alfnes, 2005). Innovation is about creation and introduction of new ideas, goods, services, and practices to someone. Innovations are not only limited to technical innovation (introduction of new products, processes or serviced into the market), but organizational and marketing innovation is as important as technical innovation to growth and competitiveness (World Investment Report, 2005). Organizational innovations are defined as the implementation of new organizational methods in firms' business practices, workplace organization or external relations. They include organizational changes designed to improve efficiency, to foster innovation activities in the firm, and to increase knowledge exchange with other firms or institutions (OECD, 2005).

Critical response activities 1-4 have an operational focus and will be central in the remaining part of the dissertation, whereas the latter two have a product focus and are not debated any further.

These six recommended business responses will end the discussion of the current business environment. The outlined business environment, with its challenges, opportunities, effects and response will represent the battleground of this PhD.

1.2 Research context (affiliation)

This PhD thesis is financed by a Norwegian research program called ***Productivity 2005 (P2005)***, which again is financed by the Norwegian Research Council (NFR) and a group of Norwegian industrial companies. A three year PhD grant was assigned to the candidate, from 01.06.1998 to 31.05.2001, to conduct a PhD within the P2005 program.

1.2.1 NTNU and SINTEF

Even though the PhD has been financed by P2005, the PhD candidate has been affiliated to ***Department of Production and Quality Engineering (IPK)*** at The Norwegian University of Science and Technology (***NTNU***[2]) as a dr.ing. stipendiat (PhD scholar). IPK is one out of ten departments at the Faculty of Engineering Science and Technology.

[1] R&D (Research and Development) is only one source of innovation, and can take various forms: basic research, applied research and product and process development (World Investment Report, 2005)
[2] NTNU is a Norwegian acronym for Norges Teknisk-Naturvitenskaplige Universitet

IPK works with the intersection between technology and management, with issues tied to operations, industrialization and production, along with quality and safety. The department has three primary divisions or research groups:

- Production Systems
- Production Management (i.e. Operations Management), and
- Reliability, Availability, Maintainability, and Safety (RAMS).

The candidate has been a part of the ***Production (Operations) Management*** group at IPK.

IPK closely collaborates with ***SINTEF*[3] *Technology and Society***. The SINTEF Group is the largest independent research organisation in Scandinavia, and has approximately 2000 employees, 1400 of which are located in Trondheim and 500 in Oslo. SINTEF Technology and Society is one of the research divisions in the SINTEF Group. SINTEF Technology and Society is further divided into several departments, including the ***Department of Operations Management***[4]. The candidate, since the start of this PhD period (in 1998) and up-till now, has had various positions at SINTEF.

1.2.2 Research initiatives related to the dissertation

Over the last 5-10 years there has been increased research activity at NTNU and SINTEF within the fields of manufacturing, logistic, supply chain management, and operations management. SINTEF and NTNU have together with The Norwegian Research Council, The European Commission and companies operating in Norway (both Norwegian and foreign) initialized several research programs and project within these scientific fields. The most dominant and influential projects have been (see appendix B for more detailed information regarding these programs/projects):

- ***P2005*** - Productivity 2005 (P2005) is a Norwegian Research Council initiative (1998-2005) to strengthen the competitiveness of the Norwegian manufacturing industry. The P2005 program is based at NTNU, financed by The Norwegian Research Council and a large group of industrial companies.
- ***SMARTLOG*** - SMARTLOG's (smart logistics for dynamic value chains) vision is to give Norwegian industry high international competence and knowledge within logistics of dynamic value chains. The program is a collaboration between SINTEF, MARINTEK and NTNU, and a set of industrial companies (partners or members), and is partly financed by The Norwegian Research Council. SMARTLOG had an initial duration of 5 years (2001-2006), but has later been prolonged as a network.
- ***MOMENT*** - MOMENT (MObile extended Manufacturing ENTerprise) is a European research project funded by the EU Fifth Framework Programme (FP5), under the thematic programme GROWTH (Competitive and sustainable growth). The project started in May 2001, with a duration of three years. Seven European partners from both industry and academia are working together, bringing in different knowledge and experience.
- ***ECOSELL*** - ECOSELL (Extended Collaborative Selling Chain) is a European research project funded by the EU Fifth Framework Programme (FP5), under the thematic programme GROWTH (Competitive and sustainable growth). The project started in January 2003, with a duration of 30 months.

[3] SINTEF is a Norwegian acronym for Stiftelsen for industriell og teknisk forskning ved Norges tekniske høgskole (NTH)

[4] In the remaining part of the thesis, SINTEF is used in short for SINTEF Technology and Society, Department of Operations Management

Even though the thesis has been conducted as a part of the P2005 research program, the research has also partly been done in, or heavily influenced by other projects (see bullet-list above). In addition to the already presented projects, three other projects/cases are worth mentioning: Mack, Stokke and Glamox (see figure 9 and appendix B). Mack and Stokke are Norwegian companies, where the author was involved in research projects at an early stage of the PhD period. Glamox, also a Norwegian company, on the other hand was a case study the candidate made also in the early stage of the PhD. These projects/cases are shortly presented in appendix B.

Table 1 lists the four major research programs/projects and indicates a link between the specific programs/projects, the involvement of the author and the contribution from the programs/projects to the thesis.

Project	Project work related to thesis
MOMENT	There is a strong correlation between the MOMENT project and the PhD thesis. The author has been heavily involved in the project throughout the life cycle of the project, and has been main responsible and participant of a set of activities within the projects: o Main author of the Deliverable (D1.3): The Raufoss (Technology) case study o Co-author of Deliverable (D1.4): The MOMENT Conceptual Methodology o Main responsible for the Work-package 3 activity: Operations Model for the Extended Manufacturing Enterprise, including: • Co-author of the Deliverable (D3.1): The extended Enterprise Design Methodology • Main author of the Deliverable (D3.2): Process Model for the Extended Enterprise o Co-author of the Deliverable (D5.1): The MOMENT Methodology o Main author of the Deliverable (D6.2): Company selection and case-design report o Co-author of the Deliverable (D6.2): Case study reports The author has been heavily involved in the Raufoss Chassis Technology case, and later with the testing of the MOMENT methodology and tools at Hydro Automotive Structure
SMARTLOG	Involvement in the development of *Operations model for dynamics value chains,* and cases at Raufoss Chassis Technology and Gilde
P2005 (PLOG)	Involvement in cases and research projects within production and logistics at several companies (Mack, Stokke, Glamox, Raufoss Chassis Technology, Hydro Automotive Structure, etc). There has been a strong link between the work done both in MOMENT and SMARTLOG, and P2005 (PLOG).
ECOSELL	Involvement on a conceptual level on development of various tools in the ECOSELL project, like ECOSELL Reengineering, Collaborative Order Management, Collaborative Forecast Management, Extended Distribution Management, and Collaborative Exception Management. As well as the Co-author of the Deliverable on State-of-the-art in ECOSELL.

Table 1 Projects related to the thesis

1.2.3 The industrial context

The research in the PhD thesis has mainly been conducted within the Norwegian Industry; more precisely within the *Norwegian Manufacturing Industry,* and further detailed, within the *Automotive Industry*.

The Economic growth in Norway over the past twenty years has been substantial and Norway has become one of the richest countries in the world. Good access to natural resources has been essential to the growth of wealth. Whereas hydropower formed the basis for building Norwegian Industry in the past century, the oil and gas industry has been a major driver of the economic growth over the past twenty years (Ministry of Trade and Industry, 2003).

Norwegian industry consists of business with very different activities. The businesses can be grouped into different business sectors, where it is normally distinguished between goods-producing and service sectors. The Norwegian Ministry of Trade and Industry (op cit) group Norwegian trade and industry into 15 main sectors, where four sectors have relevance to this thesis:

- Furniture, fabrics and consumer goods
- Food and beverages
- Technology industry
- Power-intensive industry

In total these four sectors employ about 298 000 people or 20% of the total workforce[5] within the trade and industry sector. And they contributed to about 12% of the wealth creation (gross product, excluding taxes and subsides) in trade and industry in 2002. In 2004 the gross value of production in manufacturing and mining and quarrying totaled NOK 547 billion. This is an increase of 9.1%, or NOK 45.8 billion form 2003, measured in current prices. Value added in manufacturing increased by NOK 12.4 billion or 7.7 % in 2004 (Statistics Norway, 2004a).

Both cases used in this PhD dissertation are from the automotive industry, see chapter 7 and 8 for further presentation.

The Automotive Industry ranks among the most significant business phenomena of the twentieth century and remains vitally important today, accounting for almost 11% of the GDP of North America, Europe and Japan, and one in nine jobs (Maxton and Wormald, 2004). There is a reason why Peter Drucker (1946) dubbed it *the industry of industries*. The automotive industry works on a scale so awesome and has an influence so vast that it is often difficult to see. Roughly a million new cars and trucks are built around the world each week; they are easily the most complex products of their kind to be mass-produced in such volumes (Maxton and Wormald, op cit). The industry uses manufacturing technology that is cutting edge of science. It uses 15% of the world’s steel, 40% of the world’s rubber, 24 % of the world’s glass, and the vehicles themselves use a staggering 40% of the world’s annual oil output (ibid). Today, automobile manufacturing is still the world’s largest manufacturing activity (Womack et al., 1990), with almost 58 million vehicles worldwide (Maxton and Wormald, op cit). Each vehicle contains up to 8 000 individual parts of widely varying materials, made in highly specialised factories across the world (ibid).

1.3 Research domain, topic and scope

The title of this doctoral thesis is *“The Extended Enterprise Operations Model Toolset – towards information visibility and visualization in integrated, global and responsive value chains”*. In accordance with the title it is possible to identify the conjunction of ***four domains*** (areas) which constitute the ***topic*** of this thesis (see figure 4):

- Operations Management
- Value chains and the Extended Enterprise
- Business Modeling
- Information and Communication Technology

[5] The total workforce in employment in Norway is 2 274 000 people (Statistics Norway, 2004b)

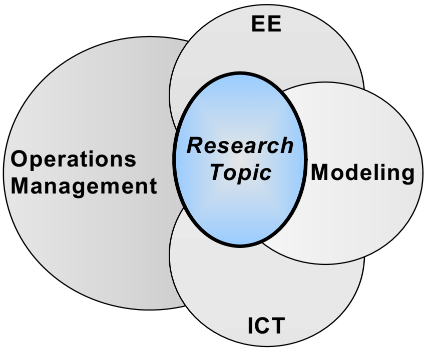

Figure 4 The research domains and topic

1.3.1 Operations Management

Operations Management is the main (first) domain of the thesis. Operations Management can be defined in many similar ways, see among others Bozarth and Handfield (2006), Reid and Sanders (2005), Chase et al. (2004), Slack et al. (2004), and Gaither and Fraizer (2002). In this thesis Waller's (2003) definition will be used: ***Operations Management covers the effective planning, organizing, and control of all the resources and activities necessary to provide the market with tangible goods and services***. Operations Management is frequently confused with operations research and management science (OR/MS) and industrial engineering (IE). The essential difference is that OM is a field of management, whereas OR/MS is the application of quantitative methods to decision-making in all fields, and IE is an engineering discipline (Chase et al., 2004).

The history or roots of Operations Management can be tracked back to the *Industrial Revolution*, via *Scientific Management* and more recently *Service Operations*, *Production Management,* and *Production and Operations Management*.

The traditional way of thinking about operations is as a transformation process that takes a set of inputs and transforms them in some way to create outputs, either goods or services, that a customer values (Bozarth and Handfield, 2006). Figure 5 illustrates the basic version of this transformation process. In figure 5 a set of input resources (such as materials and information) are transformed (utilizing transformation resources such as facilities, machines, computers, and people) into outputs of products and services. In general, the transformation process can be categorized as follows[6] (Chase et al., 2004): Physical (as in manufacturing), location (as in transportation), exchange (as in retailing), storage (as in warehousing), physiological (as in health care), and informational (as in telecommunications). This transformation process is monitored and coordinated through a control system that collects, processes, stores and disseminates information about the enterprise and the environment surrounding it (Alfnes, 2005).

[6] These transformations are not mutually exclusive.

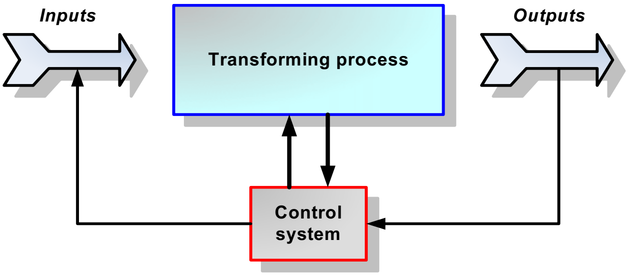

Figure 5 The transformation process

Slack et al. (2004) point out that the *operations function* is one of three core functions of any organization. The two other functions are: The *market functions* and the *product/service development function*. In addition there are support functions, which enable the core functions to operate effectively (e.g. *accounting and finance function*, and *human resource function*).

Most textbooks[7] on Operations Management list three major functions of Operations Management:

- Design of Operations
- Planning, Control and Organization (i.e. management) of Operations
- Improvements of Operations

A fourth function, *Operations Strategy,* is also quite often mentioned. However, Operations strategy is in most cases treated as a separate field or topic (see Slack and Lewis, 2003).

Within the operations functions, management decisions can be divided into three broad areas (Chase et al., 2004):

- Strategic (long-term) decisions
- Tactical (intermediate-term) decisions
- Operational planning and control (short-term) decisions

Operations and operations management will be further presented and discussed in chapter 2.5.

1.3.2 Value chains and the Extended Enterprise

The second domain of the thesis are the concepts of value chains and Extended Enterprises. The value chain concept was introduced by Porter (1985). In this book Porter claims that every firm is a collection of activities that are performed to design, produce, market, deliver and support its product. All these activities can be represented using a value chain. A firm's value chain and the way it performs individual activities reflect its history, its strategy, its approach to implementing its strategy, and the underlying economics of the activities themselves. A firm's value chain is embedded in a larger stream of activities, called the value system (op cit).

However, in this thesis a broader interpretation of the term value chain will be used. ***The value chain is a neutral description of a value system from point of origin to point of consumption***. It is important to realize that these value chains exist whether they are managed or not. In other words, there is a definite distinction between value chains as a phenomenon that exist in business and the management of those value chains (Mentzer et al., 2001).

[7] See among others Gresley (2006), Hill (2005), Slack et al. (2004), Gaither and Frazier (2002) and Chase et al. (1998)

The Extended Enterprise is one out of many (see chapter 2 for further discussion) perspectives on the value chain. ***The Extended Enterprise is a long-term, strategic, and ICT enabled network collaboration between at least two value chain partners (manufacturers, suppliers, transporters, warehouses, etc) which seeks to integrate their operations to secure a superior value creation process (products and/or services) for its customers and a sustainable competitive position for its members***. Enterprises across the whole value chain, from raw materials to end-customer, can be involved in the Extended Enterprise. However, the concept of a whole value chain is neither necessary nor a relevant condition to the formation of Extended Enterprises. An Extended Enterprise can be developed between any two or more enterprises across the value chain of any product or service.

Value chains and the Extended Enterprise are closely related to Operations Management; particularly value chains are often presented and discussed in Operations Management books. The main differences are that: 1) The value chain (according to Porter, 1985) constitute all activities within a company, whereas Operations Management only focus on the operations activities, 2) Operations Management is concerned with management of operations, whereas the value chain concept is merely a descriptive construct, and 3) Operations Management has traditional been concerned with operations within one company, and not between companies as the broader interpretation of value chains are.

A further discussion of the value chains and Extended Enterprise is provided in chapter 2.

1.3.3 Business modeling

The third domain of the thesis is business modeling. The modeling process is the set of activities to be followed for creating one or more models of something (defined by its universe of discourse) for the purpose of representation, communication, analysis, design or synthesis, decision-making, or control (Verndat, 1996). ***A model is a simplified representation or abstraction of reality. It is usually simplified because reality is too complex to describe exactly and because much of the complexity is actually irrelevant in solving the specific problem*** (Turban and Aronson, 2001). The degree of simplification and abstraction depends on the interest of the targeted audience. A model is always expressed in terms of a language (mathematics, natural languages, symbols etc) (Vernadat, op cit). Business models come in a wide variety of forms, but most of them fall into one of the three to four categories shown in figure 6.

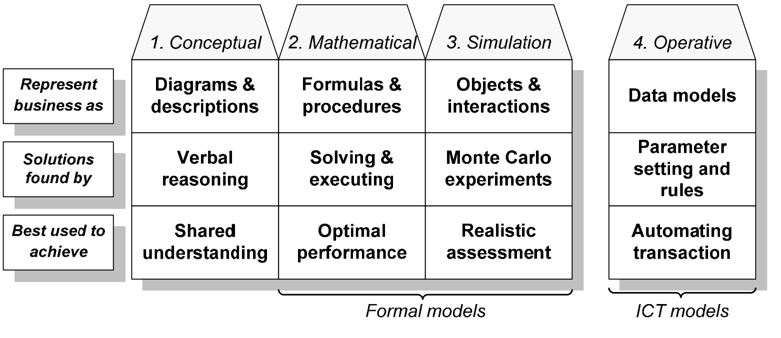

Figure 6 Three kinds of business models

Modified from Taylor (2004)

The original figure by Taylor (2004) included three categories (conceptual, mathematical and simulation models), whereas the fourth category (operative models) has been included by the candidate. Conceptual models use diagrams and descriptions to represent a business system. Mathematical models represent a business in terms of formulas and procedures, and they are solved by evaluating those formulas or procedures under a particular set of assumptions. Simulations models use software objects to represent the components of a business, and they are solved by “running” the model to see what happens when the objects interact with each other (Taylor, 2004). Operative models are data models embedded into ICT systems (e.g. ERP systems) representing the business logic of the enterprise and hence supporting the execution of operations.

The distinctions among these kinds of models are not clear and precise; hybrid forms are common. But the four types do represent four fundamentally different approaches to modeling, and each offers a unique set of capabilities and limitations (ibid).

Whatever the type of model, its purpose is to present the system (i.e. the business) and also perhaps a tool to help minimize risk, improve planning, reduce costs, expose potential problems, and to help make logical decisions in management (Waller, 2003). Hence, models play a significant role in operations management decision making (Stevenson, 2005).

A more detailed presentation of models and modeling and how models can support decision making is presented in chapter 4.4.

1.3.4 Information and Communication Technology

The fourth and last domain of the thesis is Information and Communication Technology (ICT). ***ICT can be defined as technology used to support information gathering, processing, distribution, and use*** (Beynon-Davis, 2004). Whereas ICT systems are technological information systems that collect, process, store, analyze, and disseminate information for a specific purpose.

There are many facets of ICT in business, and ICT systems are used among others to speed up processes, enable communication, decision support, automate work, etc, and ultimately to improve business profits.

Much of the current interest in value chain collaborations are motivated by the possibilities and advantages offered by ICT. The introduction and utilization of integrated ICT for managing the value chain will enable companies to gather vital information along the whole value chain and act quickly upon it to be in advance on market changes, and thereby gaining competitive advantages (Narasimhan and Kim, 2001).

What is of particular interest in this thesis is ***how ICT can support and enhance value chain collaboration (i.e. Extended Enterprises)***, facilitate a flow of real-time information between the value chain partners, and provide a visual decision support based on this information

The role of ICT in operations and Extended Enterprise will be further presented and discussed in chapter 2.6 and 3.1.

1.3.5 Research scope

The four research domains and the coincident research topic presented above is extensive and quite generic. It is therefore adequate to further narrow the research topic and specify the ***research scope*** of the thesis within the four domains of which constitutes the topic:

- Operations Management
  - Focus on manufacturing and logistics processes
  - Focus on planning and control of operations (i.e. manufacturing and logistics).
  - Focus on tactical and operational issues, and in less degree strategic aspects
- The Value Chain and the Extended Enterprise
  - Focal company perspective; the value chain is viewed from one company and how this company collaborate with its supplier and customers
  - The focal company is viewed as a 1. Tier suppler, implying that the customer always is a business and not a consumer (i.e. person)
  - Focus on long term relationships and collaborations
- Business Modeling
  - Conceptual models of operations
  - ICT supported models
- Information and communication technology
  - ICT systems supporting operations in the Extended Enterprise
  - Facilitating a timely and accurate flow of information between the members of the Extended Enterprise
  - From an applied ICT perspective (e.g. how ICT can support the three other domains, and not from a computer science perspective).

The scope of this thesis can be summarized (based on the bullets list above) as: ***The development of ICT supported conceptual models based on timely and accurate value chain information for support of planning and control of manufacturing and logistics operations in the Extended Enterprise.***

1.4 The research project

On the basis of the presented research context, domains, topic and scope a research project was established. The research addresses the challenges outlined in the business environment, in particular the mismatch between the business drivers companies are experiencing and the recommended critical response activities to these drivers.

1.4.1 Research rationale

The research rationale is funded in the presentation of the current fierce business environment given in chapter 1.1. In short, the research rationale can be specified into two headings:

- ***The growth of value chain systems***
- ***The new possibilities offered by ICT***

Both these headings have been essential in the business environment presentation (see chapter 1.1), and will remain essential throughout the rest of this thesis.

Over the past decades the business environment has experienced the ***growth of value chain systems*** (Hugos, 2006; Christopher, 2005; Davis and Spekman, 2004; Mentzer, 2004; Simchi-Levi et al., 2004; Taylor, 2004; Gattorna, 2003; Handfield and Nichols Jr., 2002; Tyndall et al., 1998); where companies form some sort of collaboration along the value chain in order to provide an improved value proposition to the customer. In most cases these collaborations are in sequence (vertical linkages) along the value chain, but parallel position (horizontal linkages) collaborations in the value chain occur quite frequently as well (e.g. in production networks or virtual organizations).

Consequently, today *no company is an island* (Fine, 1998; and Håkansson and Snehota, 1989). The destiny of the firm is firmly linked to what happens in its supply (upstream) and demand chain (downstream). The understanding of the nature of these linkages and the dynamics of power and control in the chain is necessary for survival of the company (Fine, op cit).

The value chains systems are offering great possibilities (e.g. cost reductions, better quality, improved speed, etc), but also equally challenges (e.g. the rising complexity of such systems, control issues, slowness of such systems, risks, etc) for companies. So the research seeks to develop solutions that help companies to take advantages of the opportunities, and at the same time help them manage or avoid the challenges of such value chain systems.

The growth of value chain systems, with a particular focus on manufacturing in such systems, was also the one and only prerequisite from P2005 (which financed the PhD) regarding the research focus for the PhD.

The second aspect of the research rationale is ***the new seducing possibilities offered by ICT***. The emergence of ICT has radically altered a number of aspects of both the way we live and the way we work (Bouwman et al., 2005). Over the past years, companies have invested enormous resources into ICT in hope of taking advantage of the opportunities offered by ICT and gaining a competitive advantage. Six trends/aspects within ICT can explain some of these possibilities offered, and not at least why companies have done these investments:

1. *The rapid growth and adoption of the Internet* – the Internet is reshaping the way ICT systems are being used in business by eliminating many technical, geographical and cost barriers obstructing the global flow of information.
2. *ICT is becoming a commodity* – ICT systems are continually becoming more powerful (i.e. faster, more storage, etc), the level of standardization is increasing and prices are declining.
3. *The rapid growth of Enterprise Applications (e.g. ERP systems)* - today, almost every medium sized and large corporation in the developed world have at least one Enterprise Application system implemented.
4. *Automation of processes* – the automation of data and information flow and reliance on global communication will continue to expand dramatically.
5. *The prospect of RFID* - the interest in RFID is on one hand caused by the reduction in cost of the technology, and on the other hand by the benefits offered by the technology (i.e. improved speed, accuracy, efficiency and security).
6. *The world of mobile computing* – enable people to break the barriers of geography and time – they can be reach anywhere and anytime, as long as they can connect to a network.

What is of particular interest with ICT as a research rationale in this thesis, is how *ICT can enable value chain systems collaboration and improving and supporting operations* within such systems. ICT plays an important role when people try to overcome the limitations of time and distance to communicate exchanging information or work together. There are various technologies that play a role in this process, technologies that are used to establish communication over distance (telecommunication) and technologies that are used to store, process and provide data (information technology) (op cit).

ICT can help facilitate value chain system collaboration so companies can experience the advantages listed above, and at the same time provide support tools for avoiding many of the problems due to value chain system collaboration. According to Simchi-Levi et al. (2003) the primary goal of ICT systems in value chain systems is to link the point of production seamlessly with the point of delivery of purchase. In this thesis, the focus is how ICT can enable information visibility and information visualization in the Extended Enterprise

For further information regarding value chain systems, ICT, and ICT supporting value chain system, see chapter 2.

To conclude, the research rationale of this PhD thesis can shortly be summarized as: ***To investigate how ICT can enable and support value chain systems collaborations and operations.***

1.4.2 Research assumptions

The research conducted in this PhD thesis is based on a set of assumptions. These basic assumptions can be viewed as suppositions that the research is based on, and represent, together with the research rationale, the point of departure of the dissertation. However, the origin of these assumptions is complex and not directly obvious. The assumptions are based on a combination of the literature review made on the business environment, the wider literature review presented in chapters 2-4, and the experiences gained through the initial case studies (see figure 11 and Appendix B).

The four research assumptions are as follows:

- ***Assumption # 1***: Manufacturing companies **need to form Extended Enterprises** with their key suppliers and customers.
- ***Assumption # 2***: In the Extended Enterprises, companies need to **integrate their processes with each other**. This integration will **enable coordination** of operations along the value chain.
- ***Assumption # 3***: In order to enable smooth operations, companies need to **share information** with each other, particular regarding customer demand, and create **information visibility** in the Extended Enterprise.
- ***Assumption # 4***: Due to the complexity of Extended Enterprises, **visualization of operations** is an important means to management of operations

The four assumptions have been normative for the research conducted within the PhD, and paved the way for the formulation of research problems and objectives.

1.4.3 Research problems

The research for this thesis focuses on how the gap between the ideas, visions and expectations of the Extended Enterprise on one hand, and the more grim reality in today's business environment on the other hand, can be more aligned. The research will particularly focus on the operational aspects of the Extended Enterprise, and not so much strategic and organizational aspects.

Unfortunately there are no turn-key or easy solutions on how to integrate companies along the value chain into Extended Enterprises, and none/few available solutions that support management, planning and control of operations in the Extended Enterprise. Furthermore, the exchange of information between companies is not as easy as it seems; many different systems and standards are used, the number of peer-to-peer relations with other companies in the network is usually too large to manage, most systems are not open for easy exchange of information with other systems, and most companies are very reluctant to share information with other companies in the first place (Boyson et al, 2003).

The Extended Enterprise is really about creating a defensible long-term competitive position through strong value chain integration, collaborative behaviors, and the deployment of enabling information technology (Davis and Spekman, 2004). The concept of Extended Enterprise is based upon cooperation and coordination, and the key is the integration of processes, both up- and down-stream, in the value chain. However, according to Davis and Spekman (op cit) most firms are not even close to developing the requisite mindset; they lack the skills and competencies needed and cannot implement the processes that lie at the heart of the Extended Enterprise. Herein lays the challenges the research in this thesis has been facing.

The overall research problem addressed in this thesis is: ***The lack of formalization in the Extended Enterprise concept, and the almost total absence of tools and methods supporting the management, particularly in planning and control, of operations in the Extended Enterprise.***

In 2002, the Economist (2002) surveyed CEOs to understand the effects the Extended Enterprise is having on senior managers in global companies (Davis and Spekman, 2004). Interestingly, over 65% of the respondents reported they have become, and will continue to become more dependent on external relations to achieve their business objectives. At the same time, over 65% feared that such relationships would lead to lack of control and heightened vulnerability (ibid).

This last finding (in the survey above) is in line with the prevailing perception of how companies are struggling with various issues regarding their relationships with suppliers and customers. Typical issues are:

- Trust issues - the willingness to give up control of processes and/or to share information/knowledge with partners in the value chain.
- Risk issues – getting vulnerable due to the dependence on the partners in the value chain.
- The reluctant of sharing information – particularly regarding demand information, necessary for planning and control of operations along the value chain.
- The bullwhip effect - where small amplification in demand downstream in the value chain magnitude to large fluctuation in demand upstream in the value chain.
- Integration problems, e.g. integration of ICT applications along the value chain.
- Difficulties in synchronization of processes and material flow, imposing problems for enabling a smooth flow of products along the value chain.
- Stockouts in one part of the value chain imposing large effects/problems in other parts of the value chain.
- Safety stocks, due to unreliable partners, causing unnecessary cost.

These are only some of the many issues companies are struggling with in order to become an Extended Enterprise. Stallkamp (2005) summarize many of these issues (problems) into four bullets:

1. ***Distrust and suspicion*** – the historical independence between companies sometimes forces them to view each other with suspicion instead of trust. If mistrust and suspicion replace trusting environment in business, both parties respond by building in protective mechanisms to ensure that their respective interests are protected at all costs.
2. ***Poor communication*** – despite major innovations in data processing, meaningful communication remains poor and spotty throughout many value chains. However, hierarchy and policy still control and limit communication between companies.
3. ***Lack of joint planning*** – too few companies now share their future plans with the members of their value chain that they have built to support them. Many industrial companies do their advance planning in secret, fearing that plans will leak to their competition.
4. ***Tendency towards complete control*** – conflicts over control are common today because large companies sometimes mouth the words of mutual co-existence and partnership but still seek ways to ensure that they have the final say in what happens.

The overall research problem stated above can be expressed in more detail through five sub-problems (or in this case lacks):

- There is lack of a uniform view of the Extended Enterprise
- There is a lack of holistic thinking regarding operations in the Extended Enterprise
- There is a lack of "true" Extended Enterprise ICT systems
- There is a lack of proactive principles, methods and tools for planning and control of operations in the Extended Enterprise
- There is a lack of easy, non ambiguous, simple and uniform modeling techniques and constructs for modeling operations in the Extended Enterprise

Firstly, there is ***lack of a uniform view of the Extended Enterprise***. The concept of the Extended Enterprise is relatively new, and the term Extended Enterprise has only been in use for just over ten years. To the authors knowledge there has only been written 8 books[8] within the area of the Extended Enterprise over these years:

1. Enterprise Collaboration: On-demand information exchange for Extended Enterprises, by Levermore and Hsu (2006)
2. Governance of the Extended Enterprise: Bridging business and IT strategies, by the IT Governance Institute (2005)
3. Score! : a better way to do business: moving from conflict to collaboration, by Stallkamp (2005)
4. The Extended Enterprise: Gaining competitive advantage through collaborative supply chains, by Davis and Spekman (2004)
5. Process Management for the Extended Enterprise: Organizational and ICT networks, by Tonchia and Tramontano (2004)
6. The Lean Extended Enterprise: Moving beyond the four walls to value stream excellence, by Burton et al. (2003)
7. Collaborative Advantage: Winning trough extended enterprise supplier network, by Dyer (2000)

[8] Thesis and Conference Proceedings are not included.

8. Logistics and the Extended Enterprise: Benchmarks and the best practices for the manufacturing professional, by Boyson et al. (1999)

These books all address the Extended Enterprise from different angles and no uniform view of the Extended Enterprise can be established from the work outlined in these books. However, there are of course some similarities. All authors view the Extended Enterprise as two or more companies engaged in some sort of collaboration. Three of the books are addressing how Chrysler became an Extended Enterprise in the 1990s. All authors view the Extended Enterprise in the context of the value chain, and highlight the Extended Enterprise as a extension of the more commonly known supply chains.

The same picture occurs when reviewing scientific articles, and investigating how various professionals (e.g. researchers and consultants) is referring to the term. A Google search[9] for the term "Extended Enterprise" resulted in 360 000 hits, whereas comparable terms like the "value chain" and "supply chain" resulted in respectively 3 810 000 (ten times as many) and 37 700 000 (more than 100 times as many) hits. So it is clear that the Extended Enterprise is not as common and incorporated as the value and supply chain.

Secondly, there is a ***lack of holistic thinking regarding operations***. Traditionally a company has been viewed as a number of functions. According to Melan (1993) the following conditions are usually built into the functional structure:

1. Rewards systems that promote values and support the objective of the functional department rather than the business in its entirety.
2. Group behaviour, which encourages a strong loyalty within the department and "us versus them" attitude towards other departments within the firm.
3. A high degree of decentralization, creating firms within the firm, each with its own agenda.

Bowersox et al. (2007) address much of the same conditions and use the term *the great divide*. The great divide reflects an organizational condition where achieved integration is partial but not complete on an end-to-end basis. The most common situation is when a company only achieves partially integration of distribution/marketing on the outbound side of the enterprise and procurement/manufacturing on the inbound side (ibid).

In such an environment people have clear problems with seeing *the big picture* of operations along the Extended Enterprise. As Peter Senge (1990) puts it: *"From a very early age, we are taught to break apart problems…This makes complex tasks more manageable, but we pay a hidden price. We can no longer see consequences of our actions; we lose our intrinsic sense of connection to a larger whole…When we try to "see the big picture" we try to reassemble the fragments in our minds…but the task is futile…thus, after a while we give up trying to see the whole altogether."*

Thirdly, there is a ***lack of "true" Extended Enterprise ICT systems***. There is no such thing as an ICT system for the Extended Enterprise. There is a myriad of systems serving similar and different purposes/functions, linked together by either standard or customized integration. Most of these systems are intra-enterprise systems; systems operating within the boundaries of one company.

[9] 02.11.2008

The dominant ICT systems in today's business environment are Enterprise Resource Planning (ERP) systems. ERP systems are company centric systems, and can be viewed as a standard application program, which support execution of business processes throughout the whole company. The ERP system has functionality that makes the company able to replace many of their applications with a single seamless system with one common database. Using a single database dramatically streamlines the flow of (financial and accounting, human resource, supply chain, customer, etc) information throughout the business (Davenport, 1998).

Over the past years the idea of ERP II systems or Supply Chain/Extended Enterprise systems has been introduced to the market. One of the most important reasons that Extended Enterprise or ERP II systems are needed in the new economy is the absolute necessity to move data anywhere, at any time, within the company, within the value chain (customers, vendors), with the knowledge that data are up-to-date and accurate, and independent of language, location, and currency (Weston Jr., 2003). Weston (op cit) define ERP II systems as: "*the automation and integration of information, processes, and functions in a manufacturing (or other) environment with the result being a closed-loop, functionally integrated, real-time planning, execution, and control system that is location- and language-independent and that increasingly includes customers, vendors, and partners*".

However, the ideas and visions of the Extended Enterprise systems are unfortunately still visions and not reality. Today these systems are still basically ERP systems, including Customer Relationships Management (CRM) system functionality that links to customers, and Supply Cain Management system functionality that links to vendors (Bolseth, 2002 and Weston Jr., 2003).

Another fly in the ointment is as Benton and Love (2006) puts it: "*It can be argued that the difficulties in implementing an ERP system in a single organization render it impossible to implement pan-organizationally*".

Fourthly, there is a ***lack of proactive principles, methods and tools for planning and control of operations***. The most widespread planning and control tool for operations in today's business environment is ERP systems. ERP systems are based on MRP[10]/MRP II[11] logic (Summer, 2005; Ptak and Schragenheim, 2004; Breuls an Wortman, 2002), with roots back to the 1960s and 1970s (became famous through Orlicky's first book on MRP in 1975). These ERP/MRP systems have been faced with criticism due to the push-based nature, the static BOM[12] structure, fixed lead times, long planning horizon, and infinity capacity assumption (see among others Miller, 2001; Sipper and Bulfin Jr., 1997; Browne et al., 1996; and Higgins et al., 1996).

Another important criticism is the lack of reliability of the data within the system (the *rubbish in – rubbish out* principle). This implies (from a very critical point of view) that these systems even struggle to report what has happened in the business, what is going on at the present time and to generate accurate plans for the future. Perhaps more important, they also fall short in helping companies to determine what ought to be going on (Chopra and Meindl, 2001).

[10] MRP = Material Requirements Planning
[11] MRP II = Manufacturing Resource Planning
[12] BOM = Bill of Material; defines the products structure in terms of materials and provides an optional connection to plant resources such as machinery, tooling, and labour defined by a bill of routing

According to PricewaterhouseCoopers (2000), the principles of mass production pioneered nearly a century ago remain largely intact today. This is supported by Miemczyk and Holweg (2004) who point out that the automotive industry is still largely based on Henry Ford's mass production paradigm or push logic, and the majority of vehicles in the world are built based on forecasts and expected demand, and not according to real demand. As a result, automotive manufacturers hold as many as a 100 days of sales in the marketplace (ibid). This even though production philosophies/paradigms like Lean Manufacturing and Agile Manufacturing (which is focusing on production according to real demand – pull) has originated from the automotive industry.

Recently new ICT systems, such as MES, APS, RFID etc, have however been introduced (see chapter 2.6) to the market and there are high expectations regarding how these can support planning and control of operations in the Extended Enterprise.

Fifthly, there is a ***lack of uniform modelling techniques and constructs for operations in the Extended Enterprise***. Models can be viewed as a mean to overcome some of the problems associated with the *great divide* and problems of seeing the *big picture* described above. This is particularly appropriate within the complex nature and structure of the Extended Enterprise.

Because of the nature of the Extended Enterprise dynamics, managers often do not have insight into the ripple effects of their decisions. Effects also can easily get lost in the overwhelming flood of data that crosses the supply chain manager's desk daily, weekly, and monthly (Boyson et al., 2004). This is supported by Alfnes et al. (2006) who points out that a formidable amount of information is created in the Extended Enterprise, and claims there is still a challenge related to the absorption, utilisation and grasping of the information.

Models, particularly those that offer robust visualization[13] tools, can help companies structure and simplify the complex and dynamic nature of their Extended Enterprise. These capabilities help structure, transform, condense, and visually display data from the models or real-time databases in such a way that managers can quickly grasp a situation and act upon the presented information (Boyson et al., 2004).

Gardner and Cooper (2003)[14] suggest that not only is there a need to visualize the Extended Enterprise (by models), there needs to be a well-established process for building the models so that knowledge is easily transferable and exchangeable among managers and organizations as appropriate. They further point out that there is not yet a universal set of modelling convention to represent the Extended Enterprise (ibid).

1.4.4 Research objectives

This research aims to address the challenge outlined so far in chapter 1, and more particularly the research problem stated in chapter 1.4.3. The overall objective of this research is:

To establish requirements, specifications and functionality for an information visibility and visualization toolset, as decision support for planning and control of operations (particularly manufacturing and logistics processes) in the Extended Enterprise.

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[13] In a generic sense, visualization is a method of communication that allows the brain to combine several types of data in the process of understanding and learning. It is an excellent means to communicate overviews, courses of action, coherences, connections and comparisons, (Herskin, 1997).

[14] In their article, they use the term map instead of models, and supply chains instead of Extended Enterprise.

This research objective is both narrow and wide in scope at the same time. Narrow in the sense that it only contributes to some of the challenges outlined by Davis and Spekman (however, it is more in line with the problems stated in chapter 1.4.3). Wide in the sense that it covers complex problems and involves several different scientific fields and tools.

The research aims to unite the concepts of visibility and visualization in order to create a powerful toolset for decision support in the Extended Enterprise. The primary objective is to provide new support solutions and/or concepts for planning, control and monitoring of manufacturing and logistics operations in the Extended Enterprise. These solutions and/or concepts should support companies in their tactical and operational decision making.

The combination of information visualization and information visibility is on one hand meant to provide *simple, intuitive and non-ambiguous models that structure, transform, condense, and visually display the complex structure, operations and events of the Extended Enterprise*. On the other hand however, this combination provides the models with *all the necessary and updated (real-time and on-line) information regarding the operation in the Extended Enterprise*.

The ambition is that this combination of visibility and visualization into a toolset can enable companies to quickly grasp a situation, even before it happens, and act appropriately in order to avoid or minimize the consequences of the situation.

The overall research objective can be divided into more specific objectives. These specific objectives are presented and detailed in the following sections.

Firstly, the research should ***create a common understanding of the term/concept Extended Enterprise, and contribute in the scientific development of the Extended Enterprise concept***. The research should describe the main issues associated with the Extended Enterprise in a systematically and accessible fashion. The research should:

- Define the Extended Enterprise and its relation to the value chain and other value chain system concepts.
- Describe the evolution of and the different traditions within the Extended Enterprise concept.
- Describe the characteristics of the Extended Enterprise.
- Focus on management of the Extended Enterprise, particularly planning and control of operations in the Extended Enterprise.
- Identify the key actors, and manufacturing and logistics processes in the Extended Enterprise.

Secondly, the research should ***develop a concept for information visibility in the Extended Enterprise.*** Core elements in the visibility concept are integration and information sharing along the value chain, enabled through ICT. The research should:

- Explain the rationale for visibility, and defining the concept
- Explain the relationship between visibility, integration and information sharing
- Present current visibility efforts
- Present specifications for a visibility system and the required shared information

Thirdly, the research should ***develop a concept for information visualization of operations, and particularly of processes, in the Extended Enterprise.*** The visualization concept should be enabled through models, which should be non-ambiguous and simple graphical formalism suitable for practitioner, and not expert based models. The research should:

- Describe how models can be used for visualization
- Present the most common models and modelling construct used today within value chain systems, and their limitations
- Develop a model for manufacturing and logistics processes in the Extended Enterprise
- Present a concept for visualization of operations in the Extended Enterprise

Fourthly, the research should ***explore the usage of ICT in the Extended Enterprise, and ultimately how ICT can support planning and control of manufacturing and logistics operations in the Extended Enterprise.*** The research should:

- Present the rationale for ICT in the Extended Enterprise
- Present the major ICT systems used within the Extended Enterprise, and outlines for an Extended Enterprise ICT system
- Describe how ICT enable visibility in the Extended Enterprise
- Describe how ICT enable visualization in the Extended Enterprise

Together, these systems (the concept of visibility, concept of visualization, and the outlines for an Extended Enterprise ICT system) will constitute the main elements in the toolset specified in the overall objective above. The toolset will enable and enhance a dispersed, responsive and proactive planning and control of operations along the value chain in the Extended Enterprise.

1.5 Research approach

Research is an intricate and rigorous process that should not be taken lightly nor pursued in an unstructured manner (Mentzer and Kahn, 1995). The research process is "*a series of logically ordered…choices. These choices run from formulation of the problem, through design and execution of a study, through analysis of results and their interpretation*" (McGrath, 1982, in Mentzer and Kahn, 1995).

The general objective of research, can be summarized as the creation of *"1) a body of information and knowledge that enables us better to control the environment in which we live, and 2) a body of procedures which enables us to better to add this body of information and knowledge"* (Ackoff, 1962). Thus, both the building of knowledge, and the building and improvement of research methods are an integral part of conducting research (Reichhart and Holweg, 2006).

The objective of chapter 1.5 is to outline the research approach in the thesis. In order to fully explain the chosen research approach, a short presentation of research methodologies/methods in general and more particularly within Operations Management, Logistics, and Supply Chain Management, are given.

1.5.1 Research paradigms

For any type of research the perception of paradigm is important. Before deciding on which research method to use, the underlying philosophical assumptions, the basic beliefs, should be clarified. The concept of paradigm is intimately associated with Thomas Kuhn (see Kuhn, 1962), and a paradigm can be defined *as a basic set of beliefs that guide action* (Denzin and Lincoln, 2005a). A paradigm encompass four terms/questions (ibid):

- *Ethics (axiology)* – the branch of philosophy dealing with ethics, aesthetics, and religion (ibid). How will I be as a moral person in the world?
- *Ontology* – assumptions that we make about the nature of reality (Easterby-Smith et al., 2002). Ontology refers to the claims or assumptions that a particular approach to social enquiry makes about the nature of social reality. It includes claims about what exists, what it looks like, what units make it up and how these units interact with each other (Frankel et al., 2005). What is the form and nature of reality and, therefore, what is there that can be known about?
- *Epistemology* – a general set of assumptions about the best way of inquiring into the nature of the world (Easterby-Smith, op cit). Epistemology deals with how one might understand the world and communicate that understanding knowledge to others (Frankel, op cit). How do I know the world? What is the nature of the relationship between the researcher and what can be known?
- *Methodology* – deals with how we gain knowledge about the world. Research methodology is the rationale or basis for the selection of methods used to gather data, and determining the sequence and sample of data to be collected (ibid). How can the researcher go about finding out whatever he or she believes can be known?

Burrell and Morgan (1979) conceptualize the paradigm discussion into a framework, see figure 7. The framework identifies the four sets of assumptions relevant to our understanding of social science, characterising each by the descriptive labels under which they have been debated in the literature on social philosophy (ibid):

- The ***nominalist*** position revolves around the assumption that the social world external to individual cognition is made up of nothing more than names, concepts and labels which are used to structure reality. ***Realism***, on the other hand, postulates that the social world external to the individual cognition is a real world made up of hard, tangible and relatively immutable structures.
- ***Positivism*** seeks to explain and predict what happens in the social world by searching for regularities and causal relationships between its constituent elements. ***Anti-positivism*** may take many forms, but is firmly set against the utility of a search for laws or underlying regularities in the world of social affairs.
- ***Determinism*** views man and his activities as being completely determined by the situation or "environment" in which he is located. ***Voluntarism*** views man as completely autonomous and free-willed.
- The ***ideographic*** approach is based on the view that one can only understand the social world by obtaining first-hand knowledge of the subject under investigation; i.e. an inductive research approach which is less structured and are focused on the explanation and understanding of phenomena with emphasis on qualitative data (Lanchaster, 2005). The ***nomothetic*** approach lays emphasis on the importance of basing research upon systematic protocol and technique; i.e. a deductive approach to research with highly structured research methodologies which can be replicated and controlled, and which focus on generating quantitative data with a view explaining causal relationships (Lanchaster, op cit).

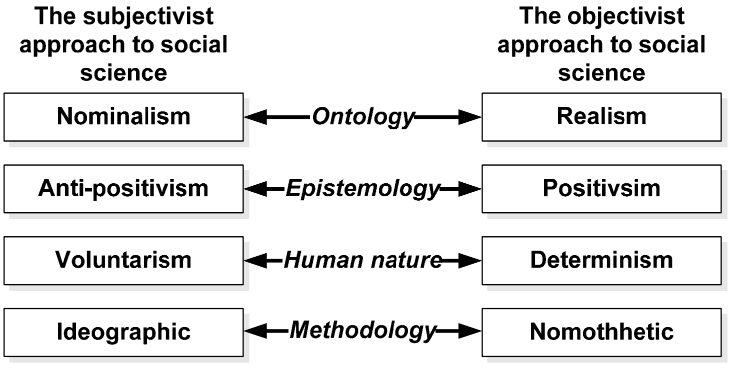

Figure 7 Framework by Burrell and Morgan

Source: Burrell and Morgan (1979)

In many ways do the discussion by Burrell and Morgan (1979) and Denzin and Lincoln, (2005a) share similar objectives (Näslund, 1999): 1) To clarify the different assumptions that, implicitly or explicitly, guide the research process, and 2) to legitimize other forms or research than only positivists forms.

The net that contains the researcher's epistemological, ontological, and methodological premises may be termed a paradigm, or an interpretive framework (Guba, 1990). All research is interpretive; it is guided by the researcher's set of beliefs and feelings about the world and how it should be understood and studied (Denzin and Lincon, op cit).

The major point is that questions of method are secondary to questions of paradigm, which is the basic belief system that guides the researcher, not only in choices of method but in ontologically and epistemologically fundamental ways (Guba and Lincoln, 1994). If, for example, a "real" world is assumed, then what can be known about it is "how things really are" and "how things really work". Then only those questions that relate to matters of real existence and real action should be investigated, while other questions, such as those concerning aesthetic or moral, fall outside the realm of legitimate scientific inquiry. Furthermore, the posture of the researcher must be one of objective detachment or value freedom in order to be able to discover "how things really are" and "how things really work". Finally, a "real" reality pursued by an "objective" researcher mandates methods, whether the methods are qualitative or quantitative, that reduce possible disturbing/uncontrolled factors. Thus, the methodological approach cannot be reduced to a question of methods. Methods must be fitted to a predetermined methodology.

Denzin and Lincoln (op cit) point out that there are four main paradigms: Positivism, post-positivism, constructivism, and participatory action framework. Alongside these paradigms are the perspectives of feminism, critical race theory, queer theory, and cultural studies. Each of these perspectives have developed their own criteria, assumptions, and methodical practices (ibid).

Other authors like Blumberg et al. (2005), Vafidis (2002), Easterby-Smith et al. (2002), Arbnor and Bjerke (1997), and Burrell and Morgan (1985 and 1979) discuss the issue of paradigm and propose classifications of the paradigms. All expect Arbnor and Bjerke (op cit), mention the various paradigms with name. All the remaining authors mention positivism, and use terms like anti-positivism, interpretivism, social constructivism, and hermeneutic[15] to describe opposing/alternative paradigm to positivism. Interpretivism will be used to describe all these paradigms opposing positivism. The main characteristics of positivism and interpretivism are (Blumberg et al., op cit):

- *Positivism* – is a research paradigm adopted from natural science. Its three basic principles are:
  1. The social world exists externally and is viewed objectively
  2. Research is value-free
  3. The researcher is independent, taking the role of an analyst
- *Interpretivism* – hold the view that the social world cannot be understood by applying research principles adopted from the natural sciences and propose that social sciences require a different research paradigm. The basic principles of interpretivism are:
  1. The social world is constructed and is given meaning subjectively by people
  2. The researcher is part of what is observed
  3. Research is driven by interest

It is important to emphasize that a research paradigm is not the same as a research method. A research paradigm consists of beliefs about knowledge, whereas research methods are specific ways of gathering data (Frankel, op cit). In order to see both the limitations and potential of different forms of research, we need to first understand the foundation (i.e. paradigm) that builds knowledge. Then we need to look at different methods before choosing the one(s) for best solving the problem (ibid).

1.5.2 Research methodologies, methods, techniques and tools

There are a number of different concepts in circulation in business today about when and how to use various methods for developing business knowledge, and even about what each method really "means" (Arbnor and Bjerke, 1997).

It is therefore appropriate to make some clarifications and quote definitions for the relevant terms and concepts. ***Research Methodology*** is the understanding of how methods are constructed, that is, how an operative[16] paradigm is developed (ibid). The most important mission for methodology is to clarify how different methodologies, problem formulations, study plans, methods, techniques, and study areas make up the parts of an integrated whole (ibid). The choice of an appropriate research methodology is influenced by several factors (Easterby-Smith et al, 1991; Bryman 1989), some of which include (Frankel et al., 2005):

- the format of the research questions (i.e., "what," "how," "who," "why," etc.), each of which requires different research designs to adequately answer them (Yin 1994);
- the nature of the phenomenon under study, i.e., contemporary or historical issues (Eisenhardt 1989);
- the extent of control required over behavioural events in the research context (Yin 1994); and
- the researcher's philosophical stance, i.e., his/her understanding of the nature of social reality and how knowledge of that reality can be gained (Blaikie 1993; Tsoukas 1989).

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[15] According to Vafidis (2002) the term Hermeneutic can be used to collectively describe research traditions covered by such word as hermeneutics, interpretive research, antipositivism, antinaturalism, ethnomenthodology, German idealism, historicism, and Marxism. Schwandt (2000) points out that interpretivism, hermeneutics, and social constructivism have many similarities and also some dissimilarity.

[16] An operative paradigm is a more "practical" paradigm and consists of methodics and methodical procedures (Arbnor and Bjerke, 1997).

Research methodologies range from two extremes; from objective, scientific (quantitative) research styles to subjective, interpretive, more constructive (qualitative) styles (Frankel et al, op cit). Qualitative research methodologies were developed in the social sciences to enable researchers to study social and cultural phenomena. Quantitative research methodologies, on the other hand, typically incorporate statistical elements, designed to quantify the extent to which certain phenomena behave/respond to stimuli in specified ways, and the extent to which a target group is aware of, think, or believe, or behave in a certain way. Studies tend to emphasize the measurement and the analysis of causal relationships between variables (ibid).

To conclude, the choice of research methodology must be appropriate for the research problems and objectives. Based upon these objectives, the choice of appropriate research methods is made.

Research methods are the data collection techniques which refer to the specific, fact-finding procedures that yield information about the research phenomenon (ibid). Research methods are also generally described as quantitative or qualitative.

Quantitative research methods can provide a wide coverage of a range of situations, is fast, and can be economical, particularly when statistics are aggregated from large samples. Questionnaires and survey methods are easily used in a quantitative way and typically provide the framework around which quantitative methods evolve. Other commonly used quantitative research methods, and examples of those now well accepted in the social sciences, include laboratory experiments, formal methods (e.g., econometrics), and numerical methods and techniques such as mathematical modeling (ibid).

Qualitative methods can be defined as an array of interpretative techniques which seek to describe, decode, translate and other wise come to terms with the meaning, not the frequency, of certain more or less naturally occurring phenomena in the social world (Van Maanen, 1983). This is line with Denzin and Lincoln (2005b) definition of qualitative research: "*Qualitative research is a situated activity that located the observer in the world. It consists of a set of interpretive, material practices that make the world visible. These practices transform the world. They turn the world into a series of representations, including filed notes, interviews, conversations, photographs, recordings, and memo to the self*".

Qualitative methods primarily create meanings and explanations to research phenomena (Frankel et al., 2005). Data collection methods are typically associated with (but not limited to) qualitative methodologies include observation and participant observation (fieldwork), interviews and questionnaires, diary methods, documents and texts, case studies, and the researcher's impressions, and reactions to observed phenomena (Denzin and Lincoln, 2005b; Frankel et al., 2005; and Bryman, 1989).

The most central characteristic of qualitative, in contrast to quantitative, research is its emphasis on the perspective of the individual being studied. Whereas quantitative research is propelled by a prior set of concerns, whether deriving from theoretical issues or from a reading of the literature in a particular domain, qualitative research tends to eschew the notion that the investigator should be the source of what is relevant and important in relation to that domain (Bryman, op cit). Furthermore, quantitative research is claimed to be infused with positivism, whereas qualitative research is in contrast often claimed to reflect a different form of knowledge (e.g. interpretivism) in which people's understanding of the nature of their social environment from the focus of attention, a focus which contrasts sharply with the tendency in much quantitative research to treat facets of their environment (such as organizations structure or job characteristics), as pre-existing "objects" akin to the physical or biological matter on which natural scientists work (ibid).

Several authors have proposed comprehensive classifications and descriptions of research methods in general, and more specific, e.g. in Business, Operation Management, Logistics Supply Chain Management etc. However, according to Reichhart and Holweg (2006) there is no single way to classify research methods beyond the paradigm level. The main differences between these classifications seem to be their granularity, i.e. the level of detail, the dimensions used and the grouping of different research methods (ibid).

Figure 8[17] gives two examples of classifications of research methods. Figure 8a is a classification of research methods within Supply Chain Management by Reichhart and Holweg (2006). Figure 8b is a classification of research method within Management Research by Easterby-Smith et al. (2002). As it appears from figure 1.8 these two classifications are both concurrent and supplementary to each other. There are however three important differences between these two classifications: 1) Figure 8a includes formalism (or analytical research), whereas this is missing in figure 8b. 2) Figure 8a separates between a quantitative and qualitative research paradigm, while figure 8b separates between a positivist and social constructionist (i.e. an interpretivism paradigm as described above). 3) Figure 8b highlights and distinguishes the role of the researcher, between involved or detached, whereas this is not included in figure 8a.

Three of the research methods mentioned in figure 8 (case study/method, action research, and literature review) will be further presented in Appendix C. These methods are selected due to their relevance to the thesis.

Research techniques refer to various ways to use tools, such as constructing a theory, developing computer software, taking a sample, or making a mathematical calculation (Ackoff, 1962). ***Research tools*** refer to physical or conceptual means, like paper and pen, instruments, computer hardware, or mathematical concept (ibid). Research techniques and tools will not be further discussed.

1.5.3 Research design

Research design can be defined as the "*overall configuration of a piece of research"* (Esterby-Smith et al., 1991), and the research design provides the opportunity for "*building, revising and choreographing"* the overall research study (Miles and Hubermann, 1994, in Frankel el at., 2005). In other words, a research design defines the study's purpose, and also drives the choices of methodology and methods (Frankel et al., op cit).

A research design describes a flexible set of guidelines that first connect theoretical paradigms to strategies of inquiry and then to methods for collecting empirical materials (Denzin and

[17] The classification made in figure 1.8 is not absolutely, and can be discussed. In figure 1.8a case study is classified as a qualitative approach, but as discussed in Appendix E, case study can be both quantitative and qualitative. Similar in figure 1.8b where action research is classified in the positivist paradigm, and in Appendix E action research is highlighted as a reaction to the traditional positivist research paradigm. In figure 1.8b case study is also labelled as positivist, whereas in appendix E case study is claimed to be both positivist and interpretivism/social constructivism. These differences emphasize why it is so difficult to enable a precise classification of research methods.

Lincoln, 2005b). A research design situates the researcher in the empirical world and connects him or her to the specific sites, persons, groups, institutions, and bodies of relevant interpretive material, including documents and archives (ibid). Five basic questions structure the issue of design (Denzin and Lincoln, 2005c):

1. How will the design connect to the paradigm or perspective being used? That is, how will empirical materials be informed by or interact with the paradigm in question?
2. How will these materials allow the researcher to speak to the problems of praxis and change?
3. Who or what will be studied?
4. What strategies of inquiry will be used?
5. What methods or research tools for collecting and analysing empirical materials will be utilized?

Dezin and Lincoln (2005c) point out that the paradigms dictate, with varying degrees of freedom, the design of a qualitative research investigation. Designs can be view as falling along a continuum ranging from rigorous design principles on one end, to emergent, less well-structures directives on the other hand (ibid).

A number of different design approaches exist, but unfortunately, no simple classification systems defines all the variations that must be considered (Blumberg et al., 2005). Table 2 gives an example of one such research design approach.

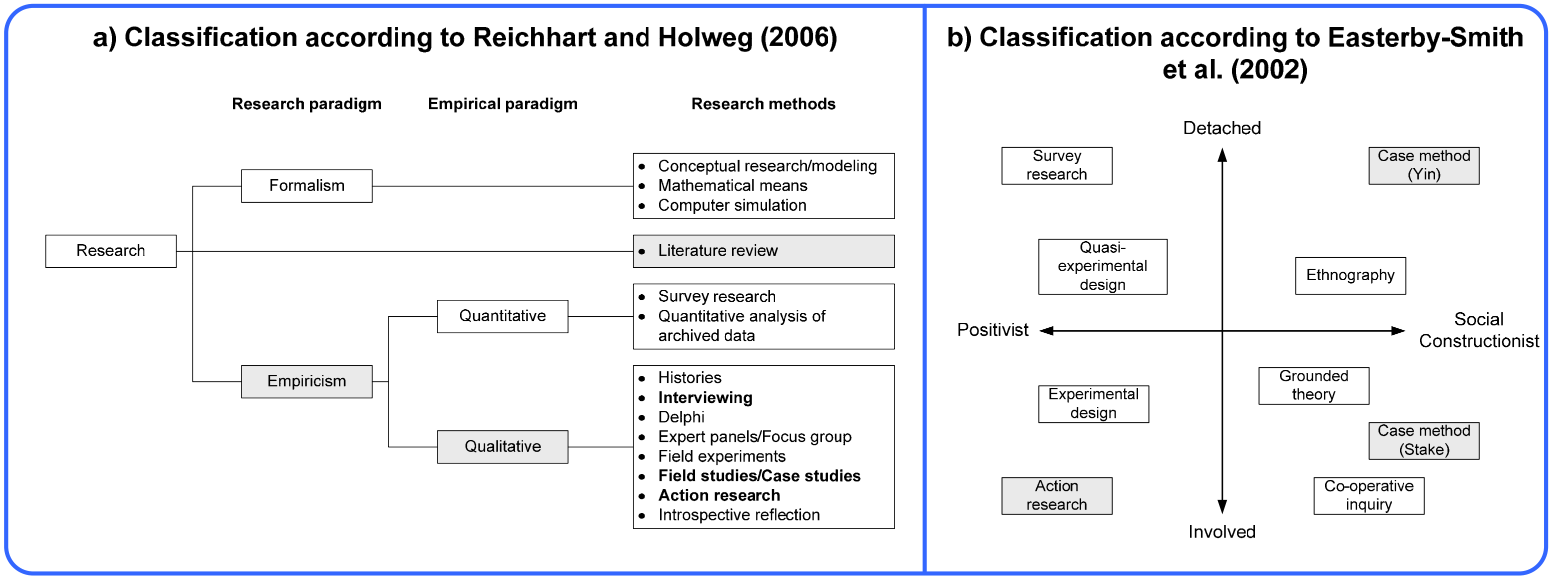

Figure 8 Two examples of classification of research methods

Adapted from Reichhart and Holweg (2005) and Easterby-Smith et al. (2002)

Category	Options	Description
The degree to which the research question has been crystallized	*Exploratory study* *Formal study*	A study may be viewed as exploratory or formal. The essential distinctions between these two options is the degree of structure and the immediate objective of the study. Exploratory studies tend towards loose structures with the objective of discovering future research tasks. The immediate purpose of exploration is usually to develop hypotheses of questions for further research. The formal study begins where the exploration leaves off – it begins with a descriptive account of the current situation followed by the hypothesis or research question, and involves precise procedures and data source specifications.
The method of data collection	*Monitoring* *Interrogation/ communication* *Archival sources*	Monitoring includes studies in which the research inspects the activities of a subject or the nature of some material without attempting to elicit responses from anyone. In the interrogation/communication study, the researcher questions the subjects and collects their response by personal or impersonal means. However, the information required to answer a research problem is often already available and the research can rely on these secondary data, i.e. archival sources.
The power of the researcher to influence the variables under study	*Experimental* *Ex post facto*	In terms of the researcher's ability to manipulate variables, we must differentiate between experimental and ex post facto designs. In an experiment, the researcher attempts to control and/or manipulate the variables in the study. With an ex post facto design, investigators have no control over the variables in the sense of being able to manipulate them. They can only report what has happened or what is happening.
The purpose of the study	*Reporting* *Descriptive* *Explanatory* *Casual* *Predictive*	At the most elementary level, a reporting study may be produced simply to provide an account or summation of some data, or to generate some statistics. A descriptive study tries to discover answers to the questions who, what, when, where and, sometimes, how. The descriptive study is popular in business research because of its versatility across disciplines. Both explanatory and predictive studies are dealing with why and how questions. An explanatory study goes beyond description and attempts to explain the reasons for the phenomenon that the descriptive study has only observed. If we can provide a plausible explanation for an event after it has occurred, it is desirable for us to be able to predict when and in what situations such an event might re-occur. A predictive study is rooted as much in theory as in explanation. Casual studies are concerned with learning why, that is, how one variable produces changes in another.
The time dimension	*Cross-sectional* *Longitudinal*	Cross-sectional studies are carried out once and represent snap-shot at one point in time. Longitudinal studies are repeated over an extended period.
The topical scope, breadth and depth, of the study	*Case* *Statistical study (sample or census)*	Statistical studies are designed for breadth rather than depth. They attempt to capture a population's characteristics by making inferences from a sample's characteristics. Case studies place more emphasis on a full contextual analysis of fewer events or conditions and their interrelations.
The research environment	*Field setting* *Laboratory research* *Simulation*	Designs also differ as to whether they occur under actual environmental conditions (field conditions) or under staged or manipulated conditions (laboratory conditions). In addition, simulations are used to replicate the essence of a system or process.
The participants' perceptions of research activity	*Actual routine* *Modified routine*	The usefulness of a design may be reduced when people in a disguised study perceive the research that is being conducted. Although there is no widespread evidence of attempts by participants or respondents to please researchers through successful hypothesis guessing or evidence of the prevalence of sabotage, when participants believe that something out of the ordinary is happening, they may behave less naturally.

Table 2 Research design approach

Adopted by Blumberg et al. (2005

1.5.4 Chosen research methodology and design

The author cannot claim to belong to a certain specified paradigm or that my ontological and epistemological opinion are crystal clear. The research is however conducted within the research tradition at my institution, Department of Production & Quality Engineering (IPK) at NTNU, and within the fields of Operations Management, Logistics and Supply Chain Management.

Unfortunately, these specifications are by no means enabling an outsider to get a clear picture of the chosen research approach. Firstly, the research tradition at IPK is by far not well formulated and precise. The research tradition is however, characterized by a *high degree of involvement* of the researcher (participatory) and is *mainly applied* research. Secondly, the disciplines of Operations Management, Logistics and Supply Chain Management are young disciplines, and lack many of the formalism that other more established disciplines (e.g. biology, physics, economics, etc) have (Pilkington and Liston-Heyes, 1999; Schmenner and Swink, 1998). As many authors have highlighted, there exists various research traditions within Operations Management (Drejer et al., 2000; Scudder and Hill 1998; Filippini, 1997; Westbrook, 1995; Flynn et al., 1990; Meredith et al., 1989), Logistics (Näslund, 2002; Ellram, 1996; Menzter and Kahn, 1995), and Supply Chain Management (Reichhart and Holweg, 2006; Golicic et al., 2005; Halldórsson and Arlbjørn, 2005; Seuring et al., 2005), and even regional differences (e.g. the U.S. vs. England vs. Scandinavia) (Drejer et al., 2000). Furthemore, many of these authors claim that most of the research conducted over the last decades has steeped in the positivist paradigm and that the research is primarily normative and quantitative (Frankel et al., 2005, Golicic et al., 2005; Näslund, 2002; Mentzer and Kahn, 1995). This is not the case for this thesis.

Regarding my paradigmatic stance, I do not belong to the positivist or interpretivism (i.e. anti-positivst) paradigm. My paradigmatic stance is somewhere in between these two opposing paradigms, more of a mixture of the realism[18], pragmatism[19] and participatory (see chapter 1.5.1 and Appendix C) paradigm. From a methodological standpoint, qualitative research has been chosen over quantitative. The research can be characterized as ideographic and does not include hypothesis testing. The chosen research methods are highlighted in figure 8.

The remaining research design and method issues are described in table 3 (which is a modified version of table 2). Figure 9 illustrates the relationships between the chosen research methods.

Design element	Chosen design
The purpose of the study	The purpose of the PhD dissertation is mainly ***descriptive***; i.e. it tries to discover answers to the questions who, what, when, where and, how.
The power of the researcher to influence	The research can be characterized as ***ex post facto***, as most of the research have been conducted within several independent companies where the researcher has

[18] Realism is a research philosophy sharing principles of positivism and interpretivism. Like positivism, its exponents believe that social science can rely on the research approach dominant in the natural science. More specifically, it accepts the existence of a reality independent of human beliefs and behavior. However, it also concedes that understanding people and their behavior requires acknowledgement of the subjectivity inherent to humans (Blumberg et al., 2005).

[19] There are many forms of pragmatism. For many of them, knowledge claims to arise out of actions, situations, and consequences rather than antecedent conditions (as in positivism). There is a concern with application – “what works” – and solutions to problem. Instead of methods being important, the problem is most important, and researchers use all approaches to understand the problem (Creswell, 2003).

Design element	Chosen design
the variables under study	minimal, if any, control of the circumstances. Further, some of the research has also been retrospective (e.g. case studies), meaning studying phenomenon that already has happened.
The time dimension	The research can be characterized as a ***cross-sectional study***, where the research has been carried out once and not repeated in the same context. The results of the first study are however tested in a second study within similar conditions. This test is also only conducted once.
The research environment	The research is conducted under actual conditions in a ***field setting***. Initial field studies were conducted at Mack and Stokke (see appendix B), and the main research has been conducted at field studies at RCT and HAST (see chapter 7and 8).
The research method	The research method in the thesis is ***a combination of literature review, case study, and action research***
	Literature review: A continual literature review has supported all research activities through out the whole PhD period. See among Part II(chapter 2, 3 and 4) for literature review; also chapter 1, 5 and 6. The literature review has used both primary and secondary sources (using all listed sources in chapter 2.6.4). In addition, the Internet has frequently been used as a source, primarily for obtaining information from international organization like the UN, World Bank, IMF, WTO, etc.
	Case study: Throughout the first three years of the PhD three different case studies were conducted (see Appendix B for more information regarding these case studies). These case studies help generate knowledge and formulate research rationale, problems and objectives.
	Action research: The majority of research conducted within this PhD has been an action research with a case at Raufoss Chassis Technology (RCT) (see chapter 7 for more information). In addition, the major result from the case at RCT has been tested through an action research case at Hydro Automotive Structure (HAST) (see chapter 8).
The method of data collection	The data collection method in the dissertation has been ***a combination of observation, interviews, and archival sources***
	Observations: The observation has been direct and not at least participant observation, where the researcher has been a part of the social setting and has acted as both an observer and participant.
	Interviews: Several key persons in the different companies included in the research have been interviewed (using a semi-structured interview approach) about past, current and future aspects.
	Archival sources: When needed, archival sources has been used to support the collection of data from the observation and interviews. Examples of such archival sources are annual reports, other company internal reports, prior research reports and master thesis, etc.

Table 3 Chosen research design and methods

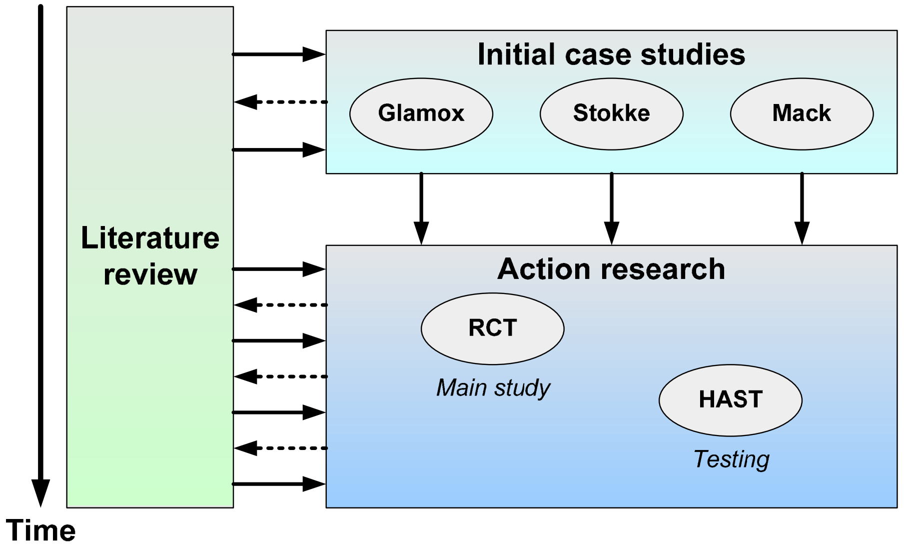

Figure 9 Relationships between chosen research methods

1.6 Quality of research

Sound research requires a systematic and rigorous approach to the design and implementation of the study, the collection and analysis of data, and the interpretation and reporting of findings (Fossey et al., 2002). Without rigor, research is worthless, becomes fiction, and loses its utility (Morse et al., 2002). Hence, a great deal of attention is applied to *reliability* and *validity* in all research methods.

In traditional, positivist and quantitative research reliability can be defined as "the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable" (Joppe, n.d.; in Golafshani, 2003). Validity can be defined as "determines whether the research truly measures that which it was intended to measure or how truthful the research results are" (ibid).

However, the traditional quality criteria such as validity and reliability lose much of its significance in qualitative research (Stenbacka, 2001; Seale, 1999; Altheide and Johnson, 1998; Leininger, 1994; Lincoln and Guba, 1985). Lincoln and Guba (op cit) outlined criteria for assessing trustworthiness of qualitative research (credibility[20], transferability[21], dependability[22] and conformability[23]) that is parallel to internal and external validity, reliability and objectivity, respectively.

[20] *Credibility* relates to how the reconstruction of the researchers fits the realities and views the participants express in the process of the inquiry (Oka and Shaw, 2000).
[21] *Transferability* refers to the possibility that what was found in one context by a piece of qualitative research is applicable to another context (ibid)
[22] *Dependability* is the qualitative researcher's equivalent of the conventional term "reliability", which is equal to replicability (ibid).
[23] *Conformability* is parallel to "objectivity" in conventional criteria, and is "concerned with establishing the fact that the data and interpretations of an inquiry were not merely figments of the inquirer's imagination (ibid).

According to Coughlan and Coghlan (2002) there are no more threats to validity in action research than in any other type of research. However, the threats of validity must be recognised and confronted (ibid). In order to maintain validity, an action researcher must consciously and deliberately enact the action research cycles, testing their own assumptions and subjecting their assumptions to public testing (Argyris et al., 1985). The principal threat to validity for action research is the lack of impartiality on the part of the researcher (Coughlan and Coghlan, op cit).

Finally, Busi (2005) summarizes a set of qualitative criteria[24] that can be used for evaluating the quality for qualitative PhD thesis, see table 4. The quality criteria listed in table 4 will be used to ensure validity, reliability and rigor of this research.

Quality criteria	Description
Contribution to knowledge	The research should contribute to existing knowledge by disclosing hypothesis, theories and constructs not yet explored in existing knowledge.
	Theory should be developed through three mechanisms: 1. As an outcome of the research process, 2. Moving from the particular to the general in small steps 3. As a template for comparison and further development of theory
	Valid theories should be well developed and informed, comprehensive, logical, parsimonious and consistent
Contribution to practice (i.e. practical relevance and usefulness)	The research outcome should be proved to be useful and relevant to practitioners. That is, the outcome of the research should be embraced by the organization being involved in the research.
Theoretical foundation	The research should be based on sound knowledge of existing theories in the area of investigation.
	Changes being studied should be triangulated.
Practical foundation	Development of new theories should develop from synthesis of data, which is obtained from the use of existing theory in practice.
Methodological coherence	The research questions must match the research method, which should match the data and analytic procedures.
Investigator(s) responsiveness	The researcher should prove that he has remained open, has been creative, and has been willing to relinquish any ideas that are poorly supported.
Iterative interaction between data analysis and data collection	The research should carry out data collection and analysis concurrently in order to ensure reliability and validity.

Table 4 Quality criteria for the research

Source Busi (2005)

1.7 Research delimitations and limitations

Two parameters for a research study establish the boundaries, exceptions, reservations, and qualifications inherent in every study (Castetter and Heisler, 1977; in Creswell, 2003):

- *Delimitations* – are used to narrow the scope of a study.
- *Limitations* – identify potential weakness of the study.

The delimitations in this thesis are mainly due to three factors: *Time*, *money* and the researcher's *competence*. Due to these three factors it has not been possible to investigate and elaborate every aspect in the thesis. Most of the relevant delimitations are specified in chapter 1.2.5 R*esearch scope*.

[24] The set of quality criteria are based on a literature review of various qualitative research literature.

The limitations in the thesis are mainly due to the chosen *research approach*. Firstly, the chosen research approach has been ***action research with a single case.*** This addresses the traditional discussion of single versus multiple cases, what generalizations can be made from cases, and the transferability from one case to another. However, the findings and results from the single case have been partially tested in a second similar case. Secondly, in an action research approach the researcher has ***minimal, if any, control of the environment***. This has clearly been an important constraint in the research. First the two initial cases at Mack and Stokke were stopped, due to lack of commitment and interest from the involved companies. Then the main case at RCT suffered at the end due to financial difficulties the company experienced. And the testing at HAST, in the second main case, allowed only a partial testing. Thirdly, the researcher role in an action research approach is ***participatory observations***. This is in contrast to the traditional criteria of objectivity in the positivist paradigm. Fourthly, most of the research has been as ***part of a team***, and it is therefore hard to identify the author's contribution. This has been a challenge in the process of writing the dissertation. Finally, due to the ***delimitations*** (time, money and competence) ***not all concepts, tools and methods are fully developed***. From the author's point of view, it would be desirable to have a set of fully developed tools that have been tested in many cases within different business sectors etc. However, this has not been possible.

1.8 The research storyline

Figure 10 outlines the various phases in the PhD period (i.e. the storyline of the PhD). The purpose of figure 10 is to give the reader an insight into the chronological sequence (i.e. the timeline) of important occurrences and activities throughout the PhD period.

The two PhD projects (RCT and HAST) are fully presented in chapter 7 and 8, whereas the other activities and projects are shortly presented in chapter 1.2 and Appendix B.

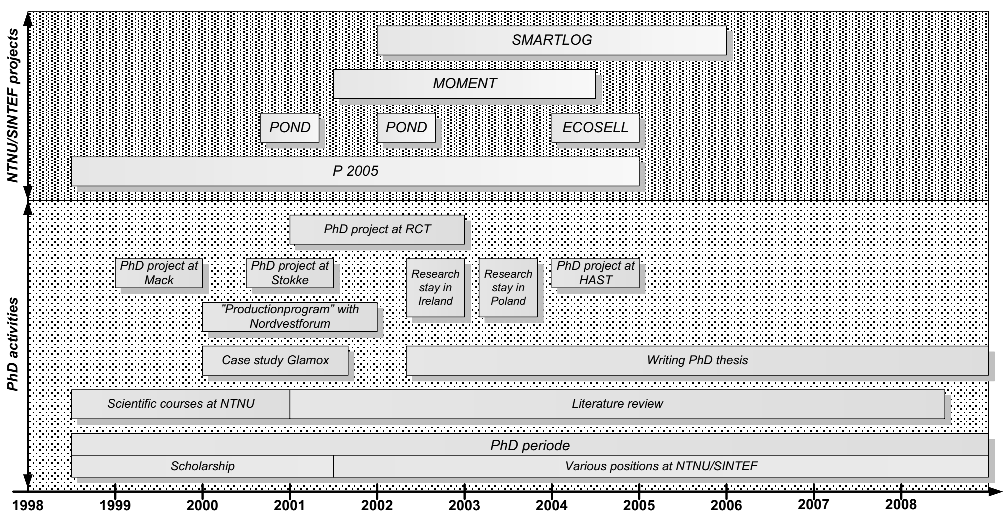

Figure 10 The research storyline

A key point in figure 10 is that the PhD project at RCT, which later became the main case in this doctoral thesis, first kicked-off in the beginning of 2001. This was just six months prior to the ending of the PhD scholarships, and is one of the reasons why the PhD period has been extended for so long.

1.9 The structure of the thesis

The overall structure of the thesis is outlined in figure 11. The remaining part of chapter 1.9 will elaborate the thesis structure in more detail.

This main objective of **Part I** is ***to introduce and present the research project***, which this doctoral thesis is based on. The aim is to provide an ***overall introduction to the topic and context of the research project,*** and describe the ***research rationale, problems, objectives, questions and approach***, together with the ***structure of the thesis***.

Chapter 1 will provide an overall introduction to the research project. The chapter will start with a presentation of the current business environment, with a focus on some important business drivers and critical responses to these drivers. This, together with the research context, affiliation, domain, topic, scope, assumptions and rationale, will pave the way for the formulation of the research problems and objectives of the thesis. Furthermore, attention is given to the chosen research approach for the research project. Finally, the limitations and the structure of the thesis are presented at the end of the chapter.

This main objective of **Part II** is to present the theoretical background of the thesis; bridge ***the gap between the research problems and objectives, and the synthesis, results and empirical study***. Part II will: 1) further ***clarify the context*** of the thesis, 2) ***underline the problems*** that the thesis is dealing with, and 3) present ***the Extended Enterprise, information visibility and visualization concepts.***

Chapter 2 will introduce the concept of the Extended Enterprise. The Extended Enterprise concept will be discussed in a value chain system context, with focus on operations management. Special attention will be given to planning and control of manufacturing and logistics. And at the end of the chapter, ICT enabling and supporting Extended Enterprises will be presented and discussed.

Chapter 3 will introduce the concept of information visibility in the Extended Enterprise. The chapter will briefly discuss information and ICT systems in value chains, with focus on the "traditional" information flow in the Extended Enterprise, and the problems this imposes on the Extended Enterprise. Then, the information visibility concept will be introduced, followed by a detailed discussion of information sharing in the value chain. At the end, an overview of some existing information visibility initiatives/systems is given.

Chapter 4 will introduce the concept of information visualization in the Extended Enterprise. The chapter will start with a discussion of the need for information visualization in value chains. Furthermore, the information visualization concept will be defined and explained. Then, the focus will be on how models and other graphical displays can contribute to information visualization. The chapter will end by presenting some of the inspiration sources for developing information visualization in the value chain.

This main objective of **Part III** is to ***present the analysis, findings and results*** of this thesis. In this part the ***literature review*** presented in Part II (chapter 2-4) is ***merged*** with the ***experience gained in the field studies***. The field studies are however not presented in this part, but rather in Part IV (chapter 7-8). The underlying assumption in this thesis is that

information visibility *and* ***visualization*** can contribute to ***powerful and efficient support in control and planning of operations in the Extended Enterprise***, and thereby ***improve material and information flow throughout the value chain***, and ultimately ***operational excellence***. ***The Extended Enterprise Operations Model Toolset*** is a set of tools providing ***information visibility and visualization*** in the value chain.

Chapter 5 is devoted to the combined concept of information visibility and visualization in the Extended Enterprise. The concept of information visibility and visualization rely greatly on the theoretical fundament brought on by literature presented in Part II (chapter 2-4), together with the needs/lacks identified in literature and in the field studies. The objective of this chapter is to introduce the concept of information visibility and visualization in the Extended Enterprise, together with functionalities for an information visibility and visualization system, and ultimately information sharing requirements in the Extended Enterprise.

Chapter 6 will introduce and present the Extended Enterprise Operations Model Toolset. The Extended Enterprise Operations Model Toolset is an information visibility and visualization system; i.e. a system enabling information visibility in the value chain and providing powerful and rich visualization of the shared information. The objective of the EE Operations Model Toolset is to provide a powerful set of tools as decision support for planning, control and monitoring of operations in the Extended Enterprise. Each tool within the toolset will be thoroughly debated, together with an overall view of the toolset.

The main objective of **Part IV** is to ***present the empirical part of this thesis***. The results of the research has already been presented in Part III, and Part IV aims **to substantiate how** these ***results can partially be derived from the two case studies*** carried out in this dissertation. These two case studies are from the automotive industry, and involve two companies; ***Raufoss Chassis Technology*** and ***Hydro Automotive Structure.*** Part IV will present these two case companies, and not so much on the various projects carried out in these companies. For more information regarding these projects, see chapter 1.2.2, table 1, figure 9 and figure 10, as well as Appendix B.

Chapter 7 will introduce and present the main case in this dissertation, the development of an Operations Model at Raufoss Chassis Technology. The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.

Chapter 8 will introduce and present the more limited (test) case in this thesis, the testing of the Operations Model at Hydro Automotive Structure. The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.

The main objective of **Part V** is to ***sum up the study*** and ***conclude the discussion of the thesis***.

Chapter 9 will conclude and discuss the work presented in this thesis. A recapitulation of the starting point for this study will be given, with focus on assessing how the objectives of the thesis are met, and assessing the applicability and quality of this work. The central finings of the study will be highlighted, together with some suggestions for further research.

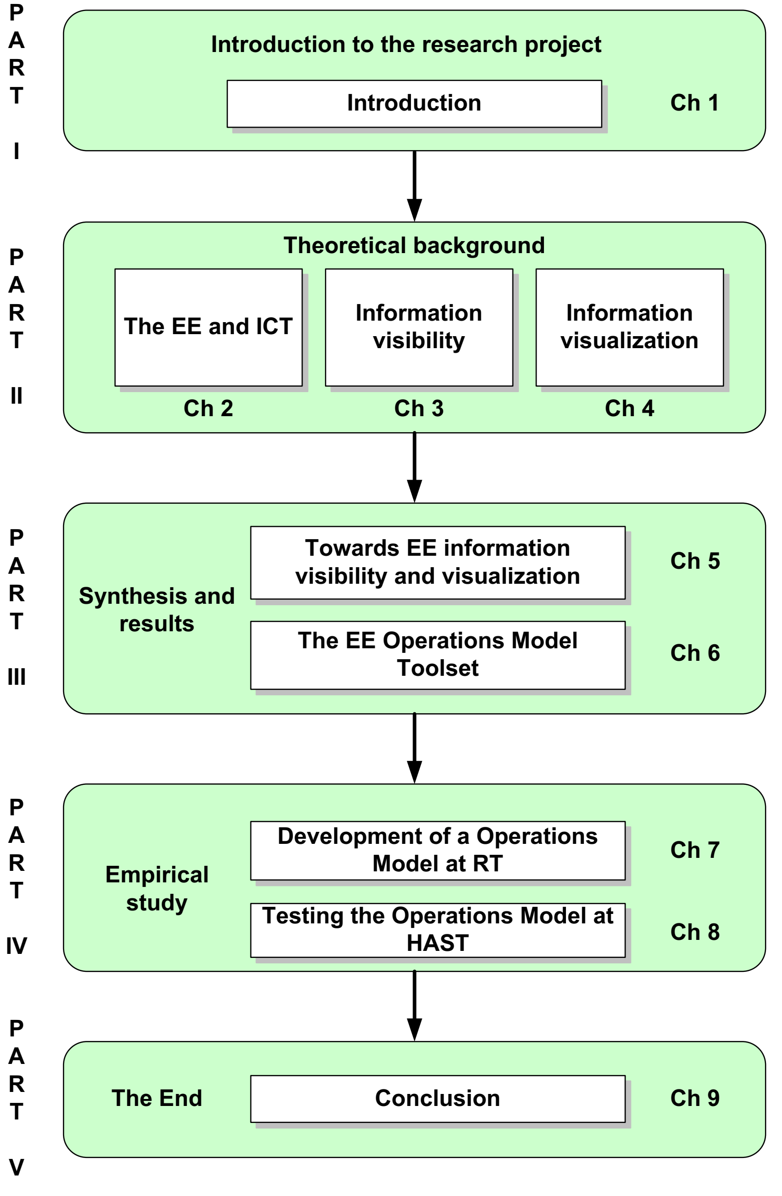

Figure 11 Structure of the thesis

1.10 The research project in brief

The objective of chapter 1 has been to introduce the research project, which this thesis is based on. Table 5 summarizes the key elements in the research projects, whereas the structure and logic of the research project is illustrated in figure 12.

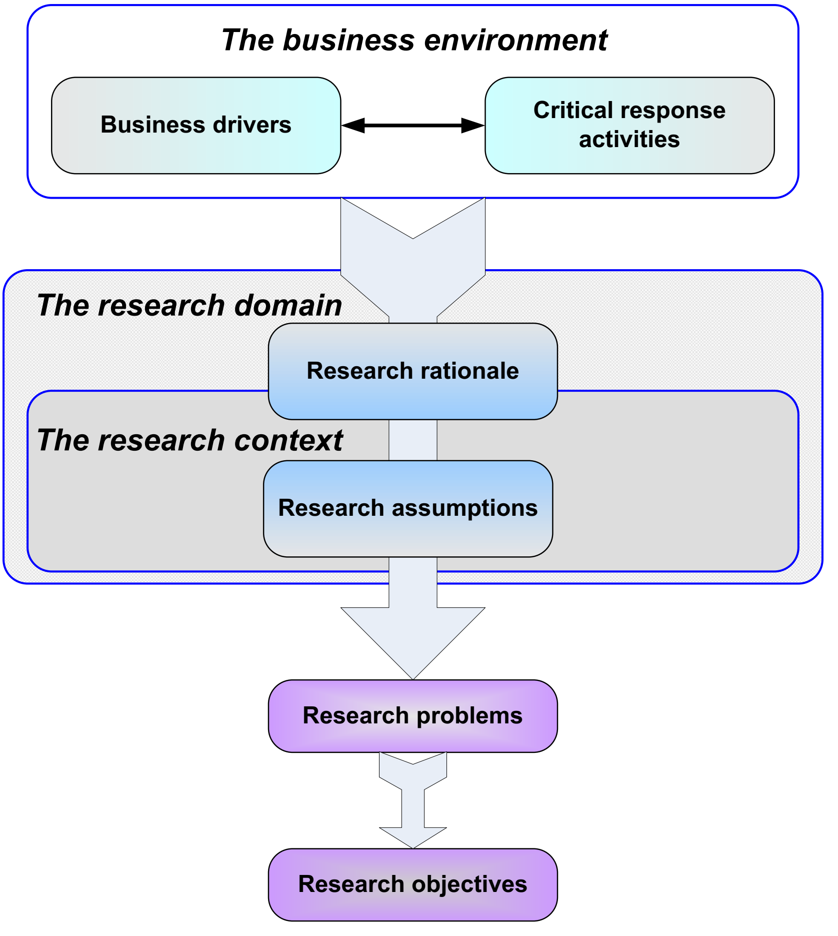

Figure 12 The structure and logic of the research project

Chapter 1 started off with an introduction to the business environment, represented through five business drivers and six generic critical response activities to these. Then the research domain and research context for the thesis were presented, narrowing the business environment into manufacturing and logistics operations in the Extended Enterprise, and in particular in the Norwegian automotive industry. Further, the thesis was limited to focus on ICT supported conceptual value chain models based on real-time and online information for support of planning and control of manufacturing and logistics operations in the Extended Enterprise.

The research project it self was introduced by specifying the research rationale (which was derive from the critical response activities), and limited by some research assumptions. Then a set of research problems were outlined, followed by a corresponding set of research objectives.

Business drivers (1.1.1)	Tangible effects (1.1.1)	Critical responses (1.1.2)	Research rationale (1.4.1)	Research assumptions (1.4.2)	Research problems (1.4.3)	Research objectives (1.4.4)
• Globalization • ICT • Time focus • Cost focus • Customization	• Distributed operations • Lack of control • Demand fluctuation • Lack of information • Information overload • Increasingly vulnerability • Lack of responsiveness	• Global integrated value chain systems • Exploiting ICT • From function to process • Rethinking planning and control • From product to solutions • Innovation and R&D	***To investigate how ICT can enable and support value chain systems collaborations and operations*** • The growth of value chain systems • The new seducing possibilities offered by ICT	• Need to form Extended Enterprise • Companies need to integrate their processes with each other, and coordinate their operations. • Companies need to share information regarding customer demand with each other, and create information visibility in the EE • Visualization of operations is an important means as support in the management of operations	***The lack of formalization in the EE concept*** • Lack of a uniform view of the EE • Lack of holistic thinking regarding operations • Lack of "true" EE ICT systems • Lack of proactive principles, methods and tools for planning and control of operations • lack of uniform modeling techniques and construct for operations in the EE	***To establish requirements, specifications, and functionalities for an information visibility and visualization toolset in the EE*** • Create a common understanding of the term/concept EE • Develop a concept for information visibility in the EE • Develop a concept for information visualization of operations, in the EE • Explore the usage of ICT in the Extended Enterprise, and ultimately how ICT can support planning and control operations in the Extended Enterprise.

Table 5 The research project in brief

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PART II

Theoretical background

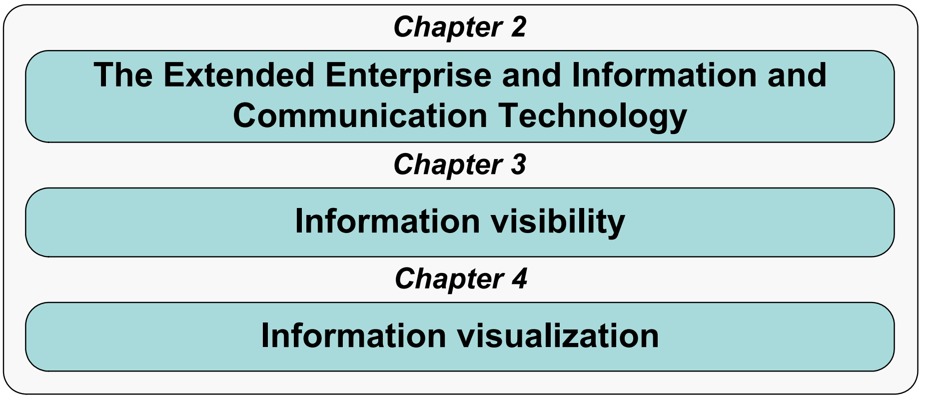
This main objective of Part II is to present the theoretical background of the thesis; bridge ***the gap between the research problems and objectives, and the synthesis, results and empirical study****. Part II will: 1) further* ***clarify the context*** *of the thesis, 2)* ***underline the problems*** *that the thesis is dealing with, and 3) present* ***the Extended Enterprise, information visibility and information visualization concepts.***

Chapter 2 *will introduce the concept of the Extended Enterprise (EE). The EE concept will be discussed in a value chain system context, with a focus on operations and the management of these. Special attention will be given to planning and control of manufacturing and logistics. And at the end of the chapter, ICT systems enabling and supporting EE will be presented and discussed.*

Chapter 3 *will introduce the concept of information visibility in the EE. The chapter will shortly discuss information and ICT systems in values chains, with focus on the "traditional" information flow in the EE, and the problems this imposes on the EE. Then, the information visibility concept will be introduced, followed by a detailed discussion of information sharing in the value chain. At the end, an overview of some existing information visibility initiatives/systems is given.*

Chapter 4 *will introduce the concept of information visualization in the EE. The chapter will start with a discussion of the need for information visualization in value chains. Further, the information visualization concept will be defined and explained. Then, the focus will be on how models and other graphical displays can contribute to information visualization. The chapter will end by presenting some of the inspiration sources for developing information visualization in the value chain.*

Part II



Chapter 2

The Extended Enterprise and Information and Communication Technology

2 The Extended Enterprise and Information and Communication Technology

Chapter 2 will introduce the concept of the Extended Enterprise. The Extended Enterprise concept will be discussed in a value chain system context, with a focus on operations and the management of these. Special attention will be given to planning and control of manufacturing and logistics. And at the end of the chapter, ICT systems enabling and supporting Extended Enterprises will be presented and discussed.

2.1 Introduction

In his book "*Collaborative Advantage: Winning through extended enterprise supplier networks*", Jeff H. Dyer (2000) asks two important and quite intriguing questions:

- Why has Chrysler been twice as profitable as GM and Ford during the 1990s even though it is a much smaller company with plants that are less efficient than Ford's?
- Why does Toyota continue to have substantial productivity and quality advantages long after knowledge of the Toyota Production System has diffused to competitors?

The answer, according to Dyer, is that Toyota and Chrysler have been the first in their industry to ***recognize that the fundamental unit of competition has changed, from the individual firm to the extended enterprise*** (ibid).

Charles Fine (2005), the author of the best selling book "Clockspeed" writes: "*I have two heroes in the field of value (or supply) chain management: Michael Dell and Tom Stallkamp*". Thomas Stallkamp is the former President of Chrysler Corporation, and he pioneered the new strategies for collaboration outlined above. The achievements of Chrysler and Stallkamp will be further presented in chapter 2.3.5. Michael Dell, on the other hand, is the founder, Chairman of the Board and Chief Executive Officer of Dell, the second largest PC provider in the world (Dell, n.d.). Dell, with its virtual integration (i.e. stitching together a business with partners that are treated as if they're inside the company) and direct business model (i.e. sidestepping distributors, retailers, and stores, by selling customers built-to-order computers directly) is often quoted as best practice within supply chains (Monczka et al., 2005; Handfield and Nichols Jr., 2002; Magretta, 2001). At Dell, ***ICT is enabling coordination across company boundaries to achieve new levels of efficiency and productivity, as well as extraordinary returns to investors*** (Magretta, 1998).

Chapter 2 will elaborate on these two success stories, and focus on the Extended Enterprise and how ICT can enhance and improve such value chain collaboration.

2.2 Interaction – inter-enterprise relationships

As stated in chapter 1.4.1, *no business is an island* (Håkansson and Snehota, 1989; and Fine, 1998), and further, no company can play alone (Ronchi et al., 2006). It is in the nature of companies to interact with each others (e.g. other companies and/or end customers, etc). Interaction is a kind of action which occurs as two or more objects have an effect upon one another (Wikipedia, 2006). The interaction ranges from strictly buyer-seller relationships to more advanced, formalized and long-term collaborations between two or more companies.

Several authors have proposed various classifications of these different types of interactions, or inter-enterprise relationships (see among Williamson, 1975, Håkansson and Snehota, 1989, 1995; Lorange and Roos, 1992; Child and Faulker, 1998; Jagdev and Thoben, 2001b). It seems like most authors agree that the various types of inter-enterprise relationships range from market transactions to (vertical) integrated companies, see figure 13. Market transaction occurs between two parties and the nature of relationship participants is strictly transaction based (Jagdev and Thoben, op cit). Vertical integrated companies possess control over all processes and these are performed within the "four walls" of the company. In between these to extreme points, there are a vast amount of different types of relationships between companies, like various forms of partnerships, joint ventures, contractual agreements etc. All kinds of value chain interactions are situated in-between these two extreme points.

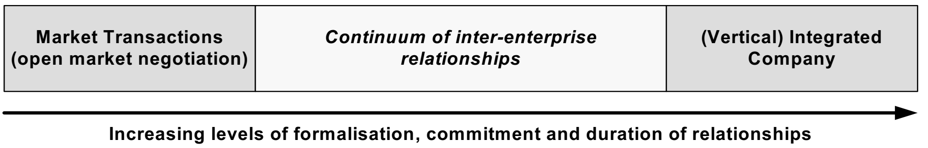


Figure 13 Inter-enterprise relationships

Adapted from Williamson (1975) and Jagdev and Thoben (2001)

2.2.1 Integration, cooperation, coordination and collaboration

When referring to inter-enterprise relationships, four words, terms and/or concepts are frequently used: ***Integration***, ***cooperation***, ***coordination***, and ***collaboration***. These words are often used partly interchangeably and in close connection to each other. It is therefore important to make some definitions and clarifications.

Table 6 defines and briefly discuss these four concepts. Table 6 is a summary of a extensive literature review of integration, cooperration, coordination and collaboration.

Key concept	**Definition**	**Discussion**
Integration	Romano (2003) defines integration a mechanism to support business processes across a supply network and is closely related with the effort to overcome intra- and inter-enterprise boundaries, with the aim to change from local optimization to system optimization.	There are several important characteristics of integration. Firstly, integration is about combining or joining smaller parts into a bigger system. Secondly, integration occurs both internal in companies and external between companies. Thirdly, integration is a process and/or mechanism for achieving coordination and collaboration. Fourthly, integration requires cooperation behaviour. Fifthly, integration is aiming to improve performance. When discussing integration in a value chain system setting, various authors seems to focus on three particular aspects of integration: 1) Type/form of integration, 2) the dimension of integration, and 3) different stages/levels of integration. These three aspects are interrelated, and highlight three important distinct aspects of integration.
Cooperation	Cooperation is interaction between at least two partners, where the partners (voluntarily) are jointly combining their tasks and resources aiming to achieving	According to Wakolbinger (2002) it is important to divide between cooperation according to: • The degree of formality. Formal cooperation are institutionalized and supported by contracts or other types of formal agreements. Informal cooperation takes place without any formal

Key concept	Definition	Discussion
	mutual outcomes exceeding each partner's individual possibilities.	agreement. • The relation between partners. Horizontal cooperation is cooperation among competitors in an industry (e.g. cartels). Vertical cooperation is cooperation between partners along the value chain (e.g. cooperation with customers and suppliers)
Coordination	Romano (2003) defines coordination as the pattern of decision-making, communication and interactions among supply chain network members, which help to plan, monitor, and align multiple flow associates with the exchanges of materials, components, services, information, money, resource, and ideas, supporting the key business processes across the supply network.	In literature and in practice, coordination and integration is often used interchangeable (Min, 2001; Mentzer, 2004; Wong and Boon-itt, 2006). Wong and Boon-itt (op cit) point out that coordination shares almost all the characteristics with integration, and Min (op cit) use the two terms/concepts interchangeable. If we compare Romano's definitions of integration and coordination, we seed that integration is about overcoming intra- and inter-enterprise boundaries, whereas coordination is more related to decision process and how to align and smoothened this process between different members of the supply chain.
Collaboration	Collaboration is diverse entities working together, sharing processes, technologies, and data to maximize value for the whole group and the customers they serve (Finley and Srikanth, 2005)	Collaboration is something more than cooperation and coordination. Collaboration is a higher state of interaction than both cooperation and coordination. Unlike coordination, collaboration seeks divergent insight and spontaneity, not structural harmony. And unlike cooperation, collaboration thrives on differences and requires the sparks of dissent (Denise, 1999).

Table 6 Key inter-enterprise relationships terms

2.2.2 A model for integration, cooperation, coordination, and collaboration

Numerous authors have discussed the relationships and difference between (all or some of the terms/concepts) integration, cooperation, coordination and collaboration; see among others Wong and Boon-iit (2006), Pollard (2005), Davis and Spekman (2004), Romano (2003), Alter (1999), Denise (1999), Spekman et al. (1998), and Tyndall et al. (1998). However, as already indicated in chapter 2.1.2 and illustrated in table 6, the relations between these terms/concepts are not always crystal clear. As an example Power (2005) and Akkermans et al. (1999) point out that cooperation and collaboration (among others) are the basis of integration, whereas others like Simatupang and Sridharan (2004), Handfield and Nichols Jr. (2002), Boyson et al. (1999), and Cooper et al. (1997a) claims that integration is a prerequisite for (coordination and) collaboration.

Alter (1999) views cooperation, coordination and collaboration in light of integration and propose a five level of integration model:

1. ***Common culture*** – shared understanding and beliefs.
2. ***Common standards*** – using consistent terminology and procedures to make business processes easier to maintain and interface.
3. ***Information sharing*** – access to each other's data by business processes that operate independently.

4. ***Coordination*** – negotiation and exchange of messages permitting separate but independent processes to respond to each other's needs and limitations.
5. ***Collaboration*** – such strong interdependence that the unique identity of separate processes begins to disappear.

The three first levels in this model can be viewed as increasing levels of cooperation.

Spekman et al. (1998), Tyndall et al. (1998) and Davis and Spekman (2004) propose another model, see figure 14. In this model, cooperation, coordination and collaboration are classified according to the level of intensity among the partners, and the level of compliance and commitment. In the original model (taken from the three quotations above) there is no reference to integration. However, in this thesis figure 14 is modified and the level of integration is included by the author. The rationale for doing this is that integration is indirectly implied in the text by the authors. In the model integration can be viewed as a mean for facilitating cooperation, coordination and collaboration. However, cooperation may also foster increased integration, which may lead to coordination, and so on. So it is fair to conclude that there is some sort of interplay between integration on one hand, and cooperation, coordination and collaboration on the other hand.

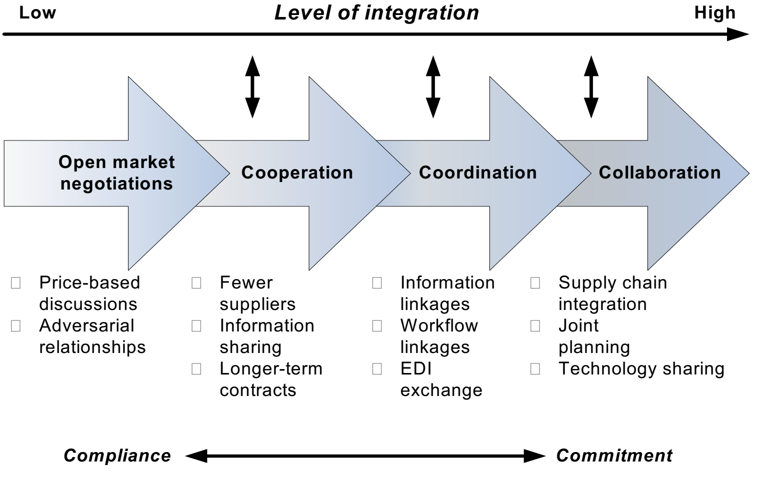


Figure 14 Model of integration, cooperation, coordination, and collaboration

Modified from Tyndall et al. (1998), Spekman et al. (1998), and Davis and Spekman (2004)

Up to this point integration, cooperation, coordination and collaboration have been discussed individually and the relationships between these concepts have been partly highlighted. The next sub-chapter will present some concepts/strategies/philosophies where integration, cooperation, coordination and collaboration are applied.

2.3 Value chain systems

In this thesis ***value chain systems*** will be used as a collective term for collaborative management concepts, strategies and/or philosophies. Other authors use terms like *Enterprise Networks* (Thoben and Jagdev, 2001), *Business Networks* (Håkansson and Snehota, 1995), *Industrial Networks* (Easton, 1992) and *Value Systems* (Porter, 1985) among others to collectively describe the same concepts.

Value chain systems is a collective term for all kind of interactions efforts between two or more companies (i.e. collaborative management concepts and philosophies), where the interaction is more than just open market negations. In this interaction, or inter-enterprise relationships, the four presented concepts of integration, cooperation, coordination and/or collaboration are key elements. The interaction between the companies can be both along the value chain (sequential), and/or at the same position in the value chain (parallel).

In this thesis the term value chain systems is chosen due to:

1. Its emphasise on the value chain, and how this indirectly refers to value creating activities between companies. The value chain is, as already mentioned in chapter 1.2.2 one of the backbones of this thesis, and it is therefore of importance to highlight this concept.
2. Its combination of chain and system, which implies that the focus is on systems of company value chains (i.e. networks), rather than on value chains internally in companies.
3. Its lack of formalism compared with the others similar terms mentions above, and the freedom that provides. For example by not using value system, but value chain systems, it is possible to distance the discussion from Porter’s theory on value systems, and just imply that there is a connection.

Value chain systems will not be discussed in detail. Value chain systems are just a collective term, or a heading, for other more important concepts. Four of the most frequently used concepts will be presented in more detail: *The value chain*, *the supply chain*, *the Extended Enterprise*, and *the virtual enterprise*.

2.3.1 The value chain

According to Kaplinsky (2000) the origin of the value chain can be traced back to several sources. The concept of the value chain was used in the 1960s and the 1970s by analysts charting a path of development for mineral-exporting economies (Grivan, 1987). It was also adopted in recent French planning literature in the form of filière[25] (Kaplinsky, op cit). But during the 1990s, value chain analysis has become widely used, particularly as a consequence of the writings of Michael Porter (ibid).

The concept of the value chain was introduced by Porter in the book *"Competitive Advantage, creating and sustaining superior performance"* in 1985. In this book Porter (1985) claims that every firm is a collection of activities that are performed to design, produce, market, deliver and support its product. All these activities can be represented using a value chain, and a firm's value chain and the way it performs individual activities are a reflection of its history, its strategy, its approach to implementing its strategy, and the underlying economics of the activities themselves (ibid).

According to Porter (op cit), a value chain is composed of value activities which can be classified as either primary or support activities, see figure 15. Primary activities are the activities involved in the physical creation of the product and its sale and transfer to the customer as well as after sales assistance. Support activities support the primary activities and each other by providing purchase inputs, technology, human resources and various firm-wide functions. Porter (op cit) has identified five distinct primary activities namely, inbound logistics, operations, outbound logistics, marketing and sales and service. He also identified

[25] Literally, the word filière means ”tread” (Kaplinsky, 2000).

four support activities namely, procurement, human resource management, technology development and firm infrastructure (ibid).

A firm's value chain is embedded in a larger stream of activities, called the value system (op cit), see figure 15. Suppliers have value chains (upstream value) that create and deliver the purchase inputs in a firm's chain. A firm's product eventually becomes part of its buyer's value chain. Gaining and sustaining competitive advantage depends on understanding not only a firm's value chain but also how the firm fits in the overall value system.

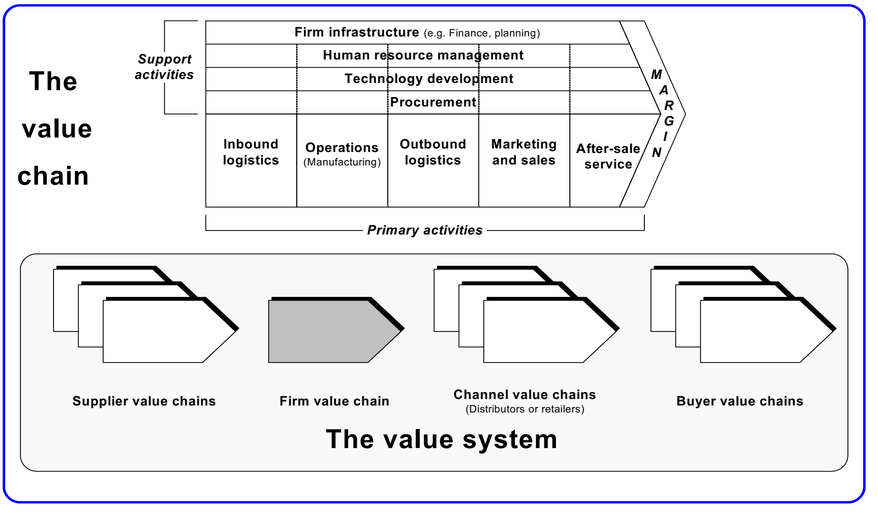


Figure 15 The value chain and value systems by Porter

Modified from Porter (1998)

In literature terms like *entire value chain*, *total value chain* and *end-to-end value chain* are used as description of a value system from point of origin to point of consumption. In this thesis a broader interpretation of Porter's value chain will be used: ***The value chain is a neutral description of a value system from point of origin to point of consumption and back (i.e. recycling)***. Figure 16 represent a very simplified version of the value chain, and will be used throughout the dissertation as the standard notation of a value chain.

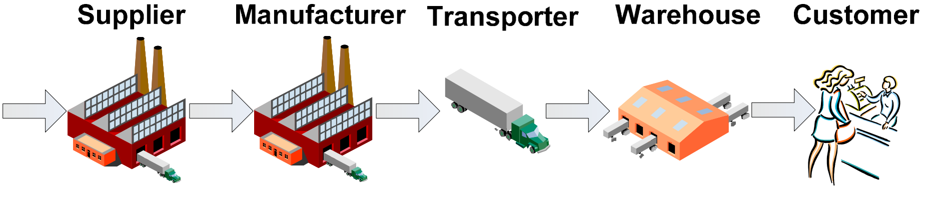


Figure 16 The value chain

It is important to realize that the value chain exist whether they are managed or not; the value chain concept is merely a descriptive construct. In other words, there is a definite distinction between value chains as a phenomenon that exist in business and the management of those value chains (Mentzer et al., 2001).

Normally the value chain is addressed from two different perspectives; product's value chain and a firm's value chain. *A product's value chain* is all those activities required for brining the product from point of origin to point of consumption and back. *A firm's value chain* is the sum of all its product's value chains, where the firm's activities are linked with all its suppliers and customers.

The value stream is a closely related concept to the value chain (Bocij et al., 2003; Kaplinsky, 2000). The concept of value stream became publicly known through Womack and Jones book "Lean Thinking" in 1996, and a value stream is all the actions (both value added and non-added) currently required to bring a product through the main flows essential to every product: 1) the production flow from raw material into the arms of the customer, and 2) the design flow from concept to launch (Rother and Shook, 1999). The difference between value chain and value stream is that it considers different types of tasks that are involved with adding value and looks at how the efficiency of the tasks can be improved (Bocij et al, op cit).

2.3.2 Value chain system concepts and philosophies

In literature and practice various perspectives of value chain systems exist. Table 7 briefly describes three management concepts and philosophies that all have the value chain as a basis, ***the supply chain***, ***the Extended Enterprise***, and ***the virtual enterprise***. These three management concepts and philosophies have different views of the value chain, and address different aspects of the value chain concepts.

Concept	Definition	Description
Supply chain (SC) and supply chain management (SCM)	A supply chain is a set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer (Mentzer el al., 2001).	By comparing these three degrees of supply chain complexity to the concept of the value chain, it is possible to conclude that the supply chain is a perspective of the value chain, which includes at least three entities and up to the entire value chain. In most cases the supply chain involves only a fraction of the parties involved in the value chain.
	Supply chain management is 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, 2005).	Some authors use the term supply network or demand chain instead of supply chain. However, the term supply chain will be used in this thesis due to its widespread use and dominate position.
Extended Enterprise (EE)	The Extended Enterprise is really about creating a defensible long-term competitive position through value chain integration, collaborative behaviors, and the deployment of enabling information technology (Davis and Spekman, 2004).	This may serve as a preliminary definition of the Extended Enterprise, until a more extended version is presented in chapter 2.4.2: Enterprises across the whole value chain, from raw materials to end-customer, can be involved in the Extended Enterprise. However, the concept of a whole value chain is neither necessary nor a relevant condition to the formation of Extended Enterprises. An Extended Enterprise can be developed between any two or more enterprises across the value chain of any product or service.
Virtual enterprise (VE)	Virtual enterprises are a temporary coalition of enterprises that come together to share skills to address business opportunities that they	In a virtual enterprise, specialist firms perform critical processes, not because they are unimportant, but rather because they are so important that the original company can not afford to have them handled in a mediocre way

Concept	Definition	Description
	could not undertake individually (Huang et al., 2002; Jagdev and Browne, 1998; Rolstadås, 1998).	(Hammer, 2000). As with the supply chains and the Extended Enterprises, Virtual enterprises often involve only a fraction of the entire value chain.

Table 7 Value chain system concepts and philosophies

Table 7 is a result of a more extensive literature review; see chapter 2.4-2.6 for the Extended Enterprise.

2.3.3 Same content, new wrapping?

A justified question to ask when addressing supply chains, the Extended Enterprises, and virtual enterprises, is: *Are these three concepts basically shades over the same basic concept, just with different names?* Not too many authors have addressed this issue and most authors use these three concepts partly interchangeables and without any clarification of the difference between them. By reading some literature, it may occur as just a question of semantics. However, these three concepts, although not necessarily synonymous, represent related concepts. Camarinha-Matos et al. (1998) and Pires et al. (2001) point out that these concepts have their peculiarities, but they also have some similarities. Perhaps the most comprehensive attempt to clarify the difference between these three related concepts is the work of Jagdev and Thoben (2001).

According to Jagdev and Thoben (op cit) there can be an almost infinite number of possibilities by which companies can collaborate and form value chain systems, and the space between market transaction and hierarchical relationships (i.e. vertical integrated company) (see figure 13) cannot be discretized into some clearly defined and distinct compartments of supply chain, Extended Enterprise and virtual enterprise. They further points out that (ibid): "*While the concept of supply chain has been well established, it is the emergence of IT (Information Technology that deals with the sharing or exchange of information between two parties) and CT (Communication Technology that focus on the tools required for the actual transfer of information between any two parties) that has expedited the nature and scope of collaboration to new and higher levels. Formation of Extended Enterprise and virtual enterprise are such recent developments. Therefore, Extended and virtual Enterprises are merely new paradigms reflecting the extent to which the information systems of the collaborating enterprises are integrated with one another and the way they actually communicate and collaborate with one another. In other words, extended and virtual enterprises are different (more sophisticated!) manifestations of the supply chains. Hence, most of the underlying principles and operational issues prevalent in a supply chain will be present in extended and virtual enterprises. Indeed, the supply chain between the collaborating enterprises has to be set-up before the "switch" to extended or virtual mode.*" This last statement is supported by both Matinez et al. (2001) and Camarinha-Matos et al. (1998) who stress that virtual and extended enterprises are evolution oriented by nature; where the Extended Enterprise is characterizes by one dominate company establishing long-term collaboration with its closest suppliers and customers, while the virtual enterprise is characterized by a more democratic structure in a dynamic and short-term environment.

Figure 17 illustrates the relationships between supply chain, extended enterprise and virtual enterprise concepts, and the diffuse boundaries between these concepts. It is not possible to define a single criterion or demarcation when the collaboration evolves from SC type of relationships to EE or from EE to VR (ibid).

To conclude this discussion of the similarities and differences of supply chain, Extended Enterprise and virtual enterprise, the author would also like to point out that there is one distinct difference between these three concepts not yet mentioned. All three concepts have different origin. As already mentioned SC has its origin in logistics and operation management, and is in many respects seen as a natural extension of logistics into the value chain. The Extended Enterprise has its roots in the Computer Integrated Manufacturing (CIM) tradition and Lean Production field, while virtual enterprise is often very closed associated with the growth of Agile Manufacturing.

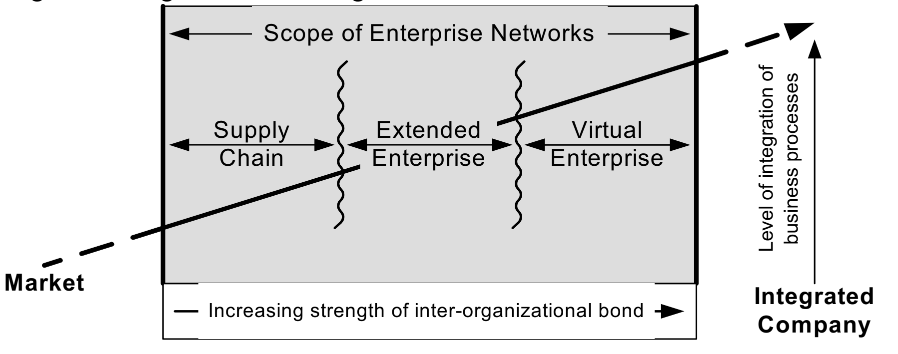


Figure 17 Types of collaboration within value chain systems

Source: Jagdev and Thoben (2001)

The remaining part of this chapter and thesis will focus only on the Extended Enterprise type of collaboration. *However, the idea, methods, tools and techniques from both supply chain and virtual enterprise will be used in the further discussion of the Extended Enterprise.*

2.4 The Extended Enterprise

Business success is now largely determined by conditions outside the four walls of any one company (Walker, 2005). Because of the accelerating rate of change and the incredible demands on time, many business executives and practitioners simply do not understand these new networks. The reality is that practitioners must learn how to design and operate a competitive, value-adding network that beats the competition in getting to the customer (ibid). The Extended Enterprise is such a value-adding network.

The Extended Enterprise is a term frequently used in today's business literature to reflect the high level of interdependence that exists between organizations as they conduct business, not only in the manufacturing industry, but also in other business areas (Browne and Zhang, 1999).

2.4.1 The history of the Extended Enterprise

The notion of an Extended Enterprise is as old as business itself (Applegate et al., 2004). Businesses have always formed partnerships and alliances to extend their business opportunities and increase their chances of success (ibid). The emergence of the concept in the 1990s is not so much the birth of a new idea, but an increase in the readiness of companies to look outside their own boundaries for sources of competitive advantage (Childe, 1998).

By looking back in time to investigate the roots of the term Extended Enterprise, 2-3 parallel courses appears (see chapter 2.3.4 for more information). Davis and Spekman (2004) highlight Tomas Stallkamp at Chrysler as the source of the term/concept[26] (see chapter 2.4.5 for more information regarding the Extended Enterprise at Chrysler). Similar do Post et al. (2002) claim that the Extended Enterprise term appears to have originated at Chrysler. Whereas Boyson et al. (1999) track the genesis of the Extended Enterprise to the early 1980s, when Japanese automobile makers engineered a lean and just-in-time manufacturing paradigm. Analogous are there several references to the Extended Enterprise in literature[27] (books, scientific articles, etc) from mid 1980s and early 1990s. However, the first scientific references with the Extended Enterprise in the title were Busby and Fan (1993) and Konsynski (1993).

Busby and Fan (op cit) relate the Extended Enterprise to: "*manufacturing firm which combine their activities for periods that greatly exceed the lead-times associated with specific transactions. This persistence means that they can build channels between themselves through which information and knowledge can pass – information and knowledge that extend far beyond the traditional exchange of specifications, drawings and contracts. The result is a combination, or network, of firms that can act rapidly and effectively in concert to introduce new products and find better ways of delivering them.*" Konsynski (op cit) on the other hand had an ICT focus and studied how ICT could change the limits of what is possible in the leveraging of strategic control through transformation (i.e. extending the enterprise) of boundaries, relations, and markets. The slightly different focus (i.e. main focus on manufacturing or ICT) of these publications has persisted, and can be found in today's literature as well (see chapter 2.4.4).

The publications by Busby and Fan (op cit) and Konsynski (op cit) were followed by an increasing number of publications the following years; among others O'Neill and Sackett (1994), Browne et al. (1995), Childe (1998), Davis and O'Sullivan (1998), Jagdev and Browne (1998), and Browne and Zhang (1999). Two leading journals, paving the way for the expansion of the Extended Enterprise, were Production Planning and Control and Computers in Industry. Since 1999/2000 there has been an explosion of publications on the topic. There has even been some books published about the Extended Enterprise (see chapter 1.4.3).

A similar trend can be found by studying research projects about the Extended Enterprise. According to Cordis[28] 5 EU-projects contained the term Extended Enterprise in the title in 1995-1999, whereas there have been/are 13 EU project with the Extended Enterprise in the title from 2000 to 2008.

2.4.2 Defining the Extended Enterprise

According to Harrison and Koulikoff-Souviron (2007) the Extended Enterprise is in need of clearer construct development. This is among others reflected in lack of a common definition of the Extended Enterprise concept and the disparity in the use of the concept.

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[26] They indicate no time for this, but form the texts and other sources it seems to be at the end of the 1980s or early 1990s. According to the Economist Intelligence Unit (2002) it was in the early 1990s.

[27] The PRODNET II webpage (PRODNET II, n.d.) contains a bibliography of books, journals and papers referencing to the Extended Enterprise. According to this bibliography is the book Modelling and Design of Flexible Manufacturing Systems by Andrew Kusiak (1986) the first reference to the Extended Enterprise. Close followed by Satori (1988), and later Rehg (1994), Bowersox and Closs (1996), Browne et al. (1996), Dobler and Burt (1996) and Ross (1996).

[28] An advanced search on cordis.europa.eu

As indicated earlier in this thesis, there are many different traditions, definitions and interpretations of the term Extended Enterprise. Very simply can the Extended Enterprise can be regarded as *a kind of 'Enterprise' which is represented by the key value chain actors engaged collaboratively in the design, development, production and delivery of a product to the end user* (Browne and Zhang, 1999; Browne et al, 1996).

Jagdev and Browne (1998) define the Extended Enterprise as *the formation of closer coordination in the design, development, costing and the coordination of the respective manufacturing schedules of cooperating independent manufacturing enterprises and related suppliers*. The keyword in this definition is the *coordination of respective manufacturing schedules*. The coordination of respective schedules (which includes not only the production schedules, but also the dispatch, transport/delivery and receipt notifications) is supposed to be performed seamless through the use of ICT technologies (Jagdev and Thoben, 2001). Only then can one truly realize the integration of respective IT infrastructures, which is a necessary condition for the formation of Extended Enterprise (Jagdev et al, 2004).

Childe (1998) concludes that *the Extended Enterprise consist of a principal (focal) company and its suppliers, but it, and do not necessary include all companies in the value chain, rather a group of companies within the value chain*. Dyer (2000) supports this view, and defines *the Extended Enterprise as a value chain in which the key players have created a set of collaboration processes that allow them to achieve virtual integration and work together as an integrated term*.

The MOMENT Project[29] aligns with all these authors and defines the Extended Enterprise as *a set of manufacturing enterprises and related suppliers that collaborate to design, engineer, manufacture, and distribute products and services to a customer*. Enterprises across the whole value chain, from raw materials to end-customer, can be involved in the Extended Enterprise. However, the concept of a whole value chain is neither necessary nor a relevant condition to the formation of Extended Enterprises. An Extended Enterprise can be developed between any two or more enterprises across the value chain of any product or service.

Other relevant and important definitions and interpretations are:

- The Extended Enterprise is a collection of legal entities ($N \geq 2$, where N is the number of legal entities) that pursue repeated emphasize, enduring exchange relations with one another (Goethals et al., 2008).
- The (Chrysler) Extended Enterprise system is a goal-driven process that unifies and extends the business relationships of suppliers and supplier tiers in order to reduce cycle time, minimize systems cost, and achieve perfect quality (Ayers, 2006).
- The Extended Enterprise is a knowledge-based organization which uses the distributed capabilities, competencies and intellectual strengths of its members to gain competitive advantage to maximize the performance of the overall Extended Enterprise (Bititci et al., 2005).
- The idea of the Extended Enterprise is to have an increasingly "boundaryless" business; meaning that internal functional barriers are being eroded in favour of horizontal process management and externally the separation between vendors, distributors, customers is increasingly lessening (Christopher, 2005).

[29] Taken from Deliverable D3.1 of the MOMENT project (restricted access).

- Extended Enterprises is a kind of organization comprised of interconnected enterprises (Hongzhao et al., 2005).
- The Extended Enterprise is really about creating a defensible long-term competitive position through strong value chain integration, collaborative behaviours, and the deployment of enabling ICT (Davis and Spekman, 2004).
- The Extended Enterprise is the organization and its network of business critical alliances (Deloitte, 2004).
- The Extended Enterprise is a set of enterprises with processes that are jointly involved in the manufacturing of a product. The Extended Enterprise perspective emphasises that manufacturing systems are no longer confined to a single factory, but cross enterprise boundaries (Bolseth et al., 2003).
- The Extended Enterprise is a form of enterprise that integrates suppliers, manufacturers, and customers in a supply chain through the effective use of ICT in order to improve information flow and communication between partners with the ultimate goal of satisfying customers' needs in terms of speed and information accuracy (Weston, 2003, in Loh et al., 2006).
- The Extended Enterprise is an enterprise that has located business-critical operations outside its direct control through outsourcing, alliances, licensing or other arrangements (Economist Intelligence Unit, 2002).
- The Extended Enterprise may be characterized as the nodal element within a network of interrelated stakeholders that create, sustain, and enhance its value-creating capacity (Post et al., 2002).
- The Extended Enterprise is a collection of firms that have an obligation to produce an output (Boardman and Clegg, 2001).
- Extended Enterprises span company boundaries and include relationships between a company, its partners, customers, suppliers and market (Martinez et al., 2001).
- An Extended Enterprise is the set of firms within a value chain or production network that collaborate to produce a finished product (Dyer, 2000). A firm selling to an end market is essentially the culmination of a production network or value chain (ibid).
- The term Extended Enterprise refers to breaking down a company's outer wall and extending its strategy, structure, and processes to its core partners (Boyson et al., 1999).
- The Extended Enterprise is a group of strategically aligned companies focused on specific market opportunities (Greis and Kasarda, 1997).
- The Extended Enterprise is a manufacturing paradigm where suppliers and manufacturers are forced to work in a tightly coupled mode (Vernadat, 1996).

From the approximately twenty definitions presented above (both in the bullets list and in the text), the following conclusion can be made:

1. The Extended Enterprise ***is about extending the boundaries of the enterprise*** and, and thus include and integrate operations ***outside the four walls of the enterprise***.
2. The Extended Enterprise is ***a perspective of the value chain***, and some authors even call it a ***value chain paradigm*** and/or ***manifestation of the value chain*** (Jagdev and Thoben, 2001).
3. However, the concept of a whole value chain is neither necessary nor a relevant condition to the formation of Extended Enterprises. An Extended Enterprise can be developed between any ***two or more enterprises*** across the value chain of any product or service.

4. The Extended Enterprise is often described as ***a network of enterprises***; a network between enterprises along the value chain (sequential), and/or at the same position in the value chain (parallel).
5. ***Collaboration*** is essential in the Extended Enterprise. It is important for a firm to directly plan and manage not only costs, but also **relationships** between companies (Stallkamp, 2005). Treating companies as informed partners jointly working on projects, with assigned and measured targets, creates a ***working atmosphere*** that brings companies closer instead of keeping them separated (ibid).
6. The focus in the Extended Enterprise is to ***create competitive value*** for customers. The value creation process begins with the customers, and they drive the process (Davis and Spekman, 2004). Products are combined with services into extended products or extended value propositions. Further, speed to market is accelerated, costs are lowered, and new market opportunities are more easily accessed (Davis and Spekman, op cit).
7. The Extended Enterprise is characterizes by ***long term and strategic thinking***. The member enterprises strategically combine their core competences and capabilities to create a unique competence (Bititci et al., 2005). As long as cost, quality, delivery, and technology targets are met, the business relationships would be preserved and not resourced (Stallkamp, op cit).
8. The Extended Enterprise is ***ICT enabled and supported***, though not a sufficient condition for an Extended Enterprise to exist (Jagdev et al., 2004). The flows of information that lie at the core of the coordination and collaboration among nework members not only link disparate ICT systems, they also provide an opportunity to build knowledge-based tools (Davis and Spekman, op cit).
9. The ***system perspective*** is essential in the Extended Enterprise, where the value chain processes are interdependent and a particular action taken by one member often affects both the operational and commercial performance of the other value chain members (Simatupang and Sridharan, 2005). The goal is to achieve system-wide synergies such that 1+1=3 and nothing less than 2, as is often the case (Davis and Spekman, op cit).
10. The Extended Enterprise has an emphasis on ***process integration***, enabling jointly processes across the value chain. Generally are value chain processes fragmented, thus contributing to various waste along the value chain that lead to unnecessarily high operating costs and considerable unnecessary cost of supply-demand mismatch, which lead to poor profitability (Simatupang and Sridharan, op cit).
11. The Extended Enterprise is often described as ***manufacturing centric networks***, but this is not a necessity.
12. ***Trust is necessary*** for enterprises to work together in the Extended Enterprise issues. Trust manifest itself in the integrity of information shared, in the belief that partners will do as they say, and the willingness to share risk and reward equitably in pursuit of common goals and interests (Davis and Spekman, op cit).
13. The Extended Enterprise is ***something different and more than supply chain management***. It represents a completely different way to work, with outside partners in a collaborative fashion (Stallkamp, op cit). It is the seamless exchange of relevant operational information on top of an existing long term (and successful) relationship that distinguishes the Extended Enterprise from other forms of long-term collaboration such as a supply chain relationship (Jagdev et al., op cit).
14. The Extended Enterprise is often described as born of necessity or as ***a response to business drivers*** such as globalization, cost focus, time focus, outsourcing, quality, need for customization, etc.

Based on these observations, the following definition of the Extended Enterprise will be used in this thesis: ***The Extended Enterprise is a long-term, strategic, and ICT enabled network collaboration between at least two value chain partners (manufacturers, suppliers, transporters, warehouses, etc) which seeks to integrate their operations to secure a superior value creation process (products and/or services) for its customers and a sustainable competitive position for its members***.

In this thesis the Extended Enterprise will be centred on a focal manufacturing company, which extends its operations with its key partners in the value chain. Thus, figure 18 will be used as an illustration of the Extended Enterprise throughout the thesis. The focal manufacturing company is in the centre of the figure, and the illustration highlights the network as well as the value chain partner perspectives of the definition above. However, aspects such as integration, operations, collaboration, value creation process, and ICT are missing (or only indirectly indicated) in the model of the Extended Enterprise.

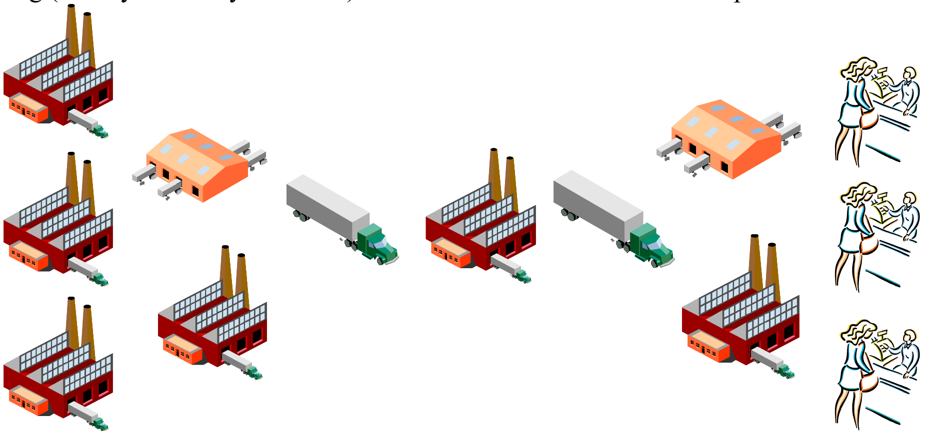


Figure 18 The Extended Enterprise

Surprisingly, few have tried to develop a more comprehensive, high-level model of the Extended Enterprise, thus incorporating some of the missing elements of figure 18. Chrysler had an Extended Enterprise system in operation in the 1990s, but this was never conceptualized into a well-known model. However, Ayers (2006) presents a model of the Extended Enterprise at Chrysler (see figure 22). Other attempts are by Browne et al. (1995) and Browne and Zhang (1999):

- Browne et al. (1995) present what we can call a layer model of the Extended Enterprise, see figure 19. Figure 19 describes the Extended Enterprise in a manufacturing-centred manner; i.e. how a manufacturing system extends its boundary to encompass its suppliers, customers and also other business partners (Browne and Zhang, 1999).
- Browne and Zhang (1999) present a product life cycle and value chain based Extended Enterprise model, see figure 55. This model identifies five top level or major business processes across the value chain, see chapter 4.4.8 for more information.

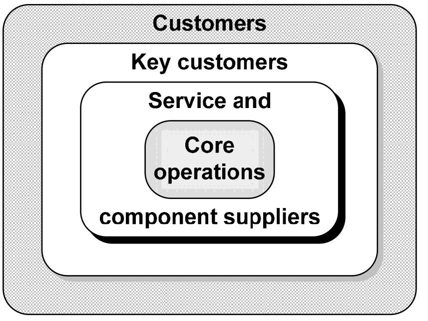


Figure 19 A layer model of the Extended Enterprise

Source: Browne et al. (1995)

Of the three models presented, the only one with some recognition is the value chain based Extended Enterprise model. But in all fairness it is correct to conclude that none of these models have been accepted as the standard description of the Extended Enterprise. Thus there is a need for developing generic Extended Enterprise models, describing the Extended Enterprise concept.

2.4.3 Characteristics of the Extended Enterprise

The baseline for an extended enterprise is always two or more willing enterprises which have chosen to concentrate on their core-competencies and wish to extend their activities into other enterprises to increase their competitiveness by achieving cost-, time- or quality-related advantages regarding their respective offerings (Jagdev and Thoben, 2001).

The essence of the Extended Enterprise can be captured in the three Cs – connectivity, community and collaboration – that serve to show the true distinctions between ordinary supply chain thinking and the system-wide view that is required by the Extended Enterprise (Davis and Spekman, 2004):

- ***Connectivity*** – illustrates the extent to which members of the Extended Enterprise are linked and the nature of the bonds that unite them for a common purpose.
- ***Community*** – the Extended Enterprise is truly a community of interest where firms with a set of compatible goals and objectives willingly work together to achieve a common vision or set of objectives. Similar to a community, there must be a set of norms, expectations, and shared values that establish how firms interact and what roles value chain members play and that define the boundaries for what is considered acceptable behaviour.
- ***Collaboration*** – at the heart of the Extended Enterprise is a set of principles, processes and structures that foster collaboration among the value chain members. Collaboration occurs when firms share compatible goals and work jointly to achieve results that each could not achieve easily alone.

Further, by examining the literature on the Extended Enterprise the following ***key characteristics of the Extended Enterprise*** can be identified (see figure 20):

- ***Strategic alignment*** – successful value chain collaboration requires strategic alignment, where business goals and objectives need to be consistent across the Extended Enterprise (Finley and Srikanth, 2005). When strategies are aligned, each member recognizes that a benefit or advantage to the other participants is also a benefit or advantage (albeit indirect) to itself (ibid). Further, it can help avoid the adversarial and competitive nature of relationships that typically characterize market transactions (Greis and Kasarda, 1997).

- ***Long-term collaboration*** – the Extended Enterprise concept relies on the assumption that the business relationship would continue over time (Stallkamp, 2005), where the partners in the Extended Enterprises are willing to form long-term relationships and treat each other as business partners. Each partner understands and accepts the other's requirements and priorities (Jagdev and Thoben, op cit). The partners in the Extended Enterprise combine their core competencies and capabilities to create a unique competency (Bititchi et al, 2005).
- ***New markets*** – in the Extended Enterprise, firms act rapidly and efficiently in concert to introduce new products and deliver them to customers (Greis and Kasarda, op cit). As market opportunities change, the Extended Enterprise can be reconfigured to assemble the right complement of resources more quickly than a single company can acquire or develop those resources internally. This is especially important as the complexity of the products increase, and thus requires a much broader range of resources, skills and technologies to produce than most organizations can support (ibid). And last, but not least, the Extended Enterprise needs to create value, or there is no purpose in either creating them of keeping them alive (IT Governance Institute, 2005).
- ***Information sharing*** - the efficiency of the Extended Enterprise is greatly determined by the speed and efficiency with which information can be exchanged and managed among business partners (Jagdev and Thoben, op cit). This information sharing in a mutual manner fosters interdependence and facilitates better responses to change in the business environment (Stallkamp, op cit). The communication between the individual ICT systems in the Extended Enterprise should be real-time and on-line, and without human intervention (ibid). The quality of the information is important as well, and the level of trust among the members of the Extended Enterprise drives the quality of information (Davis and Spekman, 2004).
- ***Process integration*** – the Extended Enterprise has a holistic value chain orientation, culture and practice that allow them to see the entire value chain as one cross-functional integrated process (Boyson et al., 1999). Their constant priority is to eliminate handoff times and process disconnects across the value chain (ibid).
- ***ICT*** – it is important to have advanced ICT systems and tools to support the Extended Enterprise (Jagdev and Thoben, op cit). The goal is to get everyone in the Extended Enterprise onto a common platform of ICT systems for greater inter-organizational "seamleesness" (Boyson et al., op cit), thus enabling a free and honest flow of information to all partners in the Extended Enterprise (Davis and Spekman, op cit). The emergence of the Internet has given companies even greater tools for tightly orchestrating relationships across the entire value chain and creating strategic partnership and operational linkages with a dynamic web of large and small firms spanning all continents (Boyson et al., op cit).
- ***Jointly decision-making*** – in the Extended Enterprise people across a number of organizations participate in the decisions-making process (Bititchi et al., op cit). Each member of the Extended Enterprise is valued, given voice, and taken into consideration when short- and long-term plans are developed (Davis and Spekman, op cit).
- ***Planning and control*** - the operations of the Extended Enterprise need to be carefully coordinated and synchronized as it is a process within a single enterprise. The use of appropriate planning and coordination systems and tools, supporting communication facilities, that will enable the team members to share information and to synchronize

the activities, are also critical prerequisites (Bititchi et al., op cit; O'Neill and Sackett, 1994). The greater synchronization of production, distribution, and customer order management activities often brings dramatic gains (Boyson et al., op cit). Work in process and finished goods inventory are slashed, order-to-delivery cycle times are compressed, and best-in-class Extended Enterprise can have a 50 percent cost advantage over median competitors (ibid).

- ***Performance measurement*** – performance measurement and management is one of the imperatives for successful value chain collaboration (Finley and Srikanth, op cit). This is supported by Stallkamp (op cit) who stresses that measurement and tracking systems are of importance to show sceptics that collaboration is actually working and producing results in the Extended Enterprise. Without cross-process, cross-organizational metrics, each company will continue to maximize the achievement of its own objectives; potentially at the expense of the system's overall performance (ibid). At a minimum, collaboration requires each participant to be able to translate its own concerns into terms relevant to the other participants. By developing a common, channel-wide "dashboard" of performance measures, collaborators can, for the first time, view how their own performance affects the overall system's performance (ibid). Ideally, performance measures for the Extended Enterprise should push every firm in the value chain and all employees in every firm to focus their efforts on increasing the total profits for all chain members as this value chain competes with other value chains for the hearts and minds of end-use customers (Davis and Spekman, op cit).
- ***Event and exception management*** – will enable tracking events/exceptions over time and identify and correct bottlenecks in the Extended Enterprise. The goal is to provide visibility from suppliers to customers on a global basis (Davis and Spekman, op cit). Event and exception management tools will monitor the critical stages of value chain processes and issue alerts when deviations from required performance occurs (Christopher, 2005). The importance of event and exception management tools increases as value chain complexity and risks rises.

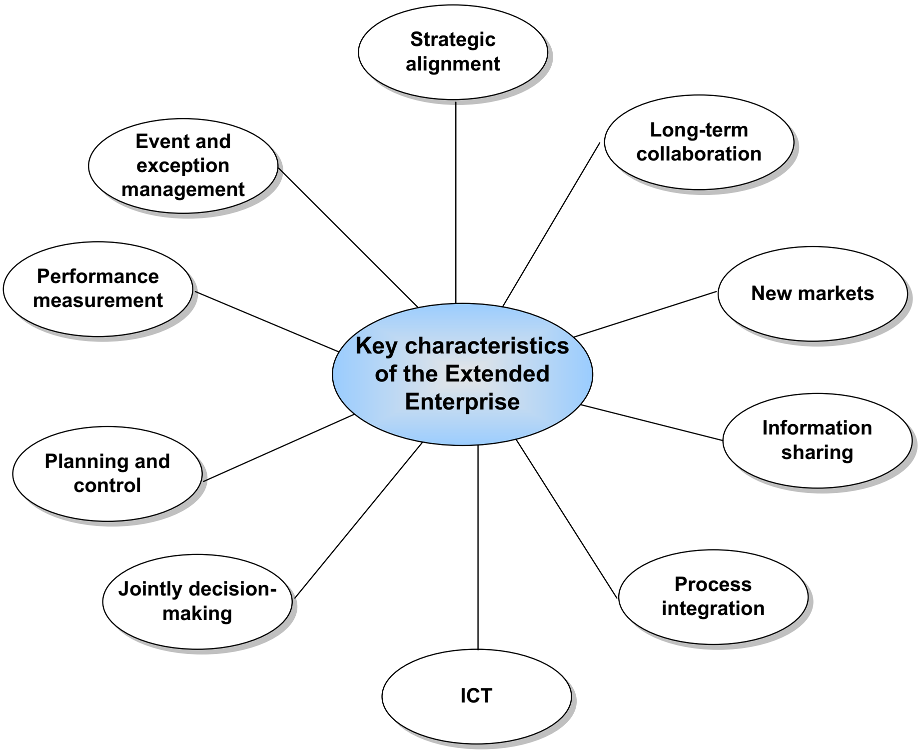


Figure 20 Key characteristics of the Extended Enterprise

Inspired by: Jagdev et al. (2004)

These key characteristics of the Extended Enterprise, together with the definition and the associated discussion, constitute a clarification of the Extended Enterprise concepts and its purpose and objectives. In some sense the discussion complement the presentation of research domain (1.3), research rationale (1.4.1), research problems (1.4.3) and research objectives (1.4.4). Further, many of the issues highlighted in the discussion will be essential throughout the remaining chapter, particular in chapter 5 and 6 (Part III Synthesis and results).

2.3.4 Different traditions with the Extended Enterprise

According to Goethals et al. (2008) there are two different conceptualizations of the Extended Enterprise in literature:

- The Extended Enterprise ***as a collection of different enterprises***, see figure 21a.
- The Extended Enterprise ***as an enterprise reaching out to its suppliers, customers, and partners***, see figure 21b

Figure 21 illustrates these two different conceptualizations. The discussion so far of the Extended Enterprise has included both of these conceptualizations. However, the focus in this thesis will be on the latter approach, where a focal manufacturing company establishes close collaborations with its key value chain partners.

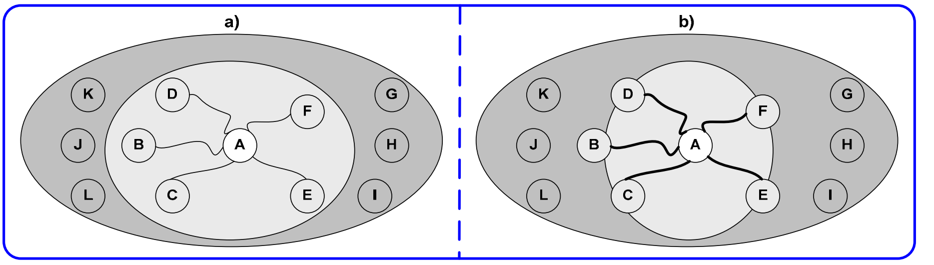


Figure 21 Two different interpretations of the Extended Enterprise

Soruce: Goethals et al. (2008)

Similar do Szegheo (2000) claims that many different Extended Enterprise concepts exist in literature, as well in practice. Furthermore these different concepts do not acknowledge each other, but each claim to be the Extended Enterprise. She distinguishes between three main Extended Enterprise models (ibid):

- ***The Extended Enterprise is an extension and synthesis of other concepts*** (model 1). Approaches such as JIT, SCM, value chain management, networking, customer driven manufacturing, focused factory, lean production, world class manufacturing, agile manufacturing, ICT and project partnering synthesized to model 1 of the Extended Enterprise.
- ***The Extended Enterprise is an integrated value chain*** (model 2). According to model 2 of the Extended Enterprise, the Extended Enterprise is not something new, a revolutionary business concept, but rather an ICT enabled reconfiguration of the value chain. The Extended Enterprise is distinct from traditional value chain relationships due to the amount of information exchanged (Fan, 1997) and due to the nature of the relationship between the partners. There is a closer collaboration maintained in the Extended Enterprise than in traditional value chains (Szegheo, 1999a and 1999b; Busby et al., 1993; Christopher, 1997).
- ***The Extended Enterprise is an enterprise that extends its traditional borders*** (model 3). This model can be further split into:
  - ***An extended Enterprise model defined by ICT specialists*** (model 3A), where the Extended Enterprise is an enterprise which extend the use of ICT to facilitate learning about its environment, to work closely with some of its partners or to be present of different kinds of electronic market (Block et al., 1995)
  - ***An Extended Enterprise model defined by researchers having focus in manufacturing*** (model 3B), where a manufacturing enterprise that extends its internal functional borders and establishes close collaborations with its partners.

According to Szegheo (op cit) model 1 and 2 are similar in the sense that both describe the Extended Enterprise as a partnerships between manufacturing enterprises, suppliers and customers, and this is in significant difference to model 3. In this sense model 1 and 2 by Szegheo (op cit) are in line with the first conceptualization of Goethals et al. (op cit), whereas model 3 is similar to the latter model by Goethals et al. (op cit).

Today most literature on the ***Extended Enterprise have basis in manufacturing*** (and partial logistics), e.g. Stallkamp (2005), Davis and Spekman (2004), Jagdev et al., (2004), Jagdev and Thoben (2001), Dyer (2000), and Boyson et al. (1999). Within this manufacturing view of the Extended Enterprise there are ***two dominating schools***:

- One tradition that ***originate from the Computer Integrated Manufacturing*** (CIM) paradigm. It is an extension of the CIM paradigm and concerns inter-enterprise integration (Vernadat, 1996).
- Another tradition that is ***inspired by the Japanese Keiretsu approach***, which is basically the Chrysler Extended Enterprise case

Both traditions include elements from other concepts (what Szegheo (2000) called extension and synthesis of other concepts), such as ICT, lean production, process integration, performance measurement, quality management, etc.

Some literature with basis in ICT exists as well (e.g. IT Governance Institute (2005), but this is dominated by white papers and pamphlet from ICT vendors and/or consultants. Furthermore, the ICT view of the Extended Enterprise is less formalized and has a much more narrow scope, than the manufacturing view of the Extended Enterprise.

And finally, the divide between true partnership (see figure 21a) and a focal company perspective on collaboration (see figure 21b) exists as well. The latter approach, where one powerful company integrates its key value chain partners dominates. This probably stems from the fact that true and honest collaboration is rare and difficult to achieve. Airbus is frequently used to describe an Extended Enterprise based on collaboration between even partners, see among other Davis and Spekman (2004).

However, regardless of traditions, conceptualizations, origins, interpretations, and/or views they all share the same objective with the Extended Enterprise concept: ***Through collaboration enable profitable and competitive operations, and thus reach customers/markets opportunities, which by themselve have been impossible or very difficult.***

2.4.5 The Extended Enterprise of Chrysler

The example of the Chrysler Extended Enterprise and its success is one that has been used in numerous books, articles and case studies over the past few years (Stallkamp, 2005).

At the end of the 1980s Chrysler was on the ropes, ending the decade with a fourth-quarter loss of $664 million (Taylor, 2004). As part of an effort to improve its competitiveness, Chrysler conducted an extensive benchmarking study of product development and manufacturing at Honda Motor Company, which was expanding its manufacturing and sales presence in the United States faster than either Toyota Motor Corporation or Nissan Motor Company (Dyer, 1996). A key feature in this benchmarking study was supplier relations. Through a combination of inspiration from the benchmarking study and various initiatives, events and decision at Chrysler, they managed to transform Chrysler into one of the most successful automotive companies within just a few years. The results have been astounding (ibid):

- The time Chrysler needs to develop a new vehicle is approaching 160 weeks, down from an average of 234 weeks during the 1980s.
- The cost of developing a new vehicle has plunged an estimated 20% to 40% during the last decade to less than $1 billion for the Cirrus/Stratus.
- At the same time, Chrysler has managed to produce one consumer hit after another (including the neon, the Dodge Ram, the Cirrus/Stratus, and the new minivan (sold as the Town&Country, Dodge Caravan, and Plymouth Voyager)).

- o As a result, Chrysler's profit per vehicle has jumped from an average of $250 in the 1980s to a record (for all U.S. automakers) of $2110 in 1994.

By benchmarking competitors, listening to suppliers, and experimenting with ideas and programs, Chrysler gradually developed a vision of the changes that they needed to make. They came to realize that those changes required transforming both the process of choosing and working with suppliers and the personal relationships between Chrysler's staff and its suppliers (ibid). Key elements in this transformation were (ibid):

- o Developing cross-functional teams internal at Chrysler and with its suppliers.
- o Pre-sourcing and target costing. This means choosing suppliers early in the vehicle's concept-development stage and giving them significant, if not total, responsibility for designing a given component and system. And at the same time they introduced target costing, which involves determining what price the market, or end customer, will pay for the vehicle and then working backward to calculate the allowable costs for systems, subsystems, and components.
- o Total value chain improvement – the SCORE program. The basic purpose of SCORE is to help suppliers and Chrysler reduce system wide costs, without hurting suppliers' profit.
- o Enhanced communication and coordination. To coordinate communication with and across suppliers more effectively, Chrysler has imitated the Japanese practice of employing resident engineers; suppliers' engineers who work side by side with Chrysler's employees.
- o Long-term commitments. To earn suppliers' trust and to encourage them to invest in dedicated assets, Chrysler is giving a growing number of suppliers increasingly longer commitments.

Through these efforts Chrysler was able to develop an "American Keiretsu" or an Extended Enterprise. Partnerships with suppliers have helped Chrysler improve performance significantly (as illustrated above) by speeding up product development, lowering development costs, and reducing procurement costs, thereby contributing to increases in Chrysler's market share and profitability (Dyer, 1996).

Ayers (2006) model of the Chrysler Extended Enterprise is illustrated in figure 22.

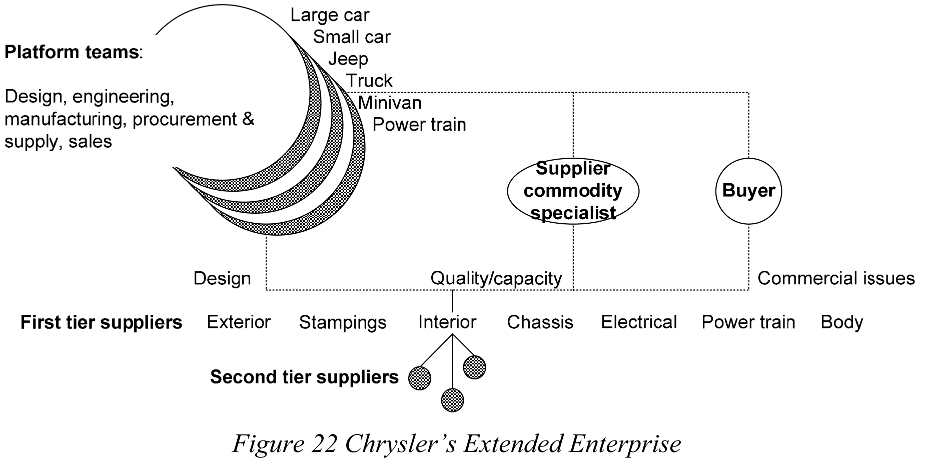


Figure 22 Chrysler's Extended Enterprise

Soruce: Ayers (2006)

If figure 22 seems complicated, that is because it is (ibid). It does not suggest the ordered structure of a traditional organization chart, which clearly defined functions, hierarchy, and line of communication. At any time, an individual in the "network" might have multiple supplier-customer relationships with others in the Extended Enterprise (ibid).

2.5 Important aspects in the Extended Enterprise

So far the Extended Enterprise has been discussed on a conceptual and high-level basis. Chapter 2.5 will go into more detail of some important, managerial and operational, aspects of the Extended Enterprise. Other aspects clearly exist, but the ones highlighted in the following sub-chapter, are the most relevant for this thesis.

2.5.1 Operations

Operations are the "machinery" of the Extended Enterprise, creating the product and/or services to the customers. Operations (also called operations function) can be broadly defined as all activities necessary for the fulfilment of customer requests (Slack et al., 2007), or more specifically as the collection of people, technology, and systems within an organization's that has primary responsibility for providing the organization's products or services (Bozarth and Handfield, 2006). However, operations are not limited to single organization, as operations can be viewed as a series of activities spanning the value chain (Russell and Taylor, 2009; Greasley, 2006; Waller, 2003).

Traditional operations are described as a transformation process that takes a set of inputs and transforms them in some way to create outputs, either goods or services, that a customer values (Bozarth and Handfield, op cit), see figure 5. In general, the transformation process can be categorized as follows (Chase et al., 2004): Physical (as in manufacturing), location (as in transportation), exchange (as in retailing), storage (as in warehousing), physiological (as in health care), and informational (as in telecommunications). This thesis will focus on manufacturing[30] and logistics (i.e. location and storage transformation). These two types of operations have a close and determining relationship (Greis and Kasarda, 1997).

Manufacturing can be defined technologically as the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given stating material to make parts or products (manufacturing also includes assembly of multiple parts to make products), or economically as the transformation of materials into items of greater value by means of one or more processing and/or assembly operations (Groover, 2007). Thus, the principal role of the manufacturing firm is to turn physical raw materials into tangible products (Waller, 2003).

Manufacturing can be characterized as discrete parts or continuous processing (Askin and Standridge, 1993). This thesis will focus on discrete manufacturing operations, which is characterized by individual parts that are clearly distinguishable. Within a discrete manufacturing factory, there are certain basic activities that must be carried out (Groover, 2008): 1) processing and assembly operations, 2) material handling, 3) inspection and test, and 4) coordination and control. These four activities may be extended into the value chain as

[30] The words manufacturing and production is often used interchangeably (Groover, 2007; Kalpakjian and Schmid, 2005), but some authors assign production a broader meaning than manufacturing (Groover, op cit).

well. Activity 1 is basically manufacturing, whereas activity 2 is logistics. Activity 3 will not be further discussed in this thesis, but activity 4 will be further discussed in chapter 2.5.3.

An extensive and continuously expanding variety of manufacturing processes are used to produce parts (Kalpakjian and Schmid, 2006), and these manufacturing processes can be divided into two basic types (Groover, 2007):

- ***Processing operations*** – transforms a work material from one state of completion to a more advanced state that is closer to the final desired product.
- ***Assembly operations*** – joins two or more components in order to create a new entity, called an assembly, subassembly, or some other term that refers to the joining process.

A further classification of manufacturing processes is presented in figure 23. The fabrication of a product may involve all processes listed in figure 23, or just a selection. ***These processes can be located in one factory, as a part of a production network within the same company, or distributed among the value chain partners in the Extended Enterprise***.

According to Shi (2003) there has been a transformation of the manufacturing system, from the traditional single site factory towards an international manufacturing network, i.e. the Extended Enterprise. This is supported by Ferdows (1997b), which claims that the world is clearly entering an age of trans-national manufacturing, where things made in one country are shipped across national borders for further work, packaging, assembly, storage, or sales, and products sold in a country are often shipped across national borders for repair, reuse, remanufacture, recycle, or disposal.

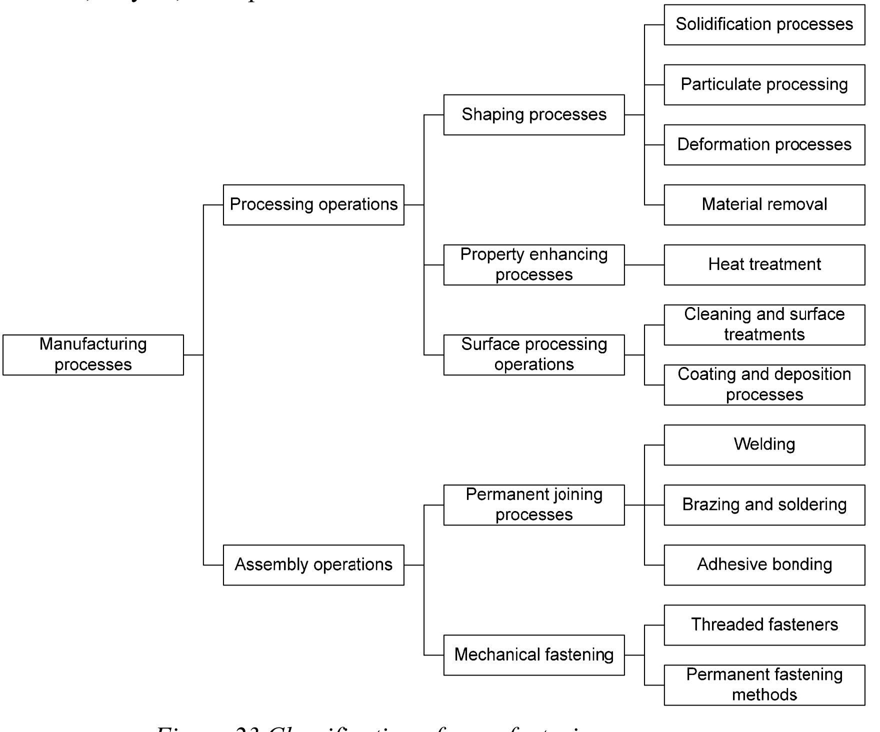


Figure 23 Classification of manufacturing processes

Source: Groover (2007)

This type of manufacturing is often called ***dispersed manufacturing***, which may be defined as the concept of manufacturing in the location that is most appropriate for the specific task (Zacharia, 2001). Dispersed manufacturing means breaking up the value chain and rationalizing the best location and firm for each activity (ibid). There are several benefits of globally dispersed manufacturing (e.g. market proximity, availability of low-cost input factors, and the availability of skills or know-how (Vereecke, 2007; Ferdows, 1997a and 1997b)), but at the same time it increases the complexity of the value chain (Deloitte, 2003; Schary and Skjøtt-Larsen, 2001; Zacharia, op cit). Ferdows (2003) identifies three key challenges with this kind of manufacturing:

- ***Balancing schedules and capacity utilizations*** – when several factories have to work together to produce a single product, coordination of production schedules becomes a necessity. The real challenge is to plan the production schedules in a way that allows a reasonable level of capacity utilization in each factory. Moreover, it is just in the factories where schedules and capacity utilizations must be planned; suppliers and inter-factory shipments, inventories, and warehouses need to be coordinated while allowing for efficient utilization of warehouses and transportation resources.
- ***Maintaining just-in-time flow through the value chain*** – building inventories between factoires is often not an effective way to smooth capacity utilization at different stages: 1) it will lengthen the lead-time for making customized products, 2) it ties up capital and increase costs, 3) it is risky when product life cycle are short and there is rapid obsolescence, and 4) it will increase the bullwhip effect in the value chain (see chapter 3.2.2).
- ***Responding quickly to unforeseen changes*** – this tightly coordinated schedule should also be flexible. The manufacturing system should be able to respond to unforeseen market demands, and this is very difficult when many factories across different organizations, regions, national boundaries are involved.

This is supported by Zacharia (2001) who stress that dispersed manufacturing requires a value chain orientation and coordination, in addition to excellent logistics. Logistics becomes important for connecting the manufacturing processes (Schary and Skjøtt-Larsen, 2001) and will become a greater challenge and a more critical success factor for manufactures (Ferdows, 1997b).

Logistics can be defined as the design and administer systems to control movement and geographical positioning of raw materials, work-in-process, and finished inventories at the lowest total cost (Bowersox et al., 2007). Alternative, as the process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders (Christopher, 2005).

The challenge is to manage the entire logistics system in such a way that order fulfilment meets and, perhaps, exceeds customer expectations (Coyle et al., 2009). At the same time, the competitive marketplace demands efficiency – controlling transportation, inventory, and other logistics-related costs (ibid). Thus, logistics is about providing the right product, in the right quantity, in the right condition, to the right place, at the right time, to the right customer and at the right costs (Johnson and Wood, 1996).

For an Extended Enterprise to realize the maximum strategic benefit from logistics, the full range of functional work must be integrated; i.e. integrated logistics (Bowersox et al., op cit). This integrated logistics can be split into five interrelated areas (i.e. the operations that span logistics) (ibid):

- ***Order processing*** – in most value chains, customer requirements are transmitted in the form of orders. The processing of these orders involves all aspects of managing customer requirements, including initial order receipt, delivery, invoicing, and collection.
- ***Inventory*** – material and component inventories exist in a logistical system for reasons other than finished product inventory. Each type of inventory and the level of commitment must be viewed from a total cost perspective. Understanding the interrelationships between order processing, inventory, transportation, and facility network decisions is fundamental to integrated logistics.
- ***Transportation*** – is the operational area of logistics that geographically moves and positions inventory. Transportation requirements can be satisfied in three ways: 1) a private fleet of equipment may be operated, 2) contracts may be arranged with dedicated transport specialists, or 3) engage the services of a wide variety of carriers that provide different transportation services as needed on a per shipment basis.
- ***Warehousing, material handling, and packaging*** – are integral part of other logistics areas. When effectively integrated into the logistical operations, warehouse, material handling, and packaging facilitate the speed and overall ease of the product flow throughout the logistical system.
- ***Facility network*** – is concerned with determining the number and location of all types of facilities required to perform logistics work.

Based on this discussion, it is possible to conclude that the ***manufacturing and logistics operations in the Extended Enterprise spans the value chain, involves globally distributed (and independent) companies, are associated with high complexity, and a great variety of (hopefully) integrated processes, where the aim is to fulfil (or exceed) customer requirements to a lowest (sustainable) cost***. And, as indicated earlier, these two types of operations have a close and determining relationship (Greis and Kasarda, 1997).

2.5.2 Management

It is apparent that the management of the Extended Enterprise is a difficult and complex task. According to Schary and Skjøtt-Larsen (2001) the value chain challenges management: 1) it is both inter-functional and inter-organizational, 2) it is a complex system contending with multiple environments, 3) the concept itself limits the scope of direct authority relationships, and 4) the potential span of management is vast, spanning the entire value chain. General (traditional) management addresses problems of structure, leadership, decision-making, human resources and control (ibid). Value chain management also deals with these areas, but it differs because of the scope and nature of the value chain (ibid).

The management of the Extended Enterprise requires an approach that is driven by the mutual value chain objectives, and combines strategy, people, process and systems (Harrison and van Hoek, 2002). Further, it should establish strategic direction, design the activity and organizational structures and processes to integrate operations, select and negotiate with potential partners and monitors operations (Schary and Skjøtt-Larsen, op cit).

Several authors have addressed the fundament/basis for management in the value chain (see among others Harrison and van Hoek (2002); Mentzer et al. (2001); Schary and Skjøtt-Larsen

(2001)) and their recommendations are more or less congruent with the key characteristics of the Extended Enterprise (see figure 20).

This thesis will however, only focus on management of operations in the Extended Enterprise issues; i.e. operations management in the Extended Enterprise.

The task of ***Extended Enterprise management*** is therefore to organize and control the total operations so that internal and external processes are performed efficiently and are responsive to customer demands (Bolseth et al., 2003).

Chapter 2.5.3-2.5.4 will in more detail discuss some of the most relevant operations management aspects in the Extended Enterprise. However, before discussing that, two other important management issues in the Extended Enterprise will be shortly debated; risk management, and event and exception management. These two issues are increasingly important as the complexity and globalization of the Extended Enterprise proceeds

Value chain processes are rarely executed as scheduled, since they happen in an environment prone to failure and disturbance (Otto, 2003). The key to efficient and effective product flow in the value chain is the elimination of events that interrupt that flow (Ross et al., 2004).

Event and exception management is the term given to the process of monitoring the planned sequence of activities along a value chain and the subsequent reporting of any divergence from that plan (Christopher, 2005).

A value chain event can occur on all levels of detail in the value chain (from broader cycles to detailed tasks) (Rohde, 2005). To be able to manage these events efficiently a reasonable grouping into event categories is inevitable (ibid). By giving the probability of an event to occur, events can be classified into standard and nonstandard events (i.e. exceptions).

The idea behind event and exception management is that the members in the Extended Enterprise collaborate to identify the critical nodes and links through which material flows across the network (Christopher and Lee, 2004). At these nodes and links, control limits are agreed within which fluctuations in the levels of activities are acceptable (ibid). If for whatever reason the level of activity goes outside the control limit, then an alert is automatically generated to enable corrective action to be taken (ibid).

Event and exception management is very close connection with value chain risk management, since the value chain risk is (mathematically) the probability of the event multiplied with the business impact of the event (Norrman and Jansson, 2004).

The impact of unplanned and unforeseen events in the supply chains can have severe financial effect across the supply chain as a whole (Christopher, 2005). In 2003 the Gartner Group, predicted that one in five businesses would be impacted by some form of supply chain disruption and that of those companies 60 percent would go out of business as a result (ibid).

Value chain risk management is to collaborate with partners in a value chain and apply risks management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources (Norrman and Jansson, 2004).

An easy way to understand and categorize value chain risks is to divide them into four categories (Manuj et al., 2007):

- ***Supply risk*** – is the possibility of an event associated with inbound supply that may cause failures from supplier(s) or the supply market, such that the outcome results in the inability of the focal firm to meet customer demand within anticipated costs or causes a threat to customer life and safe (Zsidisin et al, 2004).
- ***Operational risk*** – is the possibility of an event affecting the focal firm's internal ability to produce goods and services, the quality and timeliness of production, and the profitability of the company.
- ***Demand risk*** – is the possibility of an event associated with the outbound supply that may affect the likelihood of customer placing orders with the focal firms or with the variance in the volume an assortment desired by the customer.
- ***Security risk*** – is a threat from an unknown third party who may or may not be a member of the supply chain and whose motivation is to steal proprietary data or knowledge, tamper with sensitive and critical information, or destroy, upset, or disable a firm's operations by harming the goods or human resources.

Figure 24 illustrates the four types of risks in the value chain.

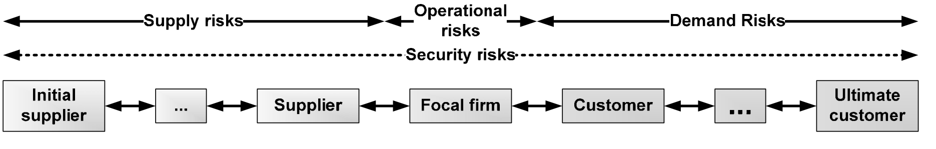


Figure 24 Risks in the value chain

Source: Manuj et al. (2007)

Because even the best managed Extended Enterprise will hit unexpected turbulence or be impacted by events that are impossible to forecast, it is critical that resilience be built into them (Christopher, 2005). Resilience implies the ability of a system to return to its original or desired state after being disturbed (Peck, 2004). Implicit in this definition is the notion of network flexibility, and given that the desired state may be different from the original, adaptability is also implied (ibid). Resilient value chains are flexible and agile and are able to change quickly (Christopher, op cit).

2.5.3 Planning and control

The sheer complexity of the Extended Enterprise makes it difficult to manage and control it (Surana et al., 2005). Along a value chain, various decisions have to be made continuously, from the rather simple choice, which job to be processed next on a certain machine, to the serious question, whether to build a new factory or to close down an existing one (Fleischmann and Meyr, 2003). These decisions differ by the management level involved, the importance for the company/value chain as a whole, the frequency in which they are made and the degree of aggregation (Günther, 2006).

Planning and control*[31] *can be used as a generic term for the whole range of those decisions on the design of the value chain, on the mid-term coordination and on the shot-term scheduling of the processes in the value chain (ibid). Or more simple as ***the reconciliation between what the market requires and what the operation's resources can deliver*** (Slack et al., 2007). Vollmann et al. (2005) point out that the essential task of (manufacturing; i.e. operations) planning and control is to manage efficiently the flow of material, the utilization of people and equipment, and to respond to customer requirements by utilizing the capacity of the suppliers, the internal (focal company) facilities, and (in some cases) that of the customers to meet customer demand.

Planning and control are often treated together, because the division between them is not clear, neither in theory nor practice (Slack et al., op cit), see figure 25a. However, there are some general features that help distinguish between the two (ibid).

Planning in general can be understood as the preparation of decisions which have to be made in business (Günther, 2006) or as all those activities required to meet desired objectives (Waller, 2003). Thus, planning is concerned with what should happen in the future (Slack et al., 2007).

In business, the planning process generally has its roots in the strategic or long-range plan that is then broken down into a more detailed operating plan (Waller, op cit). The objective of the operating plan is to enumerate in detail all the activities necessary in order to produce the products, or to provide required services for the customer in a timely manner (ibid).

Control can (from a system perspective) be viewed in terms of a monitoring subsystem that regulates the behaviour of other subsystems (Beynon-Davis, 2004). This control mechanism, subsystem or process, ensure defined levels of performance for the system through imposing a number of control inputs upon the system (ibid). Thus, control is the process of monitoring operations activity and coping with any deviations from the plan; usually involves elements of replanning (Slack et al., 2007)

Operations control concerns meeting the short-term, specific demands placed on the process or delivery system (Hill, 2005). Included in the operations control function are shop floor control, inventory control and quality control (Groover, 2008).

To sum up; ***planning and control activities provide the systems, procedures and decisions which bring together different aspects of supply and demand*** (Slack et al., op cit).

Since the fundamental work of Anthony (1965), usually three levels of managerial decision making are referred to (Fleischmann and Meyr, 2003). They mainly differ with respect to the time during which the decisions will have an impact on the future development of a value chain or company (ibid). Hence planning and control span the strategic to the tactical decision-making levels (Hill, op cit):

- ***Long-term (operations) planning*** – aims to provide the capacity requirements necessary to meet the sales forecast that underpin and organization's long-term objectives by planning for capacity changes in line with major shifts in existing

[31] Fleischmann and Meyr (2003) use the term supply chain planning

products and services and to meet plans for new products, services, technologies and markets.

- o ***Medium-term (or rough-cut) planning*** – details how demand will be met from available facilities which, in principle, are considered to be at a fixed level.
- o ***Short-term planning (or operations control, scheduling and execution)*** – is responsible for executing and controlling the short-term, day-to-day operations activities to ensure that the customer demands are met and resources used effectively.

Figure 25 illustrates the balance between planning and control activities in the long, medium and short terms (figure 25a), as well as an overview of the key steps in operations planning and control (figure 25b).

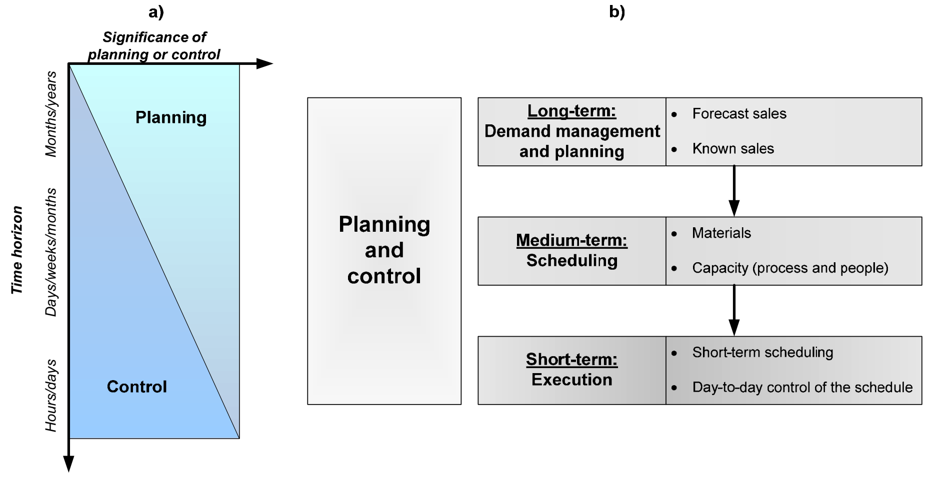


Figure 25 Planning and control time horizons and phases

Source: Slack et al. (2007) and Hill (2005)

According to Slack et al. (op cit) there are four overlapping planning and control activities: Loading, sequencing, scheduling, and monitoring and control. Similarly Hill (2005) claims that operations control (i.e. the medium- and short-term planning and control) systems includes three distinct but integrated activities design to manage and execute requirements: Loading, sequencing and scheduling. These four activities can be shortly described as:

- o ***Loading*** – determining the capacity and volumes at each stage in a process. This step will include assigning tasks to work centers or staff groups (Hill, op cit).
- o ***Sequencing*** – deciding on the order in which jobs will be completed at each stage in the process (ibid).
- o ***Scheduling*** – involves allocating a start and finish time to each actual or forecast order (ibid), or a detailed timetable of what work should be done, when it should be done and where it should be done (Slack et al., op cit).
- o ***Monitoring and control*** – having created a plan for the operations through loading, sequencing and scheduling, each part of the operation has to be monitored to ensure that planned activities are indeed happening. Any deviation from the plans can then be rectified through some kind of intervention in the operation (Slack et al., op cit).

Figure 26 illustrate an operations planning and control system, and represents the essence and sequence of the tasks that organizations need to undertake in order to calculate (if orders are known ahead of time) or assess (if order are not known and have to be forecast) demand, translate these calculations or assessments into material and capacity plans and schedules, and then develop ways to execute requirements on a short-term, day-to-day basis (ibid).

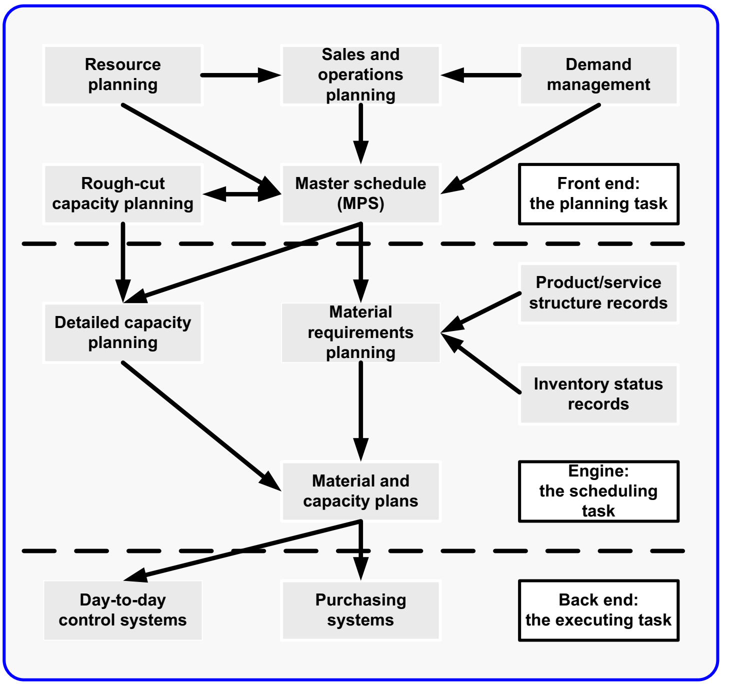


Figure 26 Operations planning and control systems

Adapted from Hill (2005) and Vollman et al. (2005)

The middle part of figure 26, or the engine of planning and control systems, is MRP/MRP II systems. These are the predominant planning and control systems used in business today (Vollman et al., 2005; Taylor, 2004). These MRP/MRP II systems have been faced with criticism due to the push-based nature, the static BOM structure, fixed lead times, long planning horizon, and infinity capacity assumption (see among others Miller, 2001; Sipper and Bulfin Jr., 1997; Browne et al., 1996; and Higgins et al., 1996).

Another important criticism is the lack of reliability of the data within the system (the rubbish in – rubbish out principle). This implies (from a very critical point of view) that these systems even struggle to report what has happened in the business, what is going on at the present time and to generate an accurate plan for the future. Perhaps more important, they also fall short in helping companies to determine what ought to be going on (Davis and Spekman, 2004; Chopra and Meindl, 2001). And finally, they have only a factory perspective, and not a value chain perspective (Schary and Skjøtt-Larsen, 2001).

The latter critic is of importance in the Extended Enterprise, as all operations in the value chain needs to be planned to quickly and flexibly react to increasingly complex demands from customers. Along a value chain hundreds and thousands of individual decisions have to be made and coordinated every minute (Fleischmann et al., 2005). The major task of value chain planning and control is the determination of manufacturing or inventory quantities for every node of the network (i.e. manufacturing facilities and warehouses) as well as the transportation quantities between these nodes (Pibernik and Sucky, 2006). Further, value chain planning and control involves the coordination of such decisions among various independent firms (ibid).

Figure 27 displays some selected and typical long-, medium-, and shot-term value chain operations issues, which needs to be planed and controlled in the Extended Enterprise.

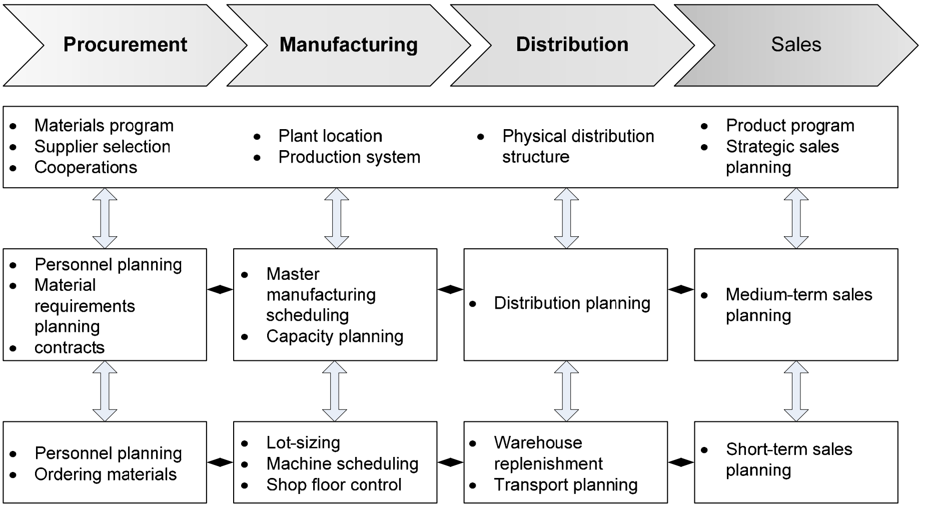


Figure 27 Value chain operations planning and control issues

Source: Fleishmann et al., (2005)

A key issue in value chain planning and control is centralized versus decentralized planning and control (Pibernik and Sucky, 2006):

- ***Centralized approach*** – requires a single decision maker to optimize the network with the union of information that the various decision makers have (Anupindi and Bassok, 1999, in Pibernik and Sucky, op cit). This is typical when one value chain partner is dominate due to financial power or exceptional knowledge of products and processes (Stadtler, 2005). Both in literature and in commercial value chain management (e.g. SCM) systems, a centralized approach to value chain planning and control is commonly proposed (Pibernik and Sucky, op cit), see figure 28 centralized value chain planning and control systems.
- ***Decentralized approach*** – is given when manufacturing, inventory and transportation decisions are distributed amongst diverse (intra- or inter-organizational) planning and control units (ibid). This is typical in a value chain where all partners are regarded as equal (Stadtler, op cit).

Other important issues when addressing value chain planning and control are:

- The growth of ***so-called supply chain management systems*** over the last decade. These systems can be seen as ad-on to ERP systems, and are designed to assist in evaluating value chain alternatives and advice in value chain decision making. Sometimes these systems are referred to as Advanced Planning and Scheduling (***APS***) systems (Bowersox et al., 2007 or just as Advanced Planning Systems (APS)

(Fleischmann et al., 2005; Stadtler, 2005; Fleischmann and Meyr, 2003). However, these systems are designed for operation within a particular firm's organizational boundaries, rather than across boundaries along the value chain (Davis and Spekman, 2004). Hence these systems can at best support value chain planning and control in a centralized manner.

- The increasing interest in ***sales and operations planning*** in global operations and the Extended Enterprise (Lapide, 2004; Ptak, 2004). An integrated sales and operations planning process is increasingly necessary for effective value chain operations (Bowersox et al., 2007). Sales and operations planning is a business process that helps firms plan and coordinate operations and value chain decisions over a medium-term horizon (Bozarth and Handfield, 2006). The sales and operations plan (see figure 2.14) provide the framework within which master production schedule is developed, subsequent MPS decisions can be planned and controlled, and material resources and plant capacity can be coordinated in ways that are consistent with strategic business objectives (Vollmann et al., 2005). At the end of the sales and operations process, there should be a common agreement about what each of the affected partners (sales, operations and finance) as well as key suppliers and transport providers needs to do to make the plan a reality (Bozarth and Handfield, op cit).
- The increasing emphasize on ***scheduling in the Extended Enterprise based on real-time information***. Scheduling in the focal company must take account of the load and capacity balance in the supply partner company as well as in the company's own factory (Childe, 1998). When the Extended Enterprise receives a customer order it needs to act rapidly and make a intelligent decision on where in the network to produce the order based on real-time information on capabilities, capacity and price (Trebilcock, 2005).

A convenient way to classify enterprise/value chain planning and control activities is in terms of the solutions that have been developed to support them (Theis et al., op cit). As fast as advancements in information technology have allowed, software application vendors have been developing solutions to meet business demands. As recently as a decade ago there were six distinct categories of planning and execution solutions, focused on the activity they were intended to support, namely (ibid), see chapter 2.6.4-2.6.13 for a more detail description of some of these systems:

- **Enterprise Resource Planning (ERP)**, including materials requirements planning (MRP)
- **Supply chain Planning (SCP),** also known as Advanced Planning and Scheduling systems
- **Order Management Systems (OMS)**
- **Warehouse Management Systems (WMS)**
- **Manufacturing Execution Systems (MES)**
- **Transportation Management Systems (TMS)**

In recent years, however, the distinction between supply chain planning and other areas of enterprise planning and execution has become blurred as applications vendors have aggressively tried to offer a wider range of functionality (ibid). Although many "best-of-breed" solutions still prosper, many activities that were previously managed using a point solution (e.g. warehouse management) can now be performed using an ERP system (ibid).

Further, there has also been an emergence of new categories of solutions such as (ibid):

- **Customer Relationship Management (CRM)**

- **Supplier Relationship Management (SRM)**
- **Supply Chain Event Management (SCEM)**

These new solutions further confuse the picture as many of them offer overlapping functionality with existing categories of solution (ibid). Figure 28 summarize the currently available categories of solutions.

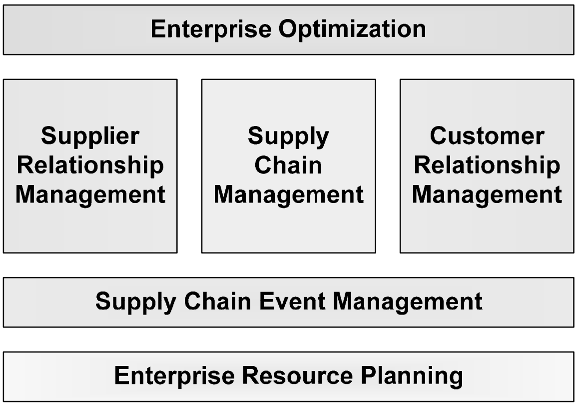


Figure 28 Enterprise/value chain planning and control solutions

Source: Theis et al. (2003)

Although point solutions for order management, warehouse management, manufacturing execution and transportation management do still exist and continue to do well, they have been subsumed into the broader categories of CRM, SRM, SCEM, and ERP in the figure.

2.5.4 Performance measurement

Performance measurement and management have been on the research agenda since the late 1980s (Johnson and Kaplan, 1987; Lynch and Cross, 1991; Eccles, 1991; Kaplan and Norton, 1992; EFQM, 1999; Thorpe, 2004). Since then, there has been a proliferation of theories, models and tools (Franco and Bourne, 2003) to support practitioners better measure their performance and hence manage through measures.

However, before going into more details about performance measurement and management, it is necessary to make some clarification and definitions. As Neely et al. (1995) puts it: "*Performance measurement is a topic which is often discussed but rarely defined*". Key elements are:

- ***Performance measure*** - can be defined as a metric used to quantify the efficiency and/or effectiveness of an action (ibid). Or, a description of something that can be directly measured (e.g. number of reworks per day) (Browne et al., 1997)
- ***Performance indicator*** – can be defined as something that is calculated from performance measures (e.g. percentage reworks per day per direct employee) (ibid)
- ***Performance measurement*** - can be defined as the process of quantifying the efficiency and effectiveness of action. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized when providing a given level of customer satisfaction (Neely et al, op cit).
- ***Performance measurement systems*** - can be defined as the set of metrics used to quantify both the efficiency and effectiveness of actions (ibid)
- ***Performance management*** – can be defined as the use of performance measurement information to effect positive change in organizational culture, systems and processes, by helping to set agreed-upon performance goals, allocating and prioritizing resources, informing managers to either confirm or change current policy or program directions to meet these goals, and sharing results of performance in pursuing those goals (Amaratunga and Baldry (2002).

This thesis will use a hierarchal structure to describe the performance measurement systems (see figure 29), with performance metrics as the fundament, followed by a selection of performance indicators (either a metric or a combination of metrics) and a few (5-7) Key Performance Indicators (KPIs) on top. KPIs are the measure that business puts into place to track their progress against both short-term goals and strategic plans.

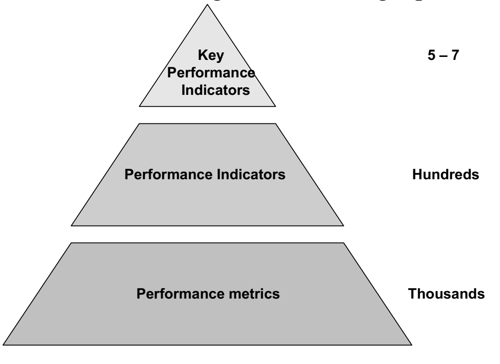


Figure 29 The Hierarchy of Performance Measurement

Performance measurements systems historically developed as a means of monitoring and maintaining organizational control which is the process of ensuring that an organization pursues strategies that lead to achievement of overall goals and objectives (Nani et al., 1990). Performance measurement provides the basis for an organization to assess how well it is progressing towards its predetermined objectives, helps to identify areas of strengths and weaknesses, and decides on future initiatives, with the goal of improving organizational performance (Amaratunga and Baldry, 2002). Performance measurement indicates what has happened, not why it happened, or what to do about it. In order for an organization to make effective use of its performance measurement outcomes it must be able to make the transition from measurement to management (ibid).

According to Nuthall (2003) performance measurements systems fulfill a variety of purposes in today's value chain organizations:

- Performance management systems provide an ***effective management framework***. They enable managers to identify the gap between target achievement and actual progress, and to compare performance with performance of competitors and partners.
- Performance measures ***facilitate communication*** throughout the organization, both. They provide mechanisms for both "top-down" and "bottom-up" communication.
- Performance measures play a determining role in ***people management*** by ***directing the behavior*** of the members of an organization. When people know the criteria on which their performance is being measured, and perhaps rewarded or penalized, it follows that their behaviour will be such as to enhance the outcome of these measures.
- An effective performance management system will do more than steer behavior; it will ***foster innovation and improvement***. Performance measures help to create an environment in which people are encouraged to look for, recognize and pursue innovative improvement opportunities.
- Performance measures help organizations to ***assess their competitive positioning and operational capacity***. Some of the most motivating measures are those that focus on potential performance rather than actual.

In order to response proactively to new emerging challenges, management requires up-to date and accurate information on performance (Bititci et al, 2002). Management and employees need to have information regarding markets and customers, competitive position, financial performance, customer service performance, operational performance, suppliers' performance etc. Furthermore, this performance information needs to be integrated, dynamic, accurate and visible to aid fast decision making to promote a proactive management style leading to agility and responsiveness (ibid).

Furthermore, in value chain collaboration, companies no longer posses control over all processes and are dependent on its partners in order to provide the customer with the desired value. Lack of control, limited access to information and poor visibility are often quoted as important problems with such collaborations (e.g. Christopher, 2005; Boyson et al. 2004; Handfield and Nichols Jr., 2002). Finley and Srikanth (2005) points out that performance measurement and management is one of the imperatives for successful value chain collaboration. This is supported by Stallkamp (2005) who stress that measurement and tracking systems are of importance to show skeptics that collaboration is actually working and producing results. Without cross-process, cross-organizational metrics, each company will continue to maximize the achievement of its own objectives; potentially at the expense of the system's overall performance (ibid). At a minimum, collaboration requires each participant to be able to translate its own concerns into terms relevant to the other participants. By developing a common, channel-wide "dashboard" of performance measures, collaborators can, for the first time, view how their own performance affects the overall system's performance (Finley and Srikanth, 2005).

The last decade has seen the introduction of several frameworks and methodologies for the development of performance measurement systems. Much of this development has been driven by the recognized need to find an alternative to traditional, management accounting performance measurement approaches (Nuthall, 2003).

Various authors (e.g. Busi and Bititci, 2006; Chan et al., 2006; Busi, 2005; Nuthall, 2003; Bititci et al., 2002; Bourne et al., 2002) lists weaknesses and flaws with exiting performance measurement and management systems. Some examples of the critique are:

- Today most performance measurement systems are ***historical and static***. That is, they are not dynamic and sensitive to changes in the internal and external environment of the firm (Bititci et al, 2002; Bititci and Carrie, 1998).
- Few performance measurement systems have an ***integrated IT structure*****.** This results in cumbersome and time-consuming data collection, sorting, maintenance and reporting (Bititci et al, 2002; Bititci and Carrie, 1998).
- There has been a lack of a ***balanced approach*** to performance measurement (Gunasekaran et al., 2001). This is, companies need to understand the balance between financial and non-financial measures.
- There has been a lack of a clear distinction between ***metrics at strategic, tactical, and operational levels*** (Gunasekaran et al., 2001).

It is therefore a need of developing new performance measurement and management systems addressing these weaknesses and flaws. Several authors are working with this issue and list requirements for future performance measurement and management systems (e.g. Chan et al., 2006; Busi, 2005; Folan and Browne, 2005; Bititci et al., 2002; Bourne et al., 2002)

Busi and Bititci (2006) and Busi (2005) points out there are a major transformation taking place in the field of performance measurement today:

- ***From performance measurement to performance management*** - in order to reap the benefits of performance measurement, organizations have to make use of the measures, i.e. they have to manage through measures (Amaratunga and Baldry, 2002).
- ***From individual to collaborative performance measurement*** - "it is clearly impossible in today's business climate to ignore those aspects of the organization that extend beyond the traditional, or legal, boundaries of the organizations" (Kosynsky, 1993).
- ***From lagging to leading performance management*** - performance measurement systems have historically been developed and used to identify poor performance and improvement areas, but fail to incorporate redesign of measures based on feedback from operations. Nonetheless, the focus of operational control is shifting from past to present, and performance measurement is a key agent of this change (Amaratunga and Baldry, 2002).

2.6 ICT in the Extended Enterprise

Perhaps more than any other single factor, ICT has changed the basis of production economics by automating many clerical tasks and greatly improving manufacturing accuracy, reliability, and predictability (Rondeau and Litteral, 2001; Jelinek and Goldhar, 1984). It is important to stress that the benefits of ICT has been rich and far-reaching and has not only been limited to automation of processes, but also enabling advanced decision support (e.g. advanced planning, modeling, simulation etc) that has been unthinkable without ICT. ICT has played a crucial role in the development of both manufacturing and logistics as management disciplines (Cooper and Tracey, 2005; Basu and Siems, 2004; Handfield and Nichols Jr., 2002; Rutner et al., 2001; Closs and Xu, 2000; Stenger, 1986). The role began not long after the first commercial use of computers occurred in the 1950s (Stenger, 1986) and as ICT developed, these new technologies and solutions have been adopted and embedded in to the manufacturing and logistics systems (Rondeau and Litteral, 2001). This development is not limited to advances in hardware and software, but includes related components such as satellite transmission, electronic data interchanges, bar coding, etc (Closs and Xu, 2000). And today interest and focus on value chain collaborations, are motivated of the recent developments within the field of ICT (Bouwman et al., 2005; Berger, 2003; Puckridge and Woolsey, 2003; Simchi-Levi et al., 2003; Narasimhan and Kim, 2001)

2.6.1 ICT

Within the area of ICT there are many related terms and terms that are used interchangeably with ICT. For example are Information Systems (IS) and Information Technology (IT) in some cases used interchangeably, and similar with Information and Communication Technology (ICT). Further, information, which constitutes one of the words in the term ICT, is often wrongly confused with data. A set of definition of the relevant terms related to ICT might therefore be adequate in order to set the record straight. Table 8 summarize the various relevant definitions. Several definitions are given for each term, partial to stress that there are no standard definitions and also to provoke differences and shades in the use of the terms. For each term and relationships between terms, a clarifying note is given.

<table>
<tr><th>Term</th><th>Definition</th><th>Source</th><th>Note</th></tr>
<tr><td rowspan="2">Data</td><td>A collection of non-random facts recorded by observation or research</td><td>Bocij et al. (2003)</td><td rowspan="4">Data are facts or observations that are considered to have little or no value until they have been processed and transformed into information.</td></tr>
<tr><td>Streams of raw facts representing events occurring in organizations or the physical environment before they have been organized and arranged into a form that people can understand and use</td><td>Laudon & Laudon (2003)</td></tr>
<tr><td rowspan="2">Information</td><td>Data that have been processes so that they are meaningful</td><td>Bocij et al. (2003)</td></tr>
<tr><td>Information is data interpreted in some meaningful context</td><td>Beynon-Davis (2004)</td></tr>
<tr><td rowspan="2">Information System (IS)</td><td>A set of interrelated components that collect (or retrieve), process, store and distribute information to support decision making, coordination, control, analysis and visualization in an organization</td><td>Laudon &Laudon (2003)</td><td rowspan="2">The stress in IT is on technology, whereas IS not may or may not contain technology. Kanban card is an example of a non-technological information system. IT provides means for constructing aspects of information systems.</td></tr>
<tr><td>An IS is a system of communication between people</td><td>Beynon-Davis (2004)</td></tr>
<tr><td>Information Technology (IT)</td><td>IT encompass the information that businesses create and use as well as a wide spectrum of increasingly convergent and linked technologies that process the information</td><td>Handfield & Nichols (1999)</td><td>IT and ICT are often used as synonyms, and not wrongly. Historical ICT can be seen as the successor of IT; it was no longer sufficient to only process the data, but there was a need to transfer the</td></tr>
</table>

	IT can be defined as technology used to acquire, process, and transmit information for more effective making	Krajewski & Ritzman (1998), Grover & Malhotra (1999)	data and information as well (e.i. communication). However, IT is a more establish term and most authors prefer to use this term instead of ICT. This will also be the case in this dissertation.
Information and Communication Technology (ICT)	ICT is any technology used to support information gathering, processing, distribution and use	Beynon-Davis (2004)	
	The equipment of computers, storages, software, communication network and other equipment necessary in order to conduct data processing as data capture, processing, storage, transfer and presentation.	Christensen (2003)	

Table 8 Important definitions and clarifications within ICT

2.6.2 ICT systems

ICT systems are technological information systems that collect, process, store, analyze and disseminate information for a specific purpose (see also discussion in chapter 5.2). Some authors use the term *computer-based information systems*, when referring to ICT systems. A computer-based information system is an information system that uses computer technology to perform some or all of its intended tasks, and is composed (not necessary all) of the following components (Turban et al., 2004):

- Hardware – is a set of devices such as processor, monitor, keyboard, and printer. Together, they accept data and information, process them, and display them
- Software – is a set of programs that enable the hardware to process data
- A database – is a collection of related files, tables, relations, and so on, that store data and the associations among them
- A network – is a connecting system that permits the sharing of resources by different computers (it may be wireless)
- Procedures – are the set of instructions about how to combine the above components in order to process information and generate the desired output
- People – are those individuals who work with the system, interface with it, or use its output

In addition, all ICT systems have a purpose and a social context (see discussion about objective of ICT in business in chapter 3.1.1 and 3.1.2) (Turban et al., 2004).

There are many types of ICT systems and they differ in the provided functionality, performance and social consequences as well as their components, inputs, outputs, and the type of user they can serve (Pontrandolfo and Scozzi, 1999). These systems spans from huge enterprise systems (e.g. ERP and MPC systems), via ICT systems that enable companies to communicate (e.g. EDI, XML, Portals etc), to small ICT systems that are dedicated to a process (e.g. SCADA system and Sales Portal). ICT systems relevant to this thesis are shortly presented throughout chapter 2.6.4 – 2.6.13.

However, before presenting these various ICT systems it is important to understand how these systems are related to each other. The best way to this is by some sort of classification of ICT systems. Such a classification may help in identifying systems, analyzing them, planning new systems, planning integration of systems, and making decisions such as the possible outsourcing of systems (Turban et al., 2004).

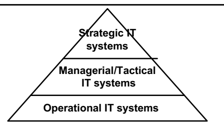
2.6.3 Classification of ICT systems

It is becoming more and more difficult to classify a specific ICT system. Many ICT systems now have multiple capabilities, and the borders between the systems are becoming vague. As a result there is no common classifications scheme of ICT systems available and ICT systems in organizations can be classified in a number of fashions. Thus, ICT systems can be classified in several ways such as (Turban et al., 2004; Barron et al., 1999; Pontrandolfo and Scozzi, 1999):

a) Classification by organizational level
b) Classification by type of support provided
c) Classification by type of organizational activities
d) Classification by IT systems architecture

Table 9 gives an introduction to these four types of classifications. There are however, other classifications as well. Some of these are worth mentioning. Due to the fact that many systems overall do not fit with the classifications presented in table 9, and the classes of ICT systems is potentially confusing and vague, some authors have proposed more comprehensive classifications. Cats-Baril and Thompson (1997) have proposed a classification scheme called the Information systems cube (with three dimensions; scope, complexity and information richness). Similarly have Barron et al (1999) develop a classifications schema with ten dimensions (or features). Opposite, other authors use much simpler classifications. Schary and Skoett-Larsen (2001) propose two categories: inter and intra enterprise ICT systems, whereas Shapiro (2001) divide between transactional and analytical oriented ICT systems. Others like, Kendall (1997) and Sanders and Premus (2002) divide respectively between production- (or process)-oriented ICT and coordination-oriented ICT, and operations-oriented ICT and marketing-oriented ICT.

Classification of IT systems			
(a) Organizational level	**(b) Support provided**	**(c) Organizational activities**	**(d) IT systems architecture**
Functional (departmental) IT systems	Transaction processing IT systems	Operational activities	Mainframe environment
Enterprise IT systems	Management IT systems	Managerial activities (also called tactical activities)	PC environment
	Office automation IT systems		
Interorganizational IT systems	Word processing IT systems	Strategic activities	Distributed computing
	Document management IT systems		
	Decision support IT systems		Legacy systems
	Executive support IT systems		Peer-to-peer architecture
	Group support IT systems		
	Expert IT systems		
	Storage and retrieval IT systems		
	Communication and collaboration IT systems		



This classification is often represented as a triangle/pyramid, illustrating the distinction in amount of operational, tactical and strategic activities as well as the organizational hierarchy

Table 9 Classification of IT systems

As the prior discussion indicates there are various types of classification of ICT systems available. In this thesis no specific classification will be preferred and used. The various ICT systems presented in this thesis covers all categories within both *a) organizational level* and *c) organizational activities* (with main focus on the operational activities), and many of the s*upport functions listed under b).* The ICT system architecture classification will partially be used in chapter 6.6 in order to sketch an ICT infrastructure for the Extended Enterprise. By applying the classifications by Shapiro (2001) and Sanders and Premus (2002), it is however possible to make two demarcations: this thesis will not focus on analytical- and market-oriented ICT systems.

The remaining part of chapter 2.6 will be devoted to short presentation of various ICT systems relevant to the work in this thesis.

2.6.4 ERP systems

Enterprise Resource Planning (ERP) systems are by far the most dominant ICT systems in today's business, and are quite frequently referred to as Enterprise Systems (Harris and Davenport, 2006; Davenport and Brooks, 2004; Rashid et al, 2002; Davenport, 1998). The term ERP was first introduced by Gartner Group in the early 1990s (Jackobs and Weston, 2007; Ponis et al., 2007). However, the roots of ERP go back to the early 1960s (Jacobs and Weston, 2007; Møller, 2005; Summer, 2005; Umble et al, 2003; Ptak and Schragenheim, 2000) and involves a transition often described through the following steps (Jacobs and Weston, 2007; McGaughey and Gunasekaran, 2007; Rashid et al., 2002; Ptak and Schragenheim, 2000): BOM processor (or inventory control or reorder point systems), MRP, Closed loop MRP, MRP II and finally ERP.

ERP can be defined as the software tools used to manage enterprise data (Summer, 2005), or more extensive as a customizable, standard application software that includes integrates business solution for the core processes (e.g. production planning and control, warehouse management, costing, financial control, sales, distribution) and the main administrative functions (e.g. accounting, human resource management) of a company (Ioannou and Papadoyiannis, 2004; Laughlin, 1999). Similar do Rashid et al. (2002) define ERP systems as software systems for business management, encompassing modules supporting functional areas such as planning, manufacturing, sales, marketing, distribution, accounting, financial, human resource management, project management, inventory management, service and maintenance, transportation and e-business.

Prior to ERP, enterprises had many different computer systems and databases to support its various departments. These systems are grouped under the heading legacy systems, which is referring to mainframe applications that were developed prior to 1990 to automate transactions such as order entry, order processing, warehouse operations, inventory management, transportation, and related financial transactions (Bowersox et al., 2002). For example, the financial department has systems for accounting and general ledger, the sales and marketing have systems for order management and pricing, while the production department can make use of a Manufacturing Resource Planning (MRPII) system. The upper part of figure 30 illustrates the interaction between various such legacy systems in the order fulfillment process.

An ERP-system is, on the other hand, a standard application program, which support execution of business processes throughout the whole company. The ERP-system has functionality that makes the company able to replace many of their applications with a single seamless system with one common database. This is illustrated in the lower part of figure 30.

The functionality described in figure 30 can be split into three different types (Akkermans et al., 2003):

- A transaction processing engine – allowing for the integrated management of data throughout the enterprise.
- Work flow management – functions controlling the numerous process flows that exist in the enterprise, such as order-to-cash process or the purchasing process.
- Decision support – assisting the creation of plans (e.g. by doing a MRP run), or in deciding on the acceptance of a specific customer order (e.g. by performing an available-to-promise (ATP) check).

A recent trend is the emergence of ERP II systems (a new term coined by Gartner Group in 2002 (Møller, 2005). ERP II systems can be defined as a business strategy and a set of industry-domain specific applications that build customer and shareholder value by enabling and optimizing enterprise and inter-enterprise, collaborative-operational and financial processes (Bond et al., 2000). Møller (op cit) point out that ERP II is essential componentized ERP, e-business and collaboration in the value chain. The conceptual framework for ERP II is illustrated in figure 31.

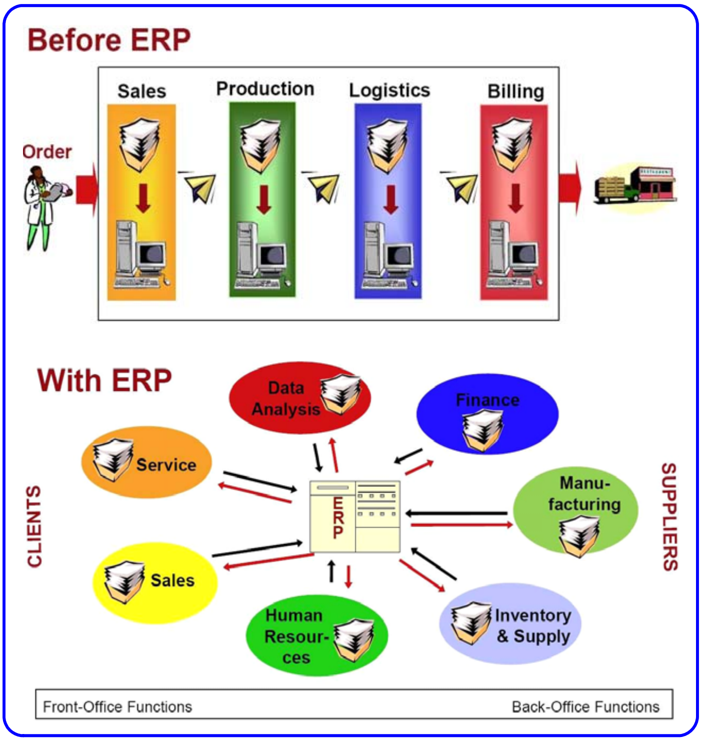


Figure 30 Business transactions before and with ERP systems

Adapted from Andreu et al. (2003)

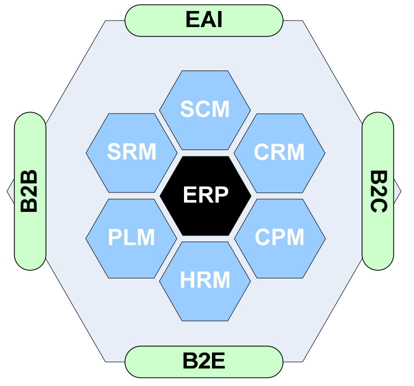


Figure 31 ERP II

Source: Møller (2005)

These ERP II systems are expanding the functionalities (compared to traditional ERP systems), both towards the shop floor (i.e. typically MES functionality) (Manetti, 2001; Rondeau and Litteral, 2001) and outward in the value chain (i.e. APS (or SCM) functionality) (Jacobs and Weston, 2007; Møller, 2005; Davenport and Brooks, 2004; Weston, 2003; Manetti, 2001), as well as performance measurement (Business Intelligence) functionality (Ponis et al. 2007; Møller, 2005).

2.6.5 APS systems

Advanced Planning and Scheduling (APS) systems consists of several software modules (eventually again comprising several software components), each of them covering a certain range of planning tasks (Meyr et al., 2005). The APS systems are also known and Advanced Planning Systems (Davis and Spekman, 2004), often labelled/market as SCM systems (Turban et al., 2006), and may be a stand-alone system or an integrated part of an ERP system (Møller (2005).

APS software uses extremely sophisticated mathematical algorithms and other approaches to analyze all aspect of a particular supply chain decision issue and develop plans that offer the best solution, given all the factors involved (Davis and Spekman, 2004). An APS system tries to find feasible, (near) optimal plans across the value chain as a whole, while potential bottlenecks are considered explicitly (Stadtler, 2007). Hence, an APS system is like the brain over the ERP body; it extracts massive amounts of data from the ERP software and analyzes it to determine the best course of action (Davis and Spekman, op cit). Further, APS systems seek to integrate information and coordinate overall manufacturing, logistics and value chain decisions while recognizing the dynamics between functions and processes (Bowersox et al., 2002)

Although developed independently by different software vendors, APS exhibit a common architecture based on the principles of hierarchical planning (Stadtler, 2005). Thus, a common structure underlying most of the APS can be identified, see figure 32 (Meyr et al., 2005). The names of the modules vary from APS provider to APS provider, but the planning tasks that are supported are basically the same (ibid).

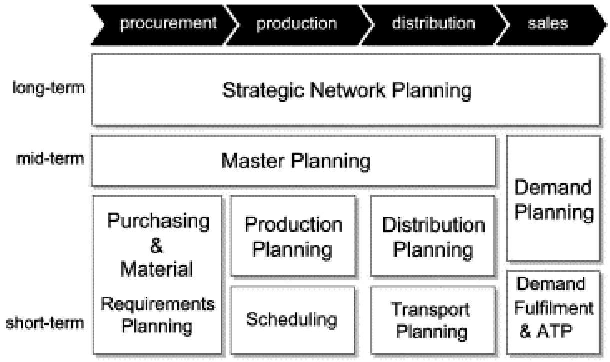


Figure 32 APS modules

Source: Meyr et al. (2005)

Although APS systems are frequently labelled as SCM systems, they are, like ERP systems, designed for operation within a particular firm's organizational boundaries, rather than across boundaries along the value chain (Davis and Spekman, op cit).

2.6.6 MES systems

Manufacturing Execution Systems (MES) is an online integrated computerized system that is the accumulation of the methods and tools used to accomplish production (McClellan, 1997). MES have evolved to fill the communication gap between the manufacturing planning system (MRP, MRP II, ERP, etc), and the control systems used to run equipment on the floor (McClellan, 1997). Hence, MES can be seen as a critical interface between a firm's ERP system and it shop floor and device control system (Rondeau and Litteral, 2001).

APICS[32] defines MES as (Manetti, 2001): "A factory floor information and communication system with several functional capabilities. It includes functions such as resource allocation and status, operations/detailed scheduling, dispatching production units, document control, data collection and acquisition, labor management, quality management, process management, maintenance management, product tracking and genealogy, and performance analysis. It can provide feedback from the factory floor on a real-time basis. It interfaces with and complements accounting-oriented, resources planning systems". McClellan (2003) is more or less in line with this, but divides the MES function into core and support functions, see figure 33. In figure 33 are the core functions located at the centre of the figure, and the figure tries to illustrate that these functions are integrated. The support functions are placed randomly around the inner circle of the figure.

Today the line between MES and ERP system have started to blur, where ERP vendors are expanding their enterprise business applications to encompass the value chain and extend closer to the plant floor, and similar, MES vendors are expanding their shop floor solutions to include front end and back end applications such as order fulfilment and warehouse management systems (Manetti, 2001).

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[32] APICS – The Association for Operations Management

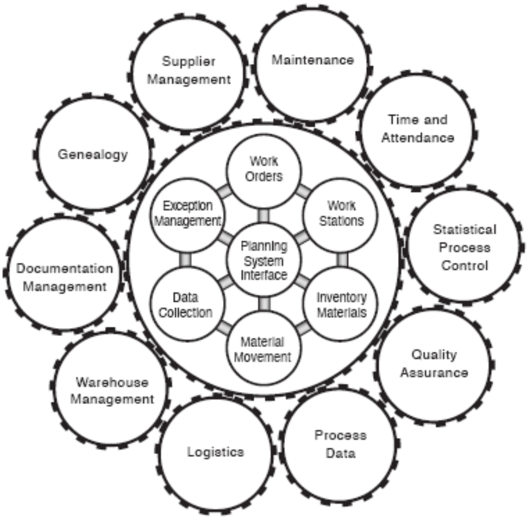

Figure 33 Core and support functions of MES

Source: McClellan (2003)

2.6.7 Warehouse Management Systems

Warehouse Management Systems (WMS) are providing real time views on material flows within the warehouse, i.e. tracking and keeping note of the movement and storage of material within a warehouse facilitating the optimal use of space, labour and equipment (Helo and Szekely, 2005). In addition to facilitating standard warehouse management functionality such as receiving, storage, shipping, and warehouse automation, WMS typically include management reporting, support for value-added services, and decision support capability (Bowersox et al., 2002). WMS can either be a stand-alone system or an integrated part of ERP systems (Verwijmeren, 2004; Bowersox et al., 2002).

2.6.8 Transport Management Systems

Transport Management Systems (TMS) are software applications that facilitate the procurement of transport services, the short-term planning and optimization of transport activities, and the execution of transport plans with continuous analysis and collaboration (Helo and Szekely, op cit). TMS typically includes routing, load building, consolidation, and management of reverse logistics activities as well as scheduling and documentation (Bowersox et al., op cit). TMS can either be stand-alone system or an integrated part of ERP systems (Verwijmeren, 2004; Bowersox et al., 2002).

2.6.9 SCADA systems

Supervisory Control and Data Acquisition (SCADA) system is a software package that is positioned on top of hardware to which it is interfaced, via PLCs to make information visually available to plant operators (Greeff and Ghoshal, 2004). SCADA systems can be defined as real-time process controls that enable a user from a single Master station to collect and analyze data received from one or more Slave units, send limited control instructions, monitor and control equipment status, and open and shut valves or motors (Majdalawieh et al., 2005). Or more simplified; SCADA systems are ICT systems supporting control and monitoring of individual machines or a set of machines on the shop floor.

A SCADA system consists of four major components (ibid):

1. The field instrumentations that measure the environment conditions (read temperature, pressures, flows, voltages, currents, frequencies, or other physical quantities) and control valves, circuit breakers, or other device that influences the physical processes
2. The remote stations
3. The control center
4. The communication links

A SCADA system gathers information (such as where a leak on a pipeline has occurred), transfers the information back to a central site, then alerts the home station that a leak has occurred, carrying out necessary analysis and control, such as determining if the leak is critical, and displaying the information in a logical and organized fashion (NCS, 2004). These systems can be relatively simple, such as one that monitors environmental conditions of a small office building, or very complex, such as a system that monitors all the activity in a nuclear power plant or the activity of a municipal water system (ibid).

2.6.10 Internet and portals

The Internet has been one of the key elements in the ICT evolution over the last ten years or so. The growth of the Internet is exceptional: In 1997 there were approximately 50 million Internet users, in 2004 there were 875 million users (Information Economy Report, 2005), whereas it is estimated to be 1,46 billion users by 2007 (Turban et al, 2006). In developed countries, a very high proportion of enterprises are connected to the Internet. On average 87% of enterprises in EU countries are connected to the Internet, where countries like Denmark and Finland reports that 97% of enterprises are connected to the Internet (Information Economy Report, 2005).

The Internet refers to the physical network that links computers across the globe. It consists of the infrastructure of network servers and communications links between them that are used to hold and transport the client PCs and web servers (Bocij et al, 2006). The Internet has it origin in the APRANET (Advanced Research Projects Agency Network) of the U.S. Department of Defense (the Defense Research Projects Agency) launched in 1969 (Leiner et al, 2003). The APRANET grew into the Internet, when more and more computers where connected to the network. The Internet began to achieve its currents form in 1991, when CERN released the World Wide Web in 1991 (CERN, n.d.).

The Internet is creating a new “universal” technology platform on which to build all sorts of new products, services, strategies and organizations. It is reshaping the way information systems are being used in business and daily life. By eliminating many technical, geographic, and cost barriers obstructing the global flow of information, the Internet is inspiring new uses of information systems and new business models. The Internet provides the primary technology platform for the digital firm (Laudon and Laudon, 2005). E-business and E-commerce are two concepts that are related to the rapid growth of the Internet and the rise of the digital firm. E-commerce is doing business electronically across the extended enterprise. It covers any form of business or administrative transaction or information exchange that is executed using any information and communication technology. E-business is a wider concept that embraces all aspects of the use of information technology in business. It includes not only buying and selling, but also servicing customers and collaborating with business partners, and often involves integration across business processes and communication within the organization (Rowley, 2002).

An **intranet** is the use of Web technologies to create a private network, usually within one enterprise (Tuban et al., 2006). Intranets allow for the secure online distribution of many forms of internal company information. Intranets are used for workgroup activities and the distributed sharing of projects within the enterprise. Intranets are usually combined with and accessed via a corporate portal (ibid).

Extranets connect several intranets via the Internet, by adding to the Internet a security mechanism and possibly some functions (ibid). They form a larger virtual network that allows remote users to securely connect over the Internet to the enterprise's main intranet. Extranets allow two or more enterprises to share information in a controlled fashion, and therefore they play a major role in the development of business-to-business electronic commerce (ibid).

(Enterprise Information) **Portals** are applications that enable companies to unlock internally and externally stored information, and provide users a single gateway to personalized information needed to make informed business decisions (Finkelstein and Aiken, 2000). Portals are web-based[33] and accessed through a web-browser. Through the portal, users can have structured and personalized access to information across large, multiple, and disparate enterprise ICT systems, as well as the Internet (Turban et al., 2006). Further, the portal technology provides the unifying structure allowing a single, shared database to coordinate all the transactions within the Extended Enterprise in real-time (Boyson et al., 2003). The use of portals to integrate enterprises in the value chain has many advantages (Linthicum, 2004). The primary one is that there is no need to integrated back-end systems directly between companies and within enterprises, which eliminates the associated cost or risk (ibid).

What makes the portal so valuable as a business tool is the fact that it serves a dual function (Boyson et al., 2004): 1) it provides a focal point for each individual in the value chain to access critical information, and 2) the portal also offers an effective mechanism with which users can input important data. This implies that users can not only read information via the portal, but also respond to the data and take action accordingly.

According to Polgar et al. (2006) there are five necessary elements of portal applications:

- A portal combines several legacy back-end systems and applications at the request time into one page;
- It provide single sign-on facility;
- The content is highly dynamic and can be filtered, personalized, and secured;
- A portal is designed to service thousands of concurrent sessions in a implementation, and;
- Portals are enterprise applications that can run on load-balanced Web and application server clusters.

2.6.11 Electronic transfer systems

EDI is a communication standard that enables the electronic transfer of routine documents, such as purchase orders, between business partners (Turban et al., 2006). The exchange of data in EDI follows a set of formatting standards that specify how information is transmitted electronically (Jessup and Valacich, 2008). EDI has been used for over four decades to

[33] Web-based refers to those applications or services that are resident on a server that is accessible using a web-browser and is therefore accessible from anywhere in the world via the web (Turban et al., 2006).

conduct business between organizations. However, the trend in business today is to use the Web as the vehicle for business-to-business electronic commerce (ibid).

XML is a WWW Consortium (W3C) standard that translates a company's business documents into a format understandable by another company. It is the universal format for structured documents and data on the Web. It is intended for open computer-to-computer communications, as it permits the efficient integration of e-commerce solutions across both the Internet and private B2B networks (Turban et al., 2006). One of the main uses of XML in e-business is the representation of the various business transactions that occur on a regular basis between trading partners (Papazoglou and Ribbers 2006). This includes purchase orders, invoices, shipping, bills of lading, and warehouse information (ibid).

2.6.12 Data collection and automatic identification systems

Automated identification (Auto ID) involves the automated extraction of the identity of an object (McFarlane and Sheffi, 2003). The rationale for Auto ID systems is that entering the information about the status of moving things (e.g. products) requires repeated data entry which is cumbersome, expensive and error-prone. Consequently, many automated systems have been developed to perform this data entry task, and these systems are referred to as Auto ID systems (ibid). Examples of such Auto ID systems are Bar coding systems, Radio Frequency Identification (RFID) systems and Geographical Information System (GIS). Auto ID is sometimes referred to as wireless product identification (Kärkkäinen and Holmström, 2002).

Auto ID can provide frquent and unique item lvel information at all points in the value chain (Chang and McFarlane, 2004). Further, Auto ID can improve the data acquisition process, make sure that deviations are captured earlier and that the data are more complete and accurate – thereby giving managers more time to recognize a problem, assess its potential impact and take corrective action (McFarlane and Sheffi, 2003).

Bar coding is the placement of computer readable codes on items (Bowersox et al., 2002). Bar codes require line of sight sensors (Jones et al, 2004), and these sensors or scanners, represent the eye of a bar code system. A scanner, either handheld or fixed position, optically collects bar code data and converts it to usable information (Bowersox et al., op cit).

RFID is the generic name for technologies that use radio waves to automatically identify individual items that carry such identification tags (Jones et al., 2004). A RFID system generally comprises four elements (McFarlane and Sheffi, 2003): 1) A unique identification number, 2) an identity tag that are capable to communicate with the system, 3) networked RFID readers and data processing systems which are capable of collecting signals from multiple tags, and 4) one or more networked data bases that store the information. The RFID tags are either active (contains a battery so that the tag can transmit a signal) or passive (do not contain a battery and are much cheaper), and the tags can be read only, write once/read many times or read-write (Li and Visich, 2006).

There are today great expectations and almost hype about RFID in business and particular within the supply chain, both among practitioners and academics. These expectations are due to the fact of reducing cost of the RFID technology and the anticipation benefits; the possibility to collect real time information about every movement and status of each process along the whole supply chain.

A **GIS** is a computer-based system that enables capturing, modeling, storing, checking, integrating, manipulating, analyzing, and displaying of geographically referenced data using digitized maps (Turban et al., 2006). Its most distinguishing characteristic is that every record or digital object has an identified geographical location (ibid). This geographical location may be retrieved by using a **Global Positioning System (GPS)**, which is a wireless system that uses satellites to enable users to determine their position anywhere on the earth (ibid).

2.6.13 Group ware

Groupware refers to software products that support groups of people who share a common task or goal and who collaborate on its accomplishment (Turban et al., 2006). These groupware systems allow a team to work in a shared workspace toward a common goal, despite spatial and temporal separation (Deek et al., 2003). Groupware implies the use of networks to connect people electronically, even if the people are in the same room (Turban et al., op cit). There are many different approaches and technologies for the support of groups on the Internet (ibid):

- Electronic meeting systems – support virtual meetings, where members are in different locations, frequently in different countries.
- Electronic teleconferencing – is the use of electronic communication that allows two or more people at different locations to have a simultaneous conference.
- Real-time collaboration tools – helps companies bridge time and space to make decisions and to collaborate on projects. These tools support synchronous communication of graphical and text-based information

2.6.14 Putting the pieces together

Each of the ICT systems presented in chapter 2.6.4 – 2.6.13 directly affect how the Extended Enterprise operations are conducted. More specifically, all of them aid in the management of product flow throughout the value chain (Boone et al., 2007). However, disparate ICT systems and internal fragmentation make it impossible for many companies to support the required responsiveness and capability demanded by their customers (Puckridge and Woolsey, 2003). The revelation is when these systems are integrated into a holistic and comprehensive ICT system for the Extended Enterprise. The goal is to get everyone in the Extended Enterprise onto a common platform of manufacturing and logistics transactions and ICT systems for greater interorganizational “seamlessness” (Boyson et al., 1999).

The Extended Enterprise ICT system initiate activities and track information regarding processes, facilitate information sharing both within the firm and between value chain partners, and assist in management decision making (Bowersox et al., 2002). There are many components (as illustrated) that must be combined to form an integrated Extended Enterprise ICT system, and there are many ways to organize and illustrate the combined components (ibid).

Several authors have attempted to illustrate how to organize and combine the various ICT systems to support the Extended Enterprise in an intuitive and easy to comprehend manner. This is however not a plain task; with reference to the similar discussion on classification of ICT systems. These attempts range from the simple and neat illustration by Simchi-Levi et al. (2003), see figure 34a, to the more schematic and classification based illustration by Stock and Lambert (2002), see figure 34b.

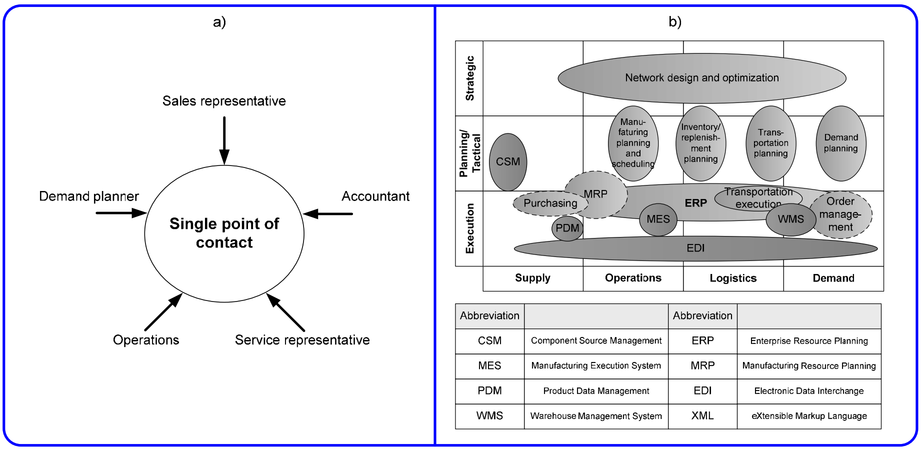

Figure 34 ICT systems supporting the Extended Enterprise

Adapted from Simchi-Levi et al. (2003) and Stock and Lambert (2002)

In figure 34a the idea is to illustrate that everyone who needs to use certain data should have access to the same real-time data through any interface device (Simchi-Levi et al., 2003), i.e. that every ICT system should be integrated into a single-point-of-contact. Figure 34b uses the same Supply Chain Planning Matrix (SCP matrix) as figure 32, with the two dimensions “planning horizon” and “supply chain process”, to illustrate the scope/reach of some of the ICT systems in the value chain. Not all discussed ICT systems in 2.6.4 – 2.6.13 are included in figure 34b, but Transport execution can be either a part of ERP systems or TMS systems. Similar, Network design and optimization, Manufacturing planning and scheduling, Inventory/replenishment planning, Transportation planning, and Demand planning are functions often included in an APS system. Further, the EDI box may be expanded to include XML and Portals. Auto ID and Groupware systems are missing. A revised version of figure 34b is illustrated in figure 35.

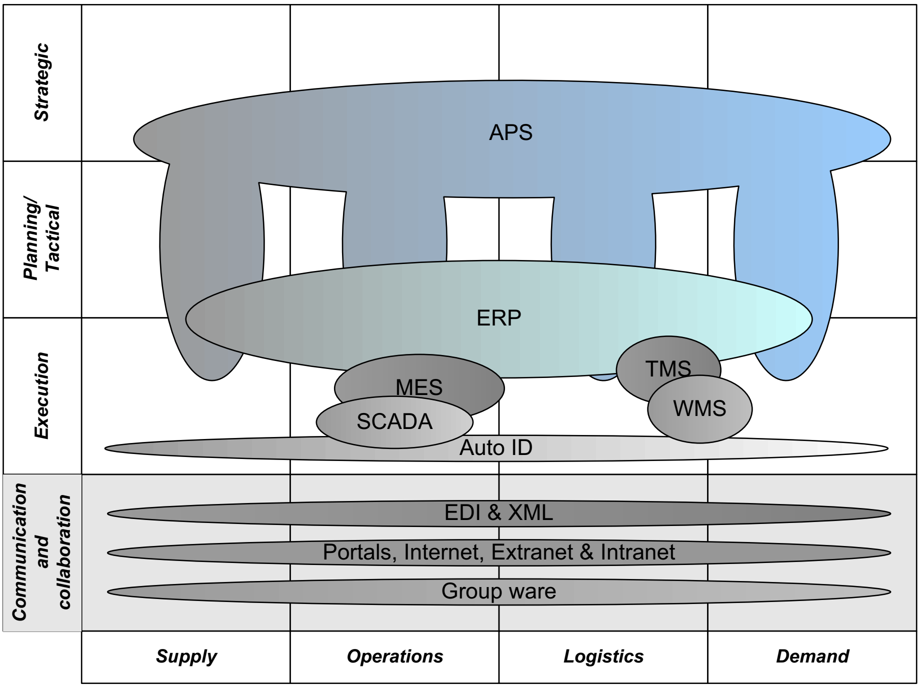

Figure 35 ICT systems in the Extended Enterprise

Figure 35 summaries the discussion regarding ICT systems in the Extended Enterprise. However, the issue of Extended Enterprise ICT systems will be further discussed and elaborated in chapter 6.6.

2.7 Summary

The objective of chapter 2 has been to introduce, define and discuss the Extended Enterprise as one perspective of value chain systems. The Extended Enterprise has been defined as: "a long-term, strategic, and ICT enabled network collaboration between at least two value chain partners (manufacturers, suppliers, transporters, warehouses, etc) which seek to integrate their operations to secure a superior value creation process (products and/or services) for its customers and a sustainable competitive position for its members".

It has been argued that companies now largely are dependet on factors outside its four walls to stay competitive and successful – thus the name Extended Enterprise. Hence, companies need to form long-term, strategic value chain collaborations with its partners. The challenge is to achieve holistic (system perspective) process integration along the value chain, create trust between the partners, establish jointly decision-making and planning and control routines, principles and mechanisms, share information, align performance measurement, and ultimately to create competitive value for the customers.

ICT has been indentified as a key enabler and support tool for the Extended Enterprise collaboration. However, most Extended Enterprises are characterized by many disparate ICT systems and internal (company wise) fragmentation, which make it impossible for many companies to support the required responsiveness and capability demanded by their customers. The objective (and the challenge) is to get all these systems on a common platform, a single-point-of-contact, which all users in the Extended Enterprise can access anywhere and anytime.

Further, manufacturing and logistics has been identified as the machinery in the Extended Enterprise. However, manufacturing and logistics operations in the Extended Enterprise spans the value chain, involves globally distributed (and independent) companies, are associated with high complexity, and are subject to high pressure regarding cost, speed, flexibility, responsiveness and quality. This challenges the management and planning and control of the operations in the Extended Enterprise.

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Chapter 3

Information visibility

3 Information visibility

Chapter 3 will introduce the concept of information visibility in the Extended Enterprise. The chapter will briefly discuss information and ICT systems in values chains, with focus on the "traditional" information flow in the Extended Enterprise, and the problems this imposes on the Extended Enterprise. Then, the information visibility concept will be introduced, followed by a detailed discussion of information sharing in the value chain. At the end, an overview of some existing information visibility initiatives/systems is given.

3.1 Introduction – the power of information

In a value chain context it is very important and critical for the value chain partners to have access to information regarding processes and activities they do not control. As companies nowadays focus on their core activities and outsource the remaining value chain operations to other business partners and parts suppliers, it is important that the company is able to monitor effectively the activities outside its boundary (Lau and Lee, 2000). To survive in this environment, companies need better information flow together with easier and quicker access to required information. This requires sharing information about all links, stages and processes involved in managing the flow of products, services, and information in the value chain. In brief, ***whether or not a company is able to compete depends heavily on the implementation and the actual running of an efficient and effective information flow system, not only within the company itself but also encompassing its business partners and suppliers*** (ibid). This is supported by Mason-Jones and Towill (1997a) who argue that ***information is the driving force for all value chains***.

3.1.1 The role of information and ICT in business

Several authors have discussed the role of *information* and *ICT* within business (and more particularly within operations, productions and logistics) and how enterprises can benefit from this (Childerhouse et al., 2003; Sanders and Premus, 2002; Carr, 2003; Bagchi and Skjoett-Larsen, 2002; Bolseth and Solem, 2001; Lau and Lee, 2000; Lee and Whang, 2000; Child and Faulkener, 1998; Bowersox and Daugherty, 1997; Closs et al., 1997; Evans and Wurster, 1997; Gustin et al., 1994; Kerr, 1989; Earl, 1989; Porter and Miller, 1985; and Parsons, 1984). With exception of Carr, every author sees ICT as a strategic weapon for achieving competitive advantage and ICT is deemed as a key enabler and driver for value chain integration and collaboration.

Earl (1989) asserts that ICT have the potential to be a strategic weapon in at least one of the following: 1) gaining competitive advantage, 2) improving productivity and performance, 3) enabling new ways of managing and organizing, and 4) developing new businesses. Carr (2003) on the other hand, claims that even though ICT's power and ubiquity have grown, its strategic importance has diminished. The core functions of ICT, data storage, data processing and data transport, have become available to all; it has become a commodity! For a more thorough discussion of ICT and ICT systems, see chapter 2.6.

In the value chain model by Porter (1985) (see chapter 2.3), information is treated as a supporting element of the value-adding process, and not as a source of value itself. Traditional managers use information that they capture on inventory, production, or logistics to help monitor or control processes, but rarely use information itself to create new value for the customer. This is supported by Sanders and Premus (2002), which state that ICT is not a source of value by itself.

However, the recent developments in ICT now allow companies to create value from information through the virtual nature of information and by taking advantages of new marketplaces (Rayport and Sviokla, 1995). According to Rayport and Sviokla (op cit) there are three ways in which information adds value:

- ***Visibility*** – information allows managers to "see" the physical and monetary flows in the value chain and thereby to better manage them.
- ***Mirroring*** – seeks to replace certain physical processes with virtual ones (e.g. virtual building and testing of prototypes in CAD systems, and automation of the information flow).
- ***Creation of new customer relationships*** – involves taking raw information and manage it in a manner that create whole new sources of value by serving a broader set of the customer needs.

Creating value in any stage of a virtual value chain involves a sequence of five activities: Gathering, organizing, selecting, synthesizing, and distributing information (ibid). Just as a company takes raw material and refines it into something useful (e.g. as in the sequence of tasks involved in assembling an automobile on a production line) so do managers today collect raw information and add value through these steps (ibid).

ICT makes it possible to process more information, more accurately, more frequently, from more sources, even from all over the globe (Boyson et al., 2003). And ICT makes it possible to digest, to understand, and to act on this growing abundance of information by using sophisticated analysis, modeling, and decision support capabilities (ibid).

Peleg and Lee (2006) point out that sharing of information and adapting the value chain ICT system are likely to improve the cooperation between value chain partners in the following ways:

- *Faster information exchange*: Substituting manual data-exchange processes with automated mechanisms substantially shortens the time involved with such activities, bringing the most updated information to the decisions makers much faster.
- *Elimination of manual processes*: The use of value chain ICT system for data exchange eliminates many of the manual operations required previously, freeing up employees for more value-added tasks.
- *Improved accuracy*: "To err is human". The elimination of manual processes reduces the chance for errors, improving the quality of the available information and allowing the business partners to base their decisions on more accurate information.
- *Increased frequency*: The considerable reduction in time required for exchanging information between business partners provides them with the opportunity to increase the frequency of such transactions. Thus, decisions can be based on more updated information.

Generally, information sharing provides substantial benefits to participating members (Simatupang and Sridharan, 2002). At the strategic level, information sharing of business objectives enables individual managers to achieve mutual understanding of competitive advantage and the system-wide value chain as a point of collaboration (Covington, 2000; in Simatupang and Sridharan, op cit). At the tactical level, the information integration helps the value chain members to mitigate demand uncertainty and cope with decision-making complexity at different levels of planning horizon and in different organizations (Lee and Wang, 2000; in Simatupang and Sridharan, op cit). Finally, information sharing is also useful when coping with the relational vulnerability of opportunistic behavior – including adverse selection and moral hazard (ibid).

3.1.2 Information in the value chain

The primary goal of ICT in the value chain is to link the point of production seamlessly with the point of delivery or purchase; the idea is to have an information trial that follows the product's physical trail (Simchi-Levi et al., 2003). According to Huang and Nof (1999) the impact of modern ICT on enterprise systems can be classified into three categories: 1) Speeding up activities, 2) Providing intelligent and autonomous decision-making processes, and 3) enabling distributed operations with collaboration. The introduction and utilization of integrated ICT for managing the value chain will enable companies to gather vital information along the whole value chain and quick act upon it and be in advance on market changes, and thereby gaining competitive advantages (Narasimhan and Kim, 2001)

The performance of a value chain relies very much on the infrastructure of the information system which provides the necessary functional support to the information value chain. It can be seen (see figure 36) that the virtual (i.e. information) value chain complements and supplements the physical value chain in order to achieve the efficient performance of the whole value chain network (Lau and Lee, 2000) (see also figure 64).

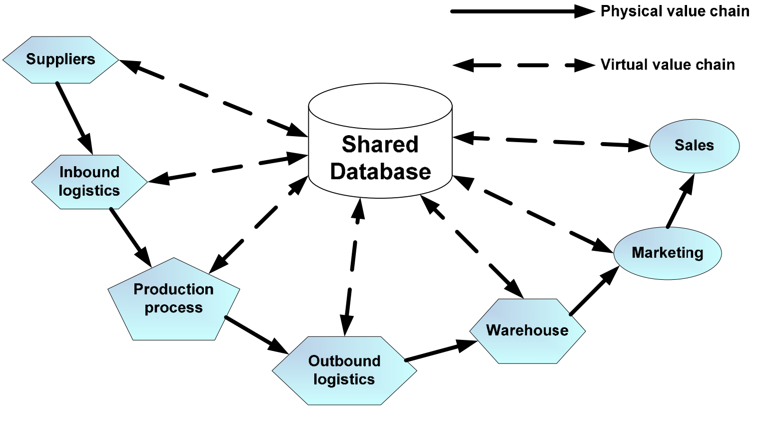

Figure 36 The virtual and physical value chain

Source: Lau and Lee (2000)

The value chain information system extends the scope and efficiency of the value chain network for the enterprise by providing an infrastructure to facilitate the efficient exchange of data among various value chain components (Lau and Lee, op cit). The value chain information system is aimed at making use of an efficient information flow mechanism for coordinating and monitoring of the operations within the value chain (ibid). With an integrated information flow system in place, companies can begin to perform value-adding activities more efficiently and effectively. In other words, information-based activities reflect the operations within the physical value chain. Moreover, the two chains must be managed distinctly, but also in concert (Rayport and Sviokla, 1995). Suppliers and business partners can adopt value-adding information processes to acquire an ability to "visualize" physical operations more effectively (Lau and Lee, op cit).

3.1.3 On-line and real-time information

Both *on-line* and *real-time* are terms/concepts that are frequently used when referring to information sharing between companies and information systems for the value chain. However, these two terms are seldom defined and explained.

On-line can be defined as:

- Connected to, served by, or available through a system and especially a computer or telecommunications system (as the Internet); also: done while connected to such a system (Merriam-Webster Online)
- A system that accepts input directly from the area where it is created. It is also a system that can return the output to the area where it is required (Yourdon, 1972; in McClellan, 2003)

Real-time can be defined as:

- The actual time during which something takes place (the computer may partly analyze the data in real time (as it comes in) (Merriam-Webster Online)
- A system that controls an environment by receiving data, processing them, and returning the results sufficiently quickly to affect the environment at that time (Martin, 1997; in McClellan, op cit).

To sum up, we can conclude that ***on-line*** is about ***availability*** through ***connected (ICT) systems*** that makes it possible to get ***access*** to ***desired information*** about occurrences that not necessarily have taken place at the same location. Whereas ***real-time*** is about ***speed*** and ***frequency*** from something happens to it is ***registered and available*** for instant use.

An on-line and real-time system is therefore a system that enables capturing and processing of data at the time of occurrence and instantly makes this data available to users at various locations, and makes these users able to respond to the occurrences.

Both on-line and real-time will be essential concepts in the development of the information visibility and visualization concepts (see also chapter 4, 5 and 6).

3.1.4 The unreleased power of information

The beauty, and therein the power of information is that information flow does not have the same lead time constraints that a production process or the material flow process has. Through the use of ICT it is possible to eliminate the information transmission lead-time from one end of the chain to the other (Mason-Jones and Towill, 1997b). Figure 37 illustrates the basic difference between the material flow and information flow in the value chain. Whereas the material flow, from source to final customer, may take days, weeks, months or even years, the information flow, from customer to source, may in principle be instant.

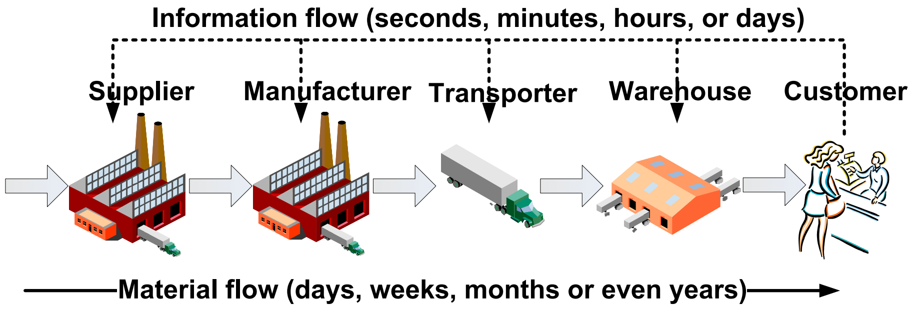

Figure 37 The power of information

Due to the difference in speed between the information flow and the material flow, a feeling/effect of seeing the future appears. It may be reasonable to make an analogy to lightning and thunder, where you may see the lightning 1-3 seconds before you are able to hear the thunder. In the same sense are companies in the value chain (e.g. manufacturer) able to foresee demand variations and new emerging trends etc from customer days, weeks or months before they are experiencing it through the material flow. The companies are therefore able to take proactive measures according to the information to achieve an improved material flow. In such an environment, there are two components of demand information that must be addressed (Hadavi, 1996; in Lummus and Vokurka, 1999): Information which allows time to sense that there is a change in demand, and information which allow companies to respond to the change.

3.2 The need for information visibility

The current and increasing interest in information visibility is motivated by many of the problems companies are facing today. This is due to global operations with many geographically dispersed value chain partners, where companies focus on their core competences and outsource the reaming operations/processes. To survive in this environment, companies need to have reliable, accurate, and timely information in order to control and monitor the activities outside it boundaries.

Lack of information or distorted information passed from one end of the value chain to the other can create significant problems (as already illustrated), including but not limited to, excessive inventory investment, poor customer service, lost revenues, misguided capacity plans, ineffective transportation, and missed production schedules (Handfield and Nichols Jr., 2002).

As Stalk and Hout (1990) neatly puts it: "***the underlying problem is that once information ages, it loses value…old data causes amplifications, delay and overhead… The only way out of this disjointed supply system between companies is to compress information flow time so that the information circulating through the system is fresh and meaningful***"

In the past, business partners used slow, manual, and error-prone collaboration tools such as phone, fax, and e-mail, which significantly limited the extent, scope, frequency, and timeliness of such information exchange, and consequently, the value of value chain integration (Peleg and Lee, 2006). Furthermore, such communication methods were not scalable in instances were high volumes of data had to be transferred on a regular basis. Consequently, the benefits that could be realized based on such forms of collaboration were usually limited (ibid).

However, the recent and rapid development within ICT (see chapter 2.6) are now offering new and seducing possibilities in gathering[34], organizing[35], selecting[6] and synthesizing[6] and distributing[36] information among the actors in the Extended Enterprise.

3.2.1 Information flow in the Extended Enterprise

The conventional information flow in the Extended Enterprise is usually in steps from plant to plant along the value chain. Information such as year plans, forecasts, orders and call offs are sent (on a regular basis with different frequency) from the customer (e.g. OEMs) to manufacturers (e.g. 1st Tiers suppliers). There is usually a delay before the data is processed by the manufacturer, e.g. in the automotive industry where 80% of the waiting time for custom vehicle is attributed to bottlenecks in the information flow at the vehicle manufacturer's headquarters – and it is more than a month before an order reaches the factory (Holweg and Pil, 2004). There is a further delay before the processed forecasts, orders and call offs are sent forward to the suppliers (e.g. 2nd Tier suppliers), and so on throughout the whole value chain. Thus, the data passed on upstream might be significantly distorted from the original data derived from the customer.

Figure 38 illustrates the information and material flow in a typical automotive value chain. As indicated above and in figure 38 is the information flow step-wise, caused by delays internally in each enterprise (as illustrated in figure 39). In the automotive industry can the lead times, from the time an end-customer order a vehicle through the different tiers of supplier, be more than 200 days with significant amounts of inventory held at each link of the value chain (dealers, OEM's, Tier-1, Tier-2, and Tier-3 suppliers) (Handfield and Nichols, 2002).

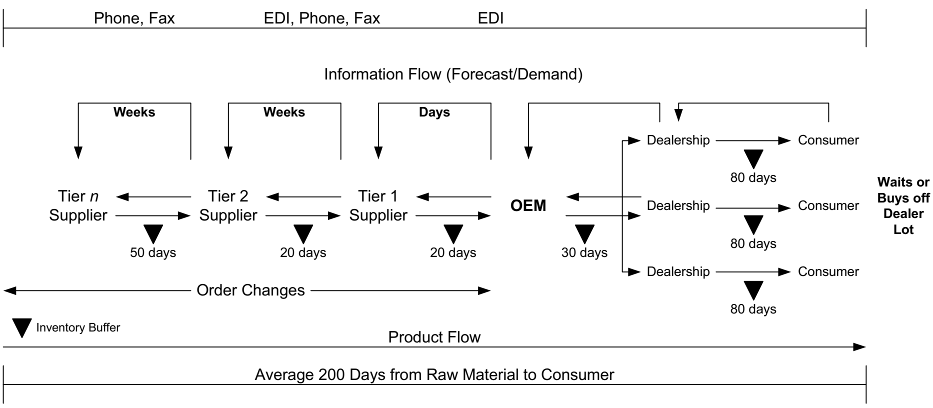

Figure 38 Information and material flow in a typical automotive vale chain

Source: Handfield and Nichols (2002)

Moreover, internally in each company in the Extended Enterprise, there might be no direct logic connection between the customer forecasts, orders and call offs and the forecasts, orders and call offs sent to suppliers. Typically there are different departments dealing with deliveries, production and purchase, with a lack of integration between these departments, as illustrated by figure 39. The result is delays and distortions through each node.

[34] e.g. RFID, GPS, PLS, etc
[35] e.g. Dashboards, Business Intellingce, Data Warehouse, etc
[36] e.g. the Internet, Portals, XMl, etc

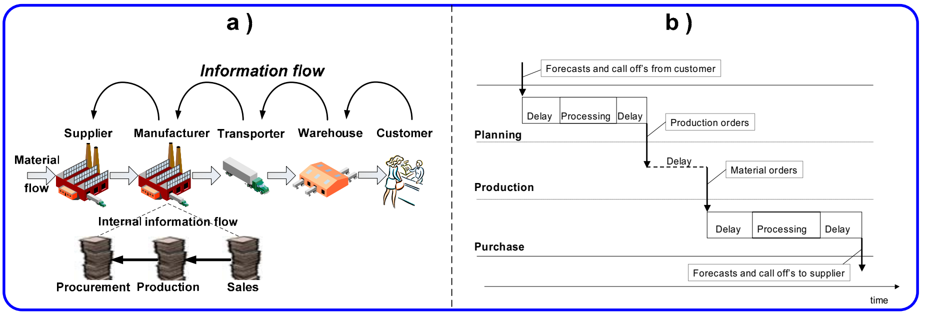

Figure 39 Traditional information flows

Source: b Martinsen et al. (2002)

Table 10 lists three typical information flow problems encountered in industrial value chains. The three examples in table 10 illustrates how information is withheld, masked and/or distorted in the value chain.

Information flow syndrome	**Typical characteristics**
”***Over to you***” (information withheld)	Supplier wins a year’s contract to supply 10 000 widgets to OEM, but customer refuses to forecast a weekly breakdown – customer says ”just deliver what we want, when we want it”
”***Badging***” (information masked)	Supplier of finished goods has no direct view of market and delivers blindly on demand to an intermediary, who “badges” before passing on to retailer; hence supplier has little opportunity for forward planning.
”***We know best***” (information distorted)	OEM provides detailed forecast throughout the chain but an intermediate player places cyclical demands on his upstream supplier even though OEM forecast proves to be reasonable accurate.

Table 10 Typical information flow problems encountered in industrial value chains

Source: Mason-Jones and Towill (1997a)

As indicated above are the information flow subject to delay, bias, and noise, or indeed may be totally absent, throughout the value chain, both internal within companies and external between companies (Mason-Jones and Towill, 1998a). In this manner, is the information flow upstream in the value chain, and thereby the production, often decoupled from the customer, and the actual demand. Hence, factories create months of finished goods inventory, but that inventory has little to do with the actual customer demand (see figure 3.3) (Holweg and Pil, op cit). In an automotive industry study, Holweg and Pil (ibid) found that fewer than 10 % of all vehicles are built to order in the US, and fewer than 50% in Europe. With few exceptions, stock levels are between one and two months, and manufactures with order-to-delivery times of less than three weeks for cars are unheard of (ibid).

White et al. (2004) have estimated the total annual costs of inadequacies in the value chain (information) infrastructure to be in excess of \$5 billion for the automotive industry, and almost \$3,9 billion for the electronics industry. So it is evident that the lack of information integration and exchange of information in the value chain is a considerable challenge and area for improvements.

To sum up; the current information flow in the vast majority of supply chains is still far from ideal (Mason-Jones and Towill, 1998b). Unfortunately, in all too many instances the old problems of distortion and magnification of order information remain, not least because the many decision processes which still remain block rapid data transference to where it is really needed. In particular, there is still much untapped mileage in seeking to improve the order fulfilment processes from utilizing undistorted point of sales information (ibid).

However, it is important to stress that, it is the quality of the information not the quantity of data which is the key enabler for improvement (Mason-Jones and Towill, 1997a).

3.2.2 The Bullwhip effect

A typical effect in value chains (as described above) is how small changes in downstream demand are dramatically amplified upstream. This is known as the Forrester effect or Bullwhip effect (Holweg and Disney, 2005; Simchi-Levi et al., 2003; McCullen and Saw, 2001; Alfnes and Strandhagen, 2000; Towill and McCullen, 1999; Towill, 1997; Metters, 1997; Lee et al., 1997a and b; Burbidge, 1984; and Forrester, 1961 and 1958),

The Forrester and/or the Bullwhip effect are not a new phenomenon, and the first academic description of the Bullwhip effect phenomenon is usually ascribed to Forrester. Forrester (1958, 1961) was working in the field of *Industrial dynamics*[37] and was studying the process of information feedback characteristics within companies and within value chains. His study led to the conclusion that an increased demand level at the final customer causes an amplified demand wave when it reaches the manufacturer level. Burbidge (1984) has called this the *Law of Industrial Dynamics*: *"If demand for products is transmitted along a series of inventories using stock control ordering, the demand variation will increase with each transfer"*.

Even though it is almost 50 years ago since Forrester presented his work within this area, companies and value chains are still struggling with the consequences of the Bullwhip effect. According to Lee et al. (2004) are the Bullwhip effect everywhere (i.e. almost every value chain are experiencing the Bullwhip today), the bullwhip effect has been viewed as one of the forces that paralyze value chains, and the Bullwhip effect has been identified as the most harmful to the efficiency of value chains.

Figure 40 illustrates 2 different ways to present how the demand amplification occurs in the value chain.

[37] Industrial dynamics is the investigation of information-feedback character of industrial systems and the use of models for the design of improved organizational form and guiding policy (Forrester, 1961)

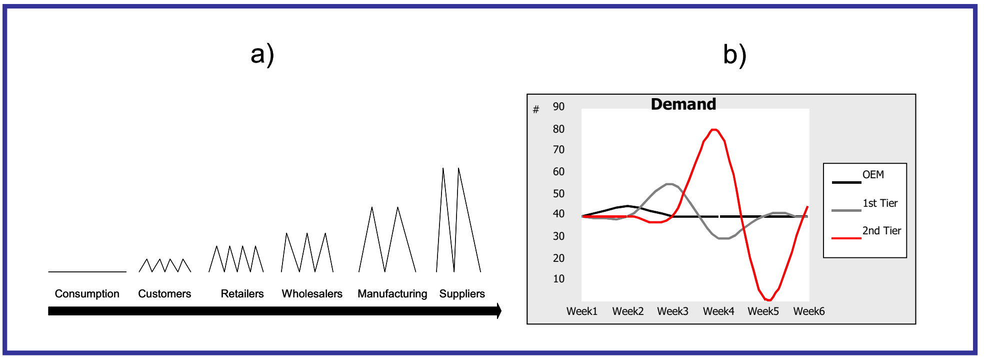

Figure 40 The Bullwhip effect

Source: a) Lee and Whang (2001), b) Strandhagen et al (2002)

Lee et al (2001, 1997a, and 1997b,) have popularized the term Bullwhip effect. In the article *The Bullwhip Effect in Supply Chain* they describe how logistics executives at Procter & Gamble examined the order patterns of one of their best selling products (Pampers) and experienced unexpected fluctuation in demand up streams in the value chain (1997b). While the consumers, in this case the babies, consumed diapers at a steady rate, the demand order variability in the value chain were amplified as they moved up the value chain. Procter & Gamble coined this phenomenon the Bullwhip effect.

Towill (1997) stress the fact that there are two specific phenomena (and just not one) which may be described as the Bullwhip (Forrester) effect:

- Demand amplification
- Triggering of rouge seasonal demands

Both are important and introduce stress and turbulence within companies and value chains.

3.2.3 Causes of the Bullwhip effect

Historically, the Bullwhip effect had been accepted as a normal occurrence and rationalized as an inevitable outcome of the order-to-delivery system that characterized the production and distribution systems of the past (Lee et al., 1997a). Since the 1950s have several authors (see Holweg and Disney (2005) for a more comprehensive historic review of the research on the Bullwhip effect.) tried to point out some of these causes of the Bullwhip effect and their relationships. From this research we can conclude that the causes of the Bullwhip effect is several and complex, see table 11.

Authors	Causes of the Bullwhip effect
Lee et al (1997b)	Demand forecast updating
	Order batching
	Price fluctuation
	Rationing and shortage gaming
Simchi-Levi et al. (2003)	Demand forecasting - gives increased variance upstream
	(Long) Lead time - requires buffers and stocks to compensate
	Batch ordering - gives larger variations than actual need upstream
	Price fluctuation - creates variations in demands
	Inflated orders - customer orders more than real demand

Stalk and Hout (1990)	Long lead times and high overheads
	Outdated ordering procedures
	Feedback lops are closed too slowly
	Too many decision makers spread throughout the chain
	An ever-changing agenda between various players
Forrester (in McClellan (n.d.))	No demand visibility along the network. Responding to current information or demand changes was not possible
	Information distortion was constant with participants affecting the process with their own interpretation of events and data
	Intentional adjustments made by one party had compounding effects at other nodes of supply chain

Table 11 Causes of the Bullwhip effect

From table 11 we can conclude that lack of *supply chain integration, coordination and information visibility*, together with poorly designed *supply chain structure* and *control and planning mechanisms* seems like obvious causes for the Bullwhip effect.

These findings are surprisingly similar to the research assumptions and problems outlined in chapter 1 of this thesis. And this further illustrate why the Bullwhip effect is such a good example of the need for information visibility in the Extended Enterprise.

The next sub-chapter will deals with how companies and Extended Enterprise can cope with the causes of the Bullwhip effect, and some of the problems outlined in chapter 1.

3.2.4 Methods for coping with the Bullwhip effect

Similar to the work presented in table 11, several authors have been working with how to avoid the Bullwhip effect. Once again, this is a complex and divers field. The causes of the Bullwhip effect origin from different aspect of business, which again implies that the action towards this phenomenon should address several areas. Table 12 summarize some of the work on coping with the Bullwhip effect.

Authors	Methods/Principles for coping with the Bullwhip effect
Lee et al. (1997b)	Avoiding multiple demand forecast updates – make downstream inventory and demand information available upstream in the value chain.
	Break order batches – companies need to devise strategies that lead to smaller batches or more frequent re-supply
	Stabilize prices – the simplest way to control the bullwhip effect caused by forward buying and diversions is to reduce both the frequency and the level of wholesale price discounting.
	Eliminate gaming in shortage situations – gaming during shortages peaks when customers have little information on the manufactures' supply situation. The sharing of capacity and inventory information helps to alleviate customers' anxiety and, consequently, lessen their need to engage in gaming.
Towill et al. (1992)	Remove distributor echelon
	Integrate information flow throughout the supply chain
	Reduce time-delays throughout the supply chain
	Improve pipeline policy and suitably modify "ordering" algorithms
	Tuning parameters of existing ordering algorithms
Towill and McCullen (1999)	Control system – this involves selection of decision support systems which contribute to the dynamic stability of the total supply chain

	Time compression – this involves the re-engineering of business processes in order to slash material flow and information flow lead times
	Information transparency – this involves sharing high integrity information between supply chain actors
	Echelon elimination – this involves the elimination of echelons and functional interfaces
Slack et al. (2001)	Information sharing – the efficient distribution of information throughout the chain can reduce demand fluctuations along the chain by linking all operations to the source of demand
	Channel alignment – this means adopting the same or similar decision-making processes throughout the chain to coordinate how and when decision are made
	Operational efficiency – this means eliminating sources of inefficiency or ineffectiveness in the chain; of particular importance is *time compression* which attempts to increase the throughput speed of the operations in the chain
Simchi-Levi et al (2003)	Reducing uncertainty – one of the most frequent suggestions for decreasing or eliminating the bullwhip effect is to reduce uncertainty throughout the supply chain by centralizing demand information, that is, by providing each stage of the supply chain complete information on actual customer demand.
	Reducing variability – the bullwhip effect can be diminished by reducing the variability inherent in the customer demand process.
	Lead time reduction - (long) lead times serve to magnify the increase in variability due to demand forecasting. Therefore, lead-time reduction can significant reduce the bullwhip effect throughout a supply chain.
	Strategic partnership – the bullwhip effect can be eliminated by engaging in any of a number of strategic partnerships, due to that these partnerships changes the way information is shared and inventory is managed within the supply chain.
Lee at al. (2004)	Information system (i.e. information visibility) – the visibility of inventory, demand, and supply in the supply chain has been at the forefront of supply chain initiatives in recent times, and new information technologies have been used to foster such sharing.
	Collaboration – the collaboration among supply chain participants and the integration of their activities and processes into a holistic chain have been at the core of the industry efforts to counter the bullwhip phenomenon.

Table 12 Coping with the Bullwhip effect

From table 12 we can conclude that *information visibility*, *integration* and *collaboration*, together with *time compression*, *improved decision support system*, and the *reduction of variability and uncertainty* are all highlighted as important principles to reduce or eliminate the Bullwhip effect.

Even though these principles are independent, they still have a mutual effect on each other. Information visibility, for example, can be one of the principles applied in order to gain time compression, improved decision support and reduction of uncertainty. To implement information visibility, on the other hand, integration and collaboration is needed.

Due to this interdependence among the principles, they all are all important in the context of this thesis.

Several other authors have addressed one or more of the elements described above in table 11 and table 12. Womack and Jones (1996, 1990) illustrates how important among other *time compression* and *echelon elimination* (waste) are in order to achieve value for the customer. In line with this works, authors like Childerhouse and Towill (2003), Alfnes and Strandhagen (2000), and Burbidge (1984), points out the importance of *time compression*, *echelon elimination*, and *information sharing* for an efficient *control system*. Simatupang and Sridharan (2002), Horvath (2001), Cox (2001a, 2001b, 2001c), Dyer (2000), Mentzer et al. (2000), Lambert et al. (1996), and Ellram and Cooper (1990) address the important issues of (value chain) power, partnerships and collaboration. The concept of supply chain risk, trust, confidence and vulnerability are discussed among other by Kidd et al. (2002), Jutter et al (2002), Christopher and Lee (2001) and Svensson (2000).

3.2.5 Information and value chain integration

Information sharing/visibility and value chain integration are pointed out as two major principles to avoid the Bullwhip effect (see table 12), and are essential in all kind of value chain systems collaborations. E.g. in Lambert et al. (1998) definition of SCM: "*the* ***integration*** *of key business processes from end user through original suppliers that provides products, services, and* ***information*** *that add value for customers and other stakeholders"*.

Information sharing can be seen upon as the foundation of value chain integration, and contrary without value chain integration it is impossible to accomplish information sharing.

Information integration refers to the management of information and knowledge flow across members of the value chain. It can be broadly classified into two groups: information sharing and collaborative planning (Kulp et al., 2004):

- Information sharing encompasses the sharing of information on demand, inventory levels at the store and/or at the retail warehouse level, and consumer research (attribute preferences, unmet needs, etc.).
- Collaborative planning covers the synchronization of decision rights, logistics, and new product development. When adopted, the parties jointly determine who is better positioned to either control the activity or determine the necessity for continued joint efforts.

The goal is to get everyone in the Extended Enterprise onto a common platform of logistics transactions and information systems for greater inter-organizational "seamlessness" or transparency resulting in faster system response time (Boyson et al., 1999). Information integration permits management to examine the operations of the organization in totality and not in a fragmented, functionally isolated manner (Bagchi and Skjoett-Larsen, 2002).

3.2.6 Information visibility – more than the Bullwhip effect

Even though the Bullwhip effect is an important problem in most value chain today, it is by far not the only reason why companies and Extended Enterprise seeks information visibility. The Bullwhip effect is however used in this thesis as an example of many of the problems companies and Extended Enterprise are experiencing, and illustrating some of the reasons why Extended Enterprise are striving to achieve information visibility.

Peleg and Lee (2006) argue that information visibility, i.e. sharing of information between value chain partners, when carrying out such processes as product development, material procurement, production planning, logistics and order fulfilment, can bring value to all parties across the Extended Enterprise. Examples of such value adding and/or improvement are (ibid):

- By obtaining and intelligently using more timely and accurate information, companies are likely to improve *production planning*, *material purchasing*, and *inventory management*, resulting in ***higher capacity utilization***, ***lower inventory levels***, ***reduced obsolescence cost***, and ***higher order fulfilment rates***.
- Through *collaborative design processes*, companies can significantly s***horten the design cycle*** and introduce ***new products that better match customer tastes***, thus giving them the opportunity to ***gain higher market share*** and ***increase their profitability***.
- *Efficient logistics networks* can further ***improve the responsiveness*** to customer preferences, ***significantly improving customer satisfaction and loyalty***.
- *Overall*, engaging in advanced collaborative initiatives may result in ***higher sales levels*** and ***increased profitability***, combined with much ***more efficient internal operations***.

3.3 Information visibility

The rationale for information visibility has been explained throughout the last pages, and is mainly due to the hurdles of information sharing in the value chain. Globally dispersed operations, characterized by a high degree of outsourcing and global suppliers and customers, have intensified the need for extensive information sharing in the value chain. With only a small portion of the operations conducted internally, the visibility and control a company have over these operations has become significantly limited (Peleg and Lee, 2006). Frequent and accurate information flow between all parties in the value chain may help companies and Extended Enterprises to gain back most of the lost visibility (ibid).

3.3.1 Definitions

Visibility can be defined *as the quality or state of being visible, where visible means capable of being seen* (Merriam-Webster Online). The term visibility has been used casually by so many disciplines, implying to different meanings that sometimes are not identical or even correlated at all (Putra and Yang, 2005):

- In aviation and navigation, *visibility* is used to refer to the distance of unimpeded visual range, because of atmospheric factors, as in visibility of 1000 meter.
- In lighting studies *visibility* relates with *glare*, or lighting indicators such as *lux*.
- Psychological and philosophical meanings of *visibility*, as implied by the English term *to see*, may imply *to understand*, instead *to view*.

Visibility was first defined for meteorological purposes *as the greatest distance at which a black object of suitable dimensions (located on the ground) can be seen and recognized when observed against the horizon sky during daylight or could be seen and recognized during the night if the general illumination were raised to the normal daylight level* (WMO, 2003).

However, this thesis is not about meteorology, aviation or navigation, but rather about Extended Enterprises and how to improve the information flow between the value chain partners. The visibility term will therefore be used in this context, as a metaphor and analogy to how visibility is used in general and more specific within aviation and meteorology. Within in the field of value chain systems and operations management is visibility one of these terms/concepts that “everybody” uses, but few define. Further, several authors address visibility from different perspectives:

- ***value chain visibility*** (e.g. Walters, 2006; Walters and Rainbird, 2004; Yang et al., 2001; Waller, 1998; Yang and Mason, 1998),
- ***supply chain visibility*** (e.g. Wei and Wang, 2007; Marufuzzaman, 2006; Schoenthaler, 2003; Simchi-Levi and Simchi-Levi, 2003; Simatupang and Sridharan, 2002),
- ***demand visibility*** (e.g. Lehtonen et al., 2005; Wanke and Zinn, 2004; Rudberg et al., 2002),
- ***information visibility*** (e.g. Wang and Wei, 2007; Marafuzzaman, op cit; Monczka et al., 2005; Wu, 2005; Handfield et al., 2004; Balasubramanian et al. 2002; Golicic et al, 2002; Handfield and Nichols Jr., 2002; Rudberg et al., op cit; Joshi, 2000; Lummus and Vorurka, 1999),
- ***process visibility*** (e.g. Kadyte, 2005; Yang and Mason, op cit) and
- ***visibility*** (e.g. Wei and Wang, 2007; Schoenthaler, 2003; Simchi-Levi and Simchi-Levi, op cit; Christopher and Lee, 2001; Rayport and Sviokla, 1995)

Even though the authors above use slightly different terms or interpretations of visibility, they are all basically addressing the same issues with just minor differences. The section below highlights some of the very few definitions of visibility found in value chain systems and operations management literature:

- Supply chain visibility is a firm's ability to collect and analyze distributed data, generate specific recommendations, and match insights to strategy (Tohamy, 2003).
- Supply chain visibility refers to providing each stage in the supply chain with complete information on customer demand and inventory levels. It also refers to the transfer of information from each stage of the supply chain on inventory and production levels, shipment status and fulfillment needs (Simchi-Levi and Simchi-Levi, 2003).
- Visibility means that important information is readily available to those who need it, inside and outside the organization, for monitoring, controlling and changing supply chain strategy and operations, from service acquisition to delivery (Schoenthaler, 2003).
- Visibility enables all supply chain members to easily see and manage the flow of products, services and information in real time or near real time, from end-to-end, as needed (Montgomery et al., 2002). True visibility is present when supply chain members can do this in concert, and they can do it across their existing technology platforms (ibid).
- Supply chain visibility is the near real-time monitoring and event management of the lifecycle of an “order” (i.e. order to cash) in terms of order, inventory, invoicing and logistics across the supply chain (Gaurav, 2006).
- Supply chain visibility is viewed as the degree to which supply chain partners have on-hand information related to demand and supply for planning and control management (Mohr and Spekman, 1994; Wei and Wang, 2007).
- Information visibility means that an information demander in a supply chain has accurate up-to-date information of critical activities and processes, such as purchasing, manufacturing, and distribution (Wang and Wei, 2007; Gustin et al., 1995).
- Information visibility within the supply chain is the process of sharing critical data required to manage the flow of products, services, and information in real time between suppliers and customers (Handfield and Nichols Jr., 2002; Handfield et al., 2004, Monczka et al., 2005).

- Visibility means how much of the operation's activities its customers experience, or how much of the operations are exposed to its customers (Slack et al., 2004).
- Visibility is the ability to see and manage the flow of products, services, and information in real time (Thompson et al., 2001).
- Visibility implies not only being able to track supply chain inventory and resources but also that information regarding available resources can be effectively evaluated and managed (Bowersox et al., 2007).

From the eleven definitions of visibility above, some important characteristics and differences can be highlighted. First, almost every definition emphasises ***information sharing*** as the critical element in visibility. Some authors also stress that the sharing of information should be in ***real-time***. Second, there seems to be a divide between those authors who regard visibility as a ***condition*** and those who regard it as a ***process*.** This is mostly a semantic difference, with few practical consequences. Third, most authors view visibility **n*ot only as an ability to se*e**, but also to ***be able to react upon the available information***. This is an enlargement of visibility concept compared to how visibility is defined in its basic form or e.g. in meteorology, aviation or navigation. Fourth, most authors focus on ***information transfer between companies***, i.e. between members in the value chain, and ***not on information flow internally within companies***. The latter aspect is also important as illustrated in chapter 3.2.1. However, the value chain focus may be explained due to the fact that most definitions are taken from value chain systems (e.g. SCM) literature. Fifth, surprisingly few (in light of the discussion made in chapter 3.1 and 3.2) authors ***link visibility to the customer and to customer demand***.

In light of the visibility definitions presented above and the discussion made due to these, information visibility will be defined and use in this thesis as: ***Information visibility is the ability to "see" (i.e. access) all relevant information, on-line and in real time, in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. This is achieved through a seamless flow of accurate and timely information (e.g. customer demand information and other operational, tactical and strategically information influencing the operations) within and between companies in the value chain***.

There are some important aspects of this information visibility definition. First, information visibility is about seeing; ***seeing more, and seeing it earlier and more clearly*** than previous. Second, information visibility is about ***seeing the business from top to bottom*** (i.e. from boardroom to shop floor) and ***horizon to horizon*** (i.e. upstream and downstream in the value chain). Third, information visibility has a ***customer demand focus***, and how to make this demand information available for every member of the value chain. According to Wanke and Zinn (2004) is information visibility also known as the Customer Order Decoupling Point (CODP)[38] (Christopher, 2000) or Order Penetration Point[39] (Sharman, 1984). However, the issue is not how far the order penetrates, but how far real demand is made visible

[38] The Customer Order Decoupling Point (CODP) defines the stage in the value chain where a particular product is linked to a specific customer order (Olhager, 2005).
[39] Order Penetration Point (OPP) is the point where product specifications typically get frozen, and as the last point at which inventory is held (Sharman, 1984). The OPP is traditionally defined as the point in the manufacturing value chain for a product, where the product is linked to a specific customer order (Olhager, 2003).

(Christopher, op cit), so in this sense information visibility is something more than the CODP. The concept of CODP is illustrated in figure 42. Fourth, information visibility is however not limited to customer demand information. Information visibility implies ***the availability of all kind of information*** regarding and/or influencing operations in the value chain. Fifth, information visibility is about ***on-line*** and ***real-time*** information. The available information needs to be timely and accurate, and easily accessible. Sixth, information visibility is about ***becoming efficient, effective and responsive***. Information visibility will enable companies in the value chain to avoid or minimize problems, improve their operations, and take advantage of opportunities that emerges.

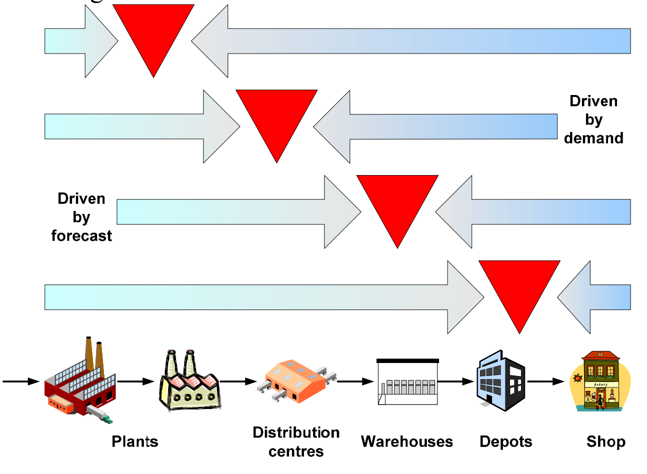

Figure 41 Customer Order Decoupling Point (CODP)

Source: Christopher (2000)

3.3.2 The information visibility concept

Information visibility implies immediate flow of correct information needed for the management and control of the processes within the Extended Enterprise. Each node can "see through" the Extended Enterprise, downstream as well as upstream, from boardroom to shop floor. Information such as year plans, forecasts, call-offs/orders, order status, production schedule, and inventory levels etc, are online and real-time available throughout the Extended Enterprise.

However, the information sharing should not only be limited to operational information, but also include strategic and tactical information. Real-time and on-line strategic and tactical information is important for value chain members to lower uncertainty, improve coordination, and enhance customer satisfaction (Wei and Wang, 2007; and Barua et al., 2004). Further, it should give the ability to know immediately (or even better; in advance) when, where, how and why a problem is occurring. Because it immediately permits alerts regarding when, where, and why a problem or changes will occur, information visibility allows managers to respond in a manner that facilitates better decision making, rather than last minute reaction (Montgomery et al., 2002). Although, problems such as shortages, changes in customer orders, engineering changes, obsolete inventory, and equipment failures can still occur with a visibility system in place, the effects of these problems are less than if the participants in the value chain were not made aware of these problems until a later date (Handfield et al., 2004). In other words, information visibility may be able to turn a potential $500 000 problem into a $5 000 problem (ibid).

In line with this, claim Koudal and Coleman (2005) that top-performing global companies have better visibility upstream and downstream in the value chain because of better information on future scenarios, product profitability, and manufacturing and distribution costs. This allows them to generate more and better ideas; evaluate them more effectively; and exploit them where, when, and in ways that hold the most promise (ibid).

Figure 42 illustrates the information visibility concept in a value chain with several actors. The "ability to see" is represented by four "eyes" enabling both internal integration and alignment (from boardroom to shop floor, and visa versa) and external integration and alignment (upstream and down stream).

In figure 42 there is a great emphasis on the external and internal integration and alignment. This is due to the problems addressed in chapter 1.4.3, with *lack of holistic thinking regarding operations, the great divide,* and *not being able to see the big picture.* True information visibility is only achieved with a combination of internal and external integration and alignment, where information ranging from the shop floor to the board room is made available for all value chain partners.

As figure 42 indicates is information visibility in the Extended Enterprise a comprehensive task. People, processes and IT systems needs to be integrated in order to provide a proper flow of information between the partners in the Extended Enterprise. In addition there needs to be an established consensus among the partners on which information that should be shared and distributed along the value chain. This is a question (among others) about power and trust between the partners.

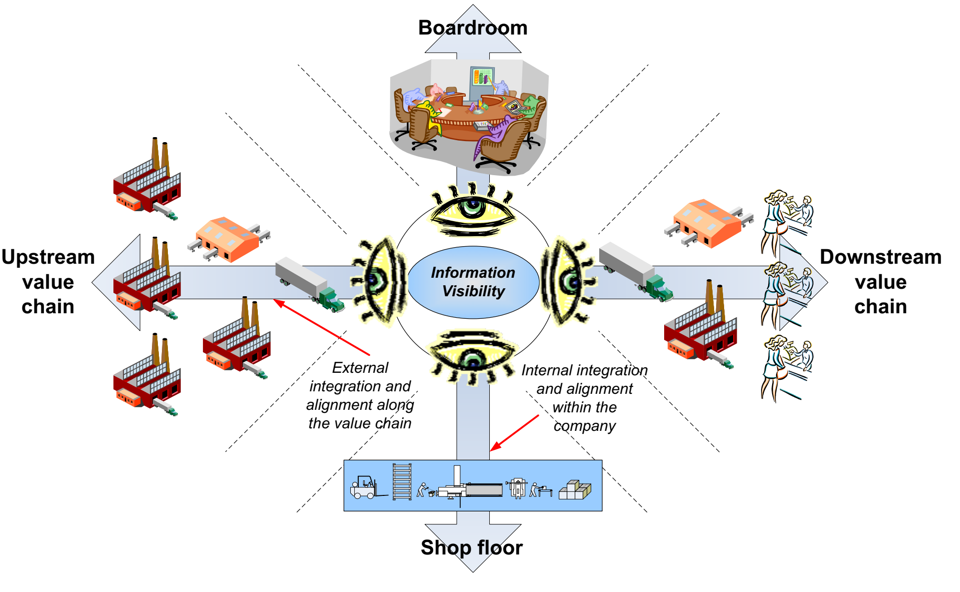

Figure 42 Information visibility in the Extended Enterprise

Balasubramanian et al. (2002) raise some important question regarding achieving visibility (these questions can been interpreted as boundaries involved in information visibility):

- Who has access to information?

- o What information are they allowed to see?
- o Where they have access to this information?
- o Why this information is pertinent to the overall information visibility of the value chain?

These questions and others will be dealt with in the following of this chapter (and further in chapter 5). But before going into more detail about information visibility, it is necessary to take one step back and make some clarifications.

3.3.3 Related terms and concepts

When discussing the concept of information visibility, very often several related terms and concepts are brought into the discussion. Table 13 gives and overview of some of these terms and concepts, and tries to relate them to information visibility.

Terms and concepts	***Definition and description***	***Relation to information visibility***
Transparency/ Transparent	Transparency in companies and in the value chain, is use as an analogy to geology, where geologists have attributed characteristics of minerals in terms of the amount of light that can pass through them (interacting with the surface) (Lamming et al., 2004). The light is analogous to information and knowledge (ibid.). The state where light enters and exits the surface of the substance and passes through its structure with alteration is called transparent or clarity (Lamming et al.,2005; Lamming et al., 2004, Lamming et al., 2001). Aubert et al. (2003) define transparency as the ease with which information that is passed from one task in a process to another can be understood.	When referring to value chain systems, visibility and transparency are basically addressing the same issues. However, visibility is a more incorporated term and more frequently used than transparency. The dominant use of the term transparency in business and government is in association with openness and anti-corruption measures (e.g. Transparency International).
Connectivity	Byrd and Turner (2000) define connectivity as the ability of any technology component to attach to any of the other components inside and outside the organizational environment. Fawcett et al. (2005) point out that connectivity is one out of two dimensions of information integration (the other dimension is willingness), and define connectivity as the technological capability to extract, quantify and share information.	Connectivity is the framework that enables end-to-end visibility (Montgomery et al., 2002). Connectivity provides (ibid): • An adaptive platform that supports an information backbone • Cross-division and cross enterprise integration • Centralized data repository to collect, store, organize and cross-reference extended value chain data.
Interoperability	Interoperability is defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged (Blanc, 2005). Morell and Phelps (2001) define interoperability as the flow of information from one system to another without the need for human intervention. The term manufacturing interoperability refers to the ability to seamlessly share	Interoperability is, like connectivity, also close connected to information integration, and therefore an important enabler for visibility. Interoperability can be viewed as step further than connectivity. Whereas

Terms and concepts	*Definition and description*	*Relation to information visibility*
	technical and business information throughout an extended manufacturing enterprise (Ray, n.d.; Ray and Jones, 2006).	connectivity enables systems to talk to each other, interoperability enables system to understand each other, without intervention. This is achieved through the use of standards, semantics, and ontology.

Table 13 Related terms and concepts

In addition to the terms listed in table 3.4, are ***Event and Exception Management*** often used in association with information visibility. These two concepts were discussed in chapter 2.5.2.

3.3.4 The four construct of information visibility

According to Wei and Wang (2007) do information visibility[40] consists of four important constructs: *Sensing for visibility*, *learning for visibility*, *coordinating for visibility*, and *integrating for visibility*.

These four important constructs can shortly be described as (ibid):

- ***Sensing for visibility*** is important from the dynamic capabilities view as it represents a firm's ability to sense and acquire real-time information about external, changing environments and to adjust its actions accordingly. In order to react to change, firms in supply chains need to obtain sensing for visibility in the following information areas: information about external-sensed events and information about supply chain change (Gosain et al., 2004). Sharing such information allows a firm to sense the needs of its partners and also communicate its own needs to the partners (Gosain et al., 2004). Firms that engage in broader information exchanges with current partners, including product changes, customer preference changes, and demand changes, are likely to be aware of new opportunities and may be able to sense and adapt to key supply chain events (Madhavan et al., 1998).
- ***Learning for visibility*** represents the extent to which a firm can learn new information and knowledge from supply chain partners. As external knowledge is fundamental to building capabilities, a firm can extend its knowledge base from supply chain relationships and explore the external sources of knowledge to improve performance (Johnson and Sohi, 2004; Eisenhardt and Martin, 2000; Teece et al., 1997).
- ***Coordinating for visibility*** is central for effective decision-making in a supply chain (Sahin and Robinson, 2002). Complete information to support specific decision-making can align all decisions to accomplish global system objectives and improve supply chain performance by effective resource allocation. This shared information provides visibility to coordinate the flow of products in the supply chain (Simatupang et al., 2004).
- ***Integrating for visibility*** emphasizes the information that can help arriving at collaborative goals and building up a collective identity for a supply chain. The integration of external activities and technologies is important for creating strategic advantage (Teece et al., 1997). Information sharing facilitates the creation of collective meanings and consensus on actions among partners (Gosain et al., 2004). It provides the understanding of each firm's capabilities, strengths, goals, and skills and helps achieve goal congruence in a supply chain (Jap, 1999). As goals become increasingly aligned, the perceived accomplishment of common goals is an important

[40] Wei and Wang (2007) use the term *supply chain visibility*

facilitating condition to achieve strategic outcomes. Long-term, collaborative relationships utilizing data exchange will display greater level of integration (Elgarah et al., 2005). In this sense, integrating for visibility can help create a supply chain identity and reach a consensus on supply chain goals and actions

These four constructs of information visibility are all relevant and included in the thesis. They will however not be treated and further presented on an individual basis, but rather be included into the information visibility concept.

3.3.5 Power and risks

When information is shared, an important strategic issue is the level of information sharing (Seidmann and Sundararajan, 1998). If sharing information generates value, one might argue, then why not make all relevant information available? As the parties in the value chain (in this case a buyer-seller relationships) move towards sharing higher levels of information, the marginal value from sharing this information (i.e. the value per additional unit of information shared) will tend to reduce. Simultaneously, the relative effect that sharing this information has on its bargaining position will tend to increase, i.e. the marginal cost of sharing information will increase. At some point, the cost of sharing additional information will outweigh the benefits, and this is the point at which the buyer will stop (ibid). This idea is illustrated in figure 43.

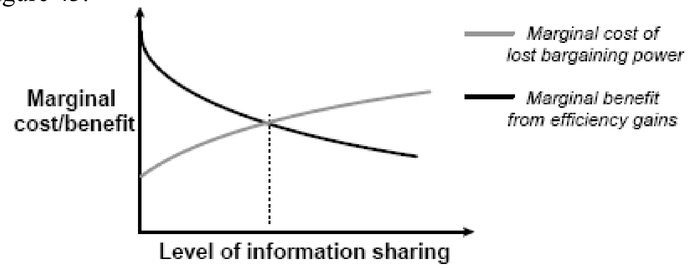

Figure 43 Tradeoffs in information sharing

Source: Seidmann and Sundararajan (1998)

Another issue is that of control. There is a limit to the gains that one can achieve from sharing only information; more value can be added when decision rights and authority related to that information are also transferred from within the organization to an external business partner (ibid).

Handfield and Nichols (2002) points out that in addition to power and control, is risk an important issue when addressing information sharing in the value chain. Risks occur when each firm must rely on other value chain members, as well as its own efforts, to determine the success of the value chain (ibid).

Stallkamp (2005) on the other hand, stress that the adversarial type of behaviour, as illustrated in figure 43 and described by Seidmann and Sundararajan (1998) where value chain partners are struggling for power, is out dated. He argues that companies needs to move away from conflicts and towards collaborations. This is supported in this thesis and is also one of the major fundaments of the Extended Enterprise thinking.

3.3.6 Information visibility benefits

The benefits of Extended Enterprise visibility are numerous. Receiving and conveying the correct information will ensure that the suppliers are aware of what needs to be produced, while at the same time, the buying firm is sure that it is possible to receive ordered quantities on time, every time (Handfield and Nichols, 2002). *The most important benefit* of a visibility system is not that the system is able to correct a supply chain problem, but that it allows people *to become aware of problems earlier*, and thus take corrective action more quickly than they would otherwise (ibid). The benefits of information visibility include *reduced lead times*, *improved constraints management*, *better decision making*, *lower costs*, and *increased profits* (Monczka et al., 2005). Although problems such as shortages, changes in customer orders, engineering changes, obsolete inventory, and equipment failures can still occur with a visibility system in place, the effects of these problems are less than if the participants in the value chain were not made aware of these problems until a later date (ibid).

Christopher and Lee (2001) points out that information visibility is one of the main elements for breaking the risk spiral in supply chains. By doing so, financial, chaos, decision and markets risk in the supply chain will be reduced, and supply chain confidence can be restored. In addition to reduced Bullwhip Effect, additional benefits can be achieved by closer information sharing between actors in a supply chain. Some of these are (Lee and Whang, 2001):

- *Early problem detection,*
- *Faster response,*
- *Trust building,*
- *Lower cost,*
- *Optimized capacity utilization, and*
- *Improved service*

Balasurbramanian et al. (2002) claims that increasing information visibility will help companies reach their overall goal of *increased stockholder value* through *revenue growth, asset utilization and cost reduction*.

Montgomery et al. (2002) argue that in addition to creating an adaptive value chain that is capable of effectively and efficiently responding to changing environment conditions, the proven outcomes in achieving visibility include:

- *Increased ability to do demand-driven replenishment*
- *Lower inventory levels*
- *Reduced cycle times*
- *Use of more cost-effective transportation of finished products*

According to Handfield et al. (2004) do a visibility system results in the following additional benefits that promote improved value chain performance:

- *Breaks organizational barriers* – enables sharing of mission-critical information about business activities and interaction on a near real-time basis across the supply chain.
- *Builds visibility into value chain* – provides people a real-time snapshot of value chain performance metrics.
- *Managing by metrics* – Aligns performance metrics with cross-organizational business processes and assigns ownership of processes and metrics to specific individuals.

- *Reduces the decision cycle process* – allows an upstream or downstream participant to respond to market or customer demand in hours or days, not weeks and months.
- *Encourages decision-making collaboration* – Facilitated the ability to make decisions collaboratively on the Internet, bringing relevant internal and external stakeholders into the process.
- *Reduces opportunity and problem resolution latency* – Measures and monitors value chain activities iteratively allowing people to quickly respond to events as they occur.

To sum up, we can conclude that the benefits of information visibility are wide-spread and far-reaching. These benefits are inter-related with each other and results in an integrated, responsive, leaner and profitable value chain.

3.4 Information sharing

One of the main considerations with information visibility is information sharing and deciding what types of information to share. Information sharing can be defined as the act of disseminating common understanding among participating members (Simatupang et al., 2004; Simatupang et al., 2002).

3.4.1 Sharing of information

At first glance, the diversity of the content of information, and the large number of sharing options makes it seemingly impossible to classify the nature or level of information sharing between companies (Seidmann and Sundarajan, 1998). Sun and Yen (2005) refer to information-sharing as the activities that distribute useful information among multiple entities (people, systems, or organizational units) in an open environment, and point out that sharing information should consider four questions: 1) what to share, 2) whom to share with, 3) how to share, and 4) when to share.

These four questions, together with the discussion made in this sub-chapter, will result in the information sharing requirements made in chapter 5.2.3.

According to Seidman and Sundarajan (op cit) there are four primary levels at which firms can share information:

- ***Ordering information*** – involves superior exchange of transaction level information (like quantities and prices) through EDI and related technology.
- ***Operational information*** – involves sharing select operational information (such as inventory levels) in order to exploit superior expertise across organizational boundaries, and possibly to further improve efficiency.
- ***Strategic information*** – the information shared has strategic value to the party that receives the information.
- ***Strategic and competitive information*** – the information adds both strategic and competitive value to the party that receives it.

Derrick (2003) proposes three different information sharing categorizes based on the time frame of the information:

- ***Execution time frames*** - companies most readily share information associated with the execution (day-to-day and hour-to-hour) time frame. Data-exchange activities here include information that pertains to automatic replenishment, vendor managed inventory and transactional collaboration in areas such as procurement, invoicing and billing.

- *Tactical time frames* - less common, but potentially more lucrative, are information-sharing activities associated with a tactical or seasonal time frame such as demand forecasting, new product introductions, end-of-product-life planning and materials planning.
- *Strategic time frames* - longer-term still is the strategic time frame, another under-utilized means of improving performance by sharing information with supply chain partners. In fact, the opportunities to remove costs and increase business effectiveness are particularly significant in this area: Tighter communication about product designs, product life cycle planning, financial planning and category planning can save companies money and even enable them to make more enlightened business decisions.

These two classifications made by Seidmann and Sundarajan (1998) and Derrick (2003) seem to be very much in line, and both stress that sharing of information should range from operational data to important strategic information.

Seidmann, Sundarajan and Derrick are however not the only authors how have addressed the issue of what information to share in the value chain. Table 14 gives an outline of which kind of information different authors mentions should be transferred between value chain partners.

Authors	Types of shared information	Comments
McClellan (2003)	Production planning	These types of information are specified in a collaborative manufacturing context, very similar to the Extended Enterprise context
	Inventory management	
	Quality assurance management	
	Schedule revisions	
	Material location	
	Production variances	
	Statistical process control	
	Engineering change orders	
Lee and Whang (2000)	Inventory level	Access to value chain inventory status can contribute to lowering the total inventory level in the value chain.
	Sales data	Seek to substitute orders with Point of sales data.
	Order status for tracking/tracing	The key benefit of this type of information sharing is the improvement of the quality of customer service, reduction in payment cycle, and saving in labour cost of manual operations.
	Sales forecast	The common form of forecast sharing involves a downstream site sharing the information with the supplier, as it is closer to the market and is thus better positioned to forecast future market demand.
	Production/delivery schedule	A manufacturer could make use of its supplier's production or delivery schedule to improve its own production schedule.
	Others	Performance metrics and capacity
Handfield and Nichols	Material releases	These are identified as most critical

Authors	Types of shared information	Comments
(2002)	Material requirements	
	Inventory	
	Order status	
	Sales forecast	
	Rejection of order	
	Quality specifications	
	Material budget	These are identified as non-critical
	Acknowledgment of order	
	Payment	
	Manufacturing capacity	
	Maximum capacity	Identified as minimum starting point of information sharing by different industry standards
	Lead times	
	Forecast	
	Purchase orders	
	Blanket contracts	
	Demand pull releases	
	Purchase order change orders	
	Advanced shipping notice	
	Invoices	
	Identifications of bottlenecks	
	On-time delivery	Performance measurements sharing between supply partners
	Quantity discrepancies	
	Past due orders	
	Planned receipts versus due dates	
	Items likely to become past due date	
	Predetermined performance criteria versus outcomes	
Christopher and Lee (2001)	Inventory	This information should be accurate, timely and accessible for all parties.
	Demand	
	Forecast	
	Production and shipment plans	
	Work in progress	
	Yields	
	Capacity	
	Backlogs	
Simatupang et al. (2004) and Simatupang and Sridharan (2002)	Customer needs	
	Customer demand	
	Product related data	
	Cost related data	
	Process related data	e.g. forecasting, ordering, delivering, replenishing, and servicing
	Performance metrics	e.g. time, quality, costs, and flexibility, etc
	The availability of resources	e.g. capacity, inventory, funds, and capability
	The status of contract	
Balasubramanian et al.	Order status	These four is regarded best practice

Authors	Types of shared information	Comments
(2002)	Sales forecast	
	Material requirements	
	Supplier's current inventory	
	Manufacturing capacity	Make sure that suppliers can supply the amount needed and promised on time.
	Manufacturing lead times	
	Delivery information	The importance of shipping method and information regarding transportation is directly related to the distance from suppliers.
	Tracking order responses	This information is important, first, because a higher order response rate means less time waiting or having to go to other suppliers; and second, because the system lets workers know which suppliers are the most consistent and reliable.
	Performance measurements	Communicating closely in this area makes both the supplier and the buyer aware of any existing problems and also facilities quicker problem solving.

Table 14 Types of shard information

In addition to the authors mention in table 14, do Lummus and Vokurka (1999) list the different type of information shared in the value chain grouped according to the various actors in the value chain (i.e. answering Sun and Yen's second question), see table 15.

Suppliers	***Manufacturers***	***Carriers***	***Dristibuters***	***Retailers***	***Consumers***
On-hand inventory Material production schedule Actual production completed Manufacturer's orders Shipping notices	On-hand inventory Material production schedule Actual production completed Summarized demand Distributor's orders Customer direct orders CRP customer inventory	In-transit inventory Planned shipments Delivery schedules	On-hand inventory Warehouse space availability Retailers' orders Shipment load parameters Shipping notices Shipment history Trade deals (forecast)	On-hand inventory Consumer dales data (POS data) Planned promotion quantities In-store display requirements Account deals (forecast)	Demand (market forecast) Consumer promotions (forecast)

	Shipment load parameters Shipping notices				

Table 15 Shared information requirements

Source: Lummus and Vokurka (1999)

Both table 14 and 15 will serve, together with the two cases, as input to the requirements for an information visibility systems made in chapter 5.2.3.

The frequency of information exchange is also important (Sun and Yen's fourth question). Whatever the information is used for, its value is dependent on its *half-life*. Half-life of information refers to how quickly the information becomes dated or obsolete; some information has a higher half-life, while other has a very short half-life (Pant and Ravichandran, 2001). In some cases, information must be exchanged in absolute real-time, while in some other cases information sharing can be, and even should be, delayed. Consequently, how quickly information needs to be exchanged between processes becomes an important information infrastructure design issue (ibid).

3.4.2 Quality of information

However, it is not only what kind of information that is shared that is important; the quality for the information is of equal importance. Each type of information varies in how finely it measures the relevant information (i.e. its precision), how accurately it can be transmitted between the parties (i.e. its reliability), and how it can be used to create value for the chain (i.e. its outcome) (Kulp et al., 2004). Bozarth and Handfiled (2006) suggest to develop a *information flow profile*, a tool that decision makers use to graph the relative performance of an information flow along a set of performance dimensions:

- ***Accuracy*** – Information need to be 100% accurate, in order to not create problems with the planning and execution of supply chain processes.
- ***Timeliness*** – Information should not be delayed before delivered to parties of software applications that need it.
- ***Reliability*** – Information flows should not "lose" important data or be subject to unexpected interruptions.
- ***Form and detail*** – Information flows should be in a form useful to the particular need at hand.
- ***Availability*** – Information should be available to all people and applications that require it.

Figure 44 illustrate a blank and filled (fictitious) information flow profile.

A perfect information flow is one that fully satisfies all dimensions. By profiling an information flow and seeing which dimensions come up short, decision makers can get a picture of exactly where they need to focus their improvement efforts (ibid).

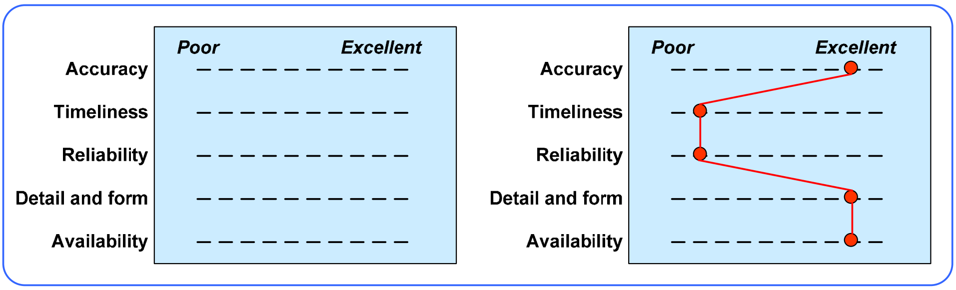

Figure 44 Information flow profile

Source: Bozarth and Handfield (2006)

According to Dedeke (2005) there are basically two approaches to improve the quality of information in the value chain. The first approach focuses on the minimization and elimination of the propensity of a process to yield outcomes with variations that fall outside acceptable norms. The second approach assimilates the concept of value to the customer. The two are not mutually exclusive, but it is important to identify the difference between managing information chains for variations and managing information chains for value (ibid). The two approaches are further described in table 16.

The variation-centered approach	The value-improvement approach
1) Capturing information only once, as close to the origin as possible, 2) Eliminating human error by capturing data electronically wherever possible 3) Using a single database wherever feasible 4) Eliminating all unnecessary handling of data by intermediaries 5) Placing accountability on the creators of data 6) Ensuring proper training 7) Defining the targets and measures of information quality	1) Enable actors to track flows and actions of the information chains 2) Enable them to consolidate information activities such as forecasting, planning, logistics, and purchasing 3) Permit them to consolidate the management of shared resources by enabling visibility across business units and territorial boundaries.

Table 16 Approaches for improving the quality of information chains

Source: Dedeke (2005)

3.4.3 Sources of information

Today's businesses have at their disposal vast stores of information that come in a variety of forms: records, instructions, designs, blueprints, maps, images, sounds, metadata, detailed data, and summarized data, to name a few (Pierce, 2005). This information may be stored in places ranging from file cabinets to databases and from library shelves to the Internet (ibid).

Extended Enterprise information systems require a great deal of data input, both from automated sources (software applications, control systems, bar code readers, sensors, analytical instruments) and manual interactions (White et al., 2004). In an ideal system, each piece of data would be entered only once and be available to any system in the information network that needs it (ibid).

Sources of such information already exist within several independent IT systems in enterprises. According to Ross et al. (2004) does a traditional (average) value chain consists of about 60 data sources, see figure 45. McClellan (2003) address the issue of data sources from a manufacturing perspective, and lists 12 different sources of data (e.g. ERP systems, MES systems, SPC systems, SCADA/HMI systems, etc) within a manufacturing facility. In this regard it seems, for a value chain consisting of several manufacturer and other members, like the estimate of 60 data sources are a bit too low. Some of the IT systems (i.e. sources) listed by McClellan and Ross et al. are described in chapter 2.7.

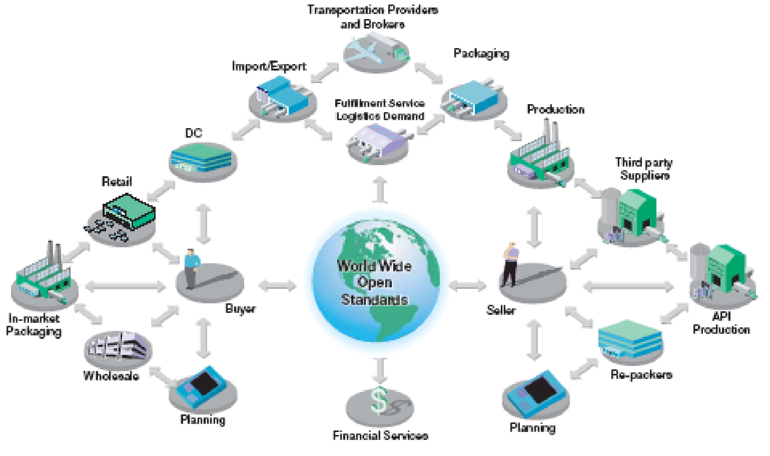

Figure 45 Data sources in the value chain

Source Ross et al. (2004)

With at least 60 different data sources in the value, this would require up to 3540 (60X59) interfaces with point-to-point integration of these data sources. Further, when the data from these various sources are collected, integrated, and transformed into information for all the products and customers in a value chain, the amount of information to be shared is almost impossible to comprehend (Moore et al., 2006). Consider just one of these data sources: A large consumer package goods company ships billions of units each year, and those units often have three or more SKU[41] numbers and descriptions as they travel through the supply chain (Moore et al., 2005). Handling this amount of information is a comprehensive task, particularly on a manual basis which makes it exponentially more costly and time consuming.

The challenge is to enable the flow of information between these sources, through connectivity, interoperability, data cleanliness, accuracy and availability. When this data is collected, integrated, and presented as information, it transforms the logistics functions from post-events analysis to a real-time adaptive supply chain (Ross et al., 2004).

However, the current situation is far from as ideal as described above. White et al. (2004) have made a study of automotive and electronic value chains, and concluded that:

- Manual data entry is widespread, even when machine sources are available; critical information is often manually re-entered at many points in the chain.
- Interventions from purchasing clerks, order processors, and expediters are required to maintain supply-chain information flows.
- The use of translators to convert data from one format to another is almost universal, even between systems that are nominally compliant with established protocols.

[41] SKU = Stock Keeping Unit

- Organizations of all sizes and across industry tiers use “informed” estimates rather than actual or production plan data in scheduling, materials management, and expediting.
- Large numbers of firms, especially in the lower tiers, simply operate without essential data.

Similarly have Ross et al. (2004) conducted a large study in the US, where almost 400 companies where asked how they interchanges orders with their customer and suppliers. According to this study, see figure 46, do the majority of the companies communicate with their suppliers and customer by e-mail or telephone.

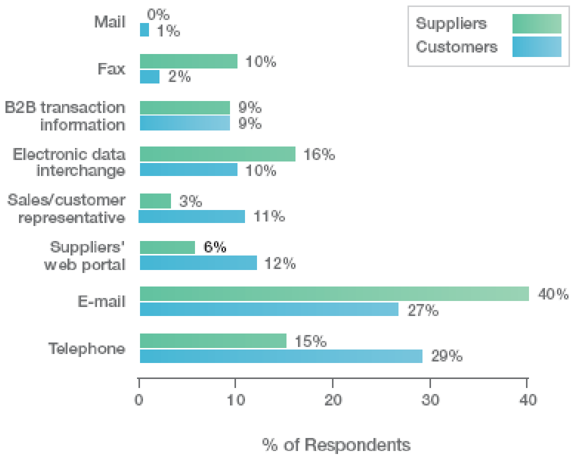

Figure 46 How do users primarily communicate regarding order status

Source: Ross (2004)

3.4.4 Hurdles of information sharing in the value chain

Until recently, many firms regarded their information and knowledge base as a proprietary asset (Kulp et al., 2004). These firms hesitated to share information with any external entity for fear it would make them strategically vulnerable (Spekman, 1998; in Kulp et al., op cit). In most value chains, both retailers and manufacturers feared that such information would be leaked to competitors or would be used to exploit the divulging party in the future (Day, 1994; in Kulp et al., op cit).

This is however not the only hurdle of information sharing in the value chain. Even with systems, as illustrated in figure 36, there are problems. There is always plenty of data available, but the real difficulty is finding the hidden information therein which is capable of leveraging improved supply chain performance (Popp, 2000). This is supported by Mason-Jones and Towill (1997a) who point out that even though there is a vast amount of data that move through companies and the value chains, companies can only thrive on information that is timely and free of bias and noise. Childerhouse et al (2003) breaks this problem into two factors:

- Internal factors – the difficulty here is bringing all data together to enable meaningful management and analysis

- o External factors – much the same difficulties as the internals, but also the opportunistic and adversarial behavior of the supply chain partners becomes a problem

One of the main issues considering information sharing is deciding who will be included in the system; it is important to ensure that every participant in the system creates added value. There is no reason to share information with suppliers that will not benefit from the information, and especially not if the end customer will not be affected (Balasubramanian et al., 2002). It is important to state that information should be available for anyone who can use it in a beneficial way for the organization. However, to ensure consistency and confidentiality very few people per supplier should be directly involved in the information sharing (ibid).

Bowersox et al. (2002) illustrate the fact that the shift in mentality from need to know to relevant information sharing is a difficult transition, but points out that there is today a shift from information hoarding to information sharing. They mention four reasons why this is so difficult (ibid):

- o Effective information sharing is heavily dependent on trust beginning within the firm and ultimately extending to supply chain partners.
- o Many organizations will not share forecast or planning data under any circumstances while others have adopted the practice of selling it to third party provider of competitive data
- o Organizations that view information as a key resource manage its exchange in a confidential manner to reduce conflict when conducting business with competing suppliers or in serving competing customers
- o Information sharing may take many forms

The reasons mentioned by Bowersox et al (ibid) is supported by Bolseth et al (2002). Similar do Lee and Whang suggest five hurdles for information sharing in the supply chain (2000):

- o The foremost is that of aligning incentives of different partners
- o The confidentiality of information shared
- o The technology constraint
- o The timeliness and accuracy of the shared information could be another major hurdle
- o Information sharing is only an enabler for better coordination and planning of the supply chain. Hence, companies must develop capabilities to utilize the shared information in an effective way.

Boysen et al. (2003) also stress that the exchange of information between companies is not as easy as it seems. Many different systems and standards are used, the number of peer-to-peer relations with other companies in the network is usually too large to manage, most systems are not open for easy exchange of information with other systems, and most companies are very reluctant to share information with other companies in the first place (ibid).

3.4.5 Information sharing models – system integration

However, several combined trends have helped change the apprehensive attitude towards value chain information sharing and coordination (Kulp et al., 2004):

- o First of all, the ability to mange knowledge within and across organizations has greatly increased. Heavy investment in IT, both equipment and personnel, have created an infrastructure (as described in figure 36) for capturing, disseminating, and monitoring information assets.

- Second, many manufacturers and retail chains expanded both nationally and globally. This created a need for more formal mechanisms to coordinate value chain activities, as the problems alluded to earlier became much more acute.
- Lastly, and perhaps most importantly, once mechanisms to improve physical product flows and financial arrangements became commonplace, they no longer served as a basis for sustaining above industry average profits. This left the improvement of information flows an untapped source of value creation, both internally within the chain (i.e. directly improving the operations between manufacturer and retailer) and externally (i.e. to end customer).

System (or enterprise/application) integration can be viewed as the technical aspect of information sharing and visibility in the value chain, and address the first trend outlined by Kulp et al. (2004). System integration has been driven by a number of emerging developments, including the need to expose information found in existing systems to the Web, the need to participate in electronic marketplaces, the need to integrate the value chain, and most importantly, the need for existing system to finally share information and common processes (Linthicum, 2004). Several authors have defined system/enterprise/application integration:

- ***System integration*** refers to the extent to which a firm integrates its various ICT systems to provide visibility to customer and supplier data and to allow online information sharing and transaction execution across the value chain (Barua et al., 2004).
- ***Enterprise integration*** reflects the capability to integrate a variety of different system functionalities (Lee et al., 2003).
- ***Application integration*** is a strategic approach to binding many information systems together, at both the service and information levels, supporting their ability to exchange information and leverage processes in real time (Linthicum, op cit).

It is apparent that these three terms are coincident, and deals with the issue of integration of ICT systems in the value chain; i.e. enable and enhance information sharing and information visibility in the value chain. System integration gives the companies the ability to business in real-time, in an event-driven atmosphere, and with reduced latency (ibid).

The brut force approach to system integration is ***point-to-point integration*** of all necessary ICT systems (see discussion of data sources, interfaces and point-to-point integration in chapter 3.4.3). Point-to-point integration means applications are linked through hand-coded, custom-built connectivity systems and data is interchanged directly between two systems (Papazoglou and Ribbers, 2006). This is however not a recommended solution; the point-to-point relations are too large to mange (Boyson et al., 2003), and further the integration of the various IT systems is time consuming, very costly, dependent of specialists, and static (in the sense that every time a system is modified or a new system is included, the integration has to be redone) (Ray and Jones, 2006).

In the mid-1990s, a new approach to system integration known as ***Enterprise Application Integration (EAI)*** was introduced (Lee et al., 2003). EAI seeks to eliminate islands of data and automation caused by disparate software development activities and to integrate custom and package applications (including legacy) to drive operational efficiency within the organization (Papazoglou and Ribbers, op cit). EAI is not a technology per se, but a collection of tools, techniques and technology that enable applications to interoperate effectively. EAI may involve applications running on the same computer, on disparate computers within the same data center or on computer distributed across an enterprise network (ibid). The EAI approach has had some success and may be the best solution for specific, mission critical and high-performance systems (Liu and Vijayaraman, 2007). However, EAI had some serious limitations and drawbacks when it is applied to enterprise-wide integration and inter-enterprise integration (ibid). EAI solutions depend on many point-to-point links that connect specific elements and functions of each system (ibid).

More recently there has been much buzz about ***web-services*** and ***Service-Oriented-Architecture (SOA)***. Web-services are self-contained, self-describing business and consumer modular applications, delivered over the Internet, that user can select and combine through almost any device, ranging from personal computers to mobile phones (Turban et al., 2006). These will soon be able to integrate applications, business processes, databases, and more into all kind of applications, and do so rapidly and inexpensively (ibid). SOA, on the other hand, defines how two computing entities interact in such a way as to enable one entity to perform a unit of work (service) on behalf of another entity (ibid). The term SOA signifies the way that Web services are described and organized so that dynamic, automated discovery and use of network-available services can take place (Papazoglou and Ribbers (2006). This architectural approach is particularly applicable when multiple applications running on varied technologies and platforms need to communicate with each other (ibid). The traditional EAI approach quickly leads to hundreds of custom bridges for every new application or process change, whereas SOA requires just one integration point for each (Liu and Vijayaraman, 2007). Organizations can extend the SOA beyond the boundaries of the enterprise to link to suppliers and customers, and offer collaboration with outside systems via the same architecture (ibid).

System integration can take many forms, as indicated above, and it is possible to create some general categories, which include (Linthicum, 2004):

- ***Information-oriented*** – is providing simple mechanism to exchange information between two or more systems. Information-oriented solutions can be grouped into three categories:
  - Data replication is simply moving data between two or more databases.
  - Data federation is the integration of multiple databases and database models into a single, unified view of the databases; i.e. creating a virtual database.
  - Interface processing externalizes information out of packaged applications (e.g. ERP systems) through a well-defined Applications Programming Interfaces (APIs).
- ***Business process integration-oriented*** – is the ability to define a common business process model that addressed the sequence, hierarchy, events, execution logic, and information movement between system residing in the same organization (application integration) and system residing in multiple organizations (B2B). As the technology moves forward, we will not control the integration of applications through the exchange of information or the binding or processes, but through the modeling and execution of a business process model that binds processes and information within many systems, intra- or inter-company.
- ***Service-oriented*** – allows enterprises to share common application services as well as information. Enterprises accomplish this sharing by defining application services they can share, and therefore integrate, or by providing the infrastructure for such application service sharing.
- ***Portal-oriented*** – allows us to view a multitude of systems – both internal enterprise systems and external enterprise systems – through a single user interface or application. Hence, it avoids the back-end integration problem altogether by

extending the user interface of each system to a common user interface (aggregated user interface) - most often a Web browser. As a result, all participating system is integrated through the browser, although is does not directly integrate the applications within or between the enterprises.

Similar do Lee and Whang (2000) propose three different information sharing models, see figure 47. These three models are synthesized from the business environment, with a focus on information sharing in value chains, and are from a non-technical point of view. There are however similarities with the four categories by Linthicum (2005).

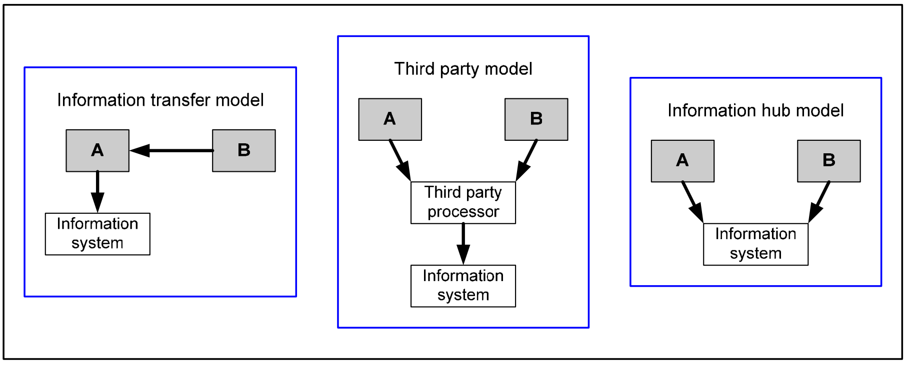

Figure 47 Information sharing models

Source: Lee and Whang (2000)

In the **information transfer model,** a partner transfers information to the other value chain partners, who maintain the database for decision making. This is a natural evolution from the EDI-based transactional model. The ***third party model*** involves a third party whose main function is to collect information and maintain it in a database for the value chain. The third party company may also provide services for transactional processes. The ***information hub model*** is similar to the third party model except that the third party is replaced by a system.

Essential key words in all information sharing models and approaches are ***on-line*** and ***real-time*** information sharing.

3.5 Information visibility systems

A value chain visibility system/application tracks the movement of inventory as it flows through the chain, providing graphical displays that shows expected and actual levels at each locations (Taylor, 2004).

An Extended Enterprise visibility system should provide a clear and common view of events in an Extended Enterprise to all designated participants. Many scholars, researchers, consultants and practitioners are currently working with the visibility concepts. Looking in literature, case studies from industry and solution provided from consultancy companies and ICT vendors, it is hard to find true visibility systems.

The succeeding part of this sub-chapter will discuss six different proposals for visibility systems:

- Supply chain information visibility system (Handfield and Nichols, 2002)

- The Mega-portal and/or the e-supply chain portal (Boyson et al., 2004; Boyson et al., 2003)
- The supply chain planning studio (Jonsson and Lindau, 2002)
- On-line, real-time information sharing in collaborative manufacturing system (McClellan, 2003)
- Information visibility system (Balasuramanian et al (2002)
- PipeChain (www.pipechain.com)

A seventh initiative may be mentioned; the Inventory Visibility and Interoperability (IV&I) project[42]. The project is about sharing electronic data between trading partners. In a greater sense, the IV&I Project is about sharing information that supports specific and multiple business processes across several functional areas within an enterprise as well as across the supply chain itself. The IV&I project is not yet finished and few (if any) publications are available. The project is consequently not further mentioned in the discussion.

The six proposals are somewhat different regarding origin, context, approach and content. Common for all are the underlying assumption that visibility is essential for collaboration between enterprises in the value chain. Together with the specifications made in the case study of RCT (in chapter 7), will the presentation and discussion of these proposals serve as the input for specification for an Extended Enterprise visibility system outlined in chapter 5 and 6.

3.5.1 Supply chain information system

Handfield and Nichols (2002) divide their specifications for a true visibility system into two categories: ***Key information*** shared in the Extended Enterprise and ***properties*** of the system. Some of the *key information* that should be included in an Extended Enterprise visibility system is (ibid):

- Present production rate (as percent of capacity)
- On-hand inventory
- Inventory in transit
- Advanced ship notices
- Forecast
- Damaged goods
- Actual vs. delivered amounts
- Real-time alerts
- Upcoming engineering changes

In addition, the system should have the following *properties* (ibid):

- A simplified approach to system installation should make it easy to install the system
- A web-based “Point and Click” graphic interface
- A “wizard” to guide users in the systems operation
- Ability to interface with legacy, MRP and ERP systems
- Cellular and mobile capabilities. Given that the system may generate alerts to participants of shortages, engineering changes or capacity problems, the system should be able to alert users via cell phones, pagers, faxes, or e-mail.

[42] The IV&I project are joint project between AIAG (the Automotive Industry Action Group, www.aiag.org), OESA (the Orginal Equipment Supplier Association, www.oesa.org), Odette (Organisation for Data Exchange by Tele Transmission in Europe, www.odette.org) , OEMs, Suppliers and solution providers in the automotive industry.

- Real-time updates. The system should be capable to updating inventory status on a real-time basis.
- Verification of information input to ensure accuracy. Wherever possible, the system should automate tasks, eliminating manual intervention
- Alert notices for shortages, emergencies, bottlenecks, etc

According to these authors there are some considerations that must be addressed prior to implementing an information visibility system including the size of the supply base and customer base with which to share information, the criteria for implementing, the content of information shared and the technology used to share it (ibid). Clarifying these issues will help to ensure that all participants have access to the information required to effectively control the flow of materials, mange the level of inventory, fulfil service level agreements, and meet quality standards as agreed upon in the relationship performance metrics.

3.5.2 E-supply chain portal

Boysen et al. (2004) and Boyson et al. (2003) have a somewhat analogous approach. They introduce Portal Technology as opportunity to achieve visibility in the supply chain. This work seems to be inline and inspired by the earlier work of Kehoe and Boughton (2001a, 2001b) which address the use of Internet across the manufacturing supply chain, and in particular focus on the impact on the planning and control operations. The idea is that all partners in the supply chain can log onto a single portal site and immediately get the relevant information they need to make certain decisions. The data are extracted from different sources and are transmitted from the partners to the portal, wirelessly, over fibre optic cable or via satellite (Boyson et al., 2003).

The supply chain mega-portal deploys five distinct solution layers to link systems and processes together and thereby create a seamless value chain system for users (Boyson et al., 2004). The supply chain mega-portal's five solution levels are as follows (ibid):

- ***The Presentation layer*** – provides secure role-based and actionable management information
- ***The Integration layer*** – provides the middleware and information bus to facilitate near real-time translation and sends out events and alerts based on exceptions to pre-set, system-wide performance parameters
- ***The Application layer*** – provides software modules for process solutions
- ***The Sensor-Grid layer*** – which enables distributed devices to monitor systems and report on conditions in real-time
- ***The Exception conferencing layer*** – facilitates real-time decision conferences to deal with those exceptions/alerts with the potential to disrupt the flow of the supply chain

Figure 48 gives an outline of the composition and structure of such a supply chain mega-portal.

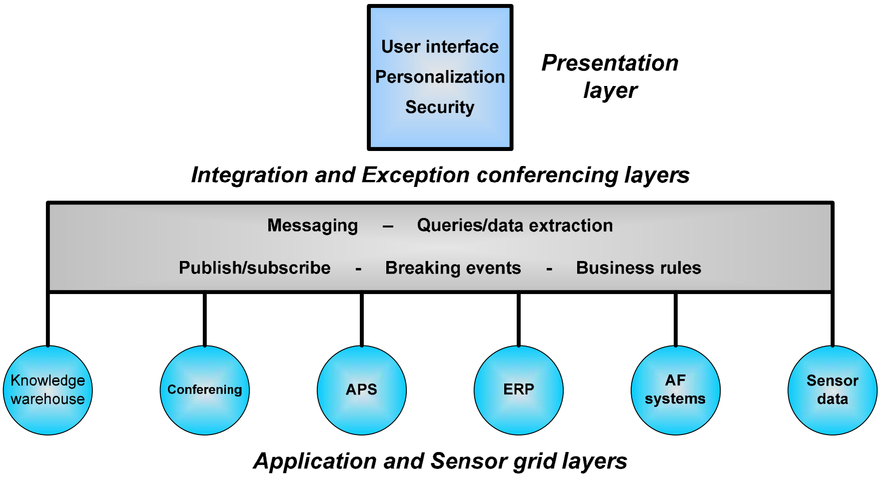

Figure 48 Supply chain portal composition and structure

Source: Boyson et al. (2004)

Through the use of the supply chain portal all members in the supply chain can access and utilize on-line and real-time data sources to (Boyson et al., 2003):

- provide a unified format and middleware platform for disparate asset management data sources including legacy, enterprise, and internet data;
- use real time messaging to assure key asset management service levels; and to help keep supply chain operations within optimal inventory level parameters;
- personalize portal views based on user requirements and security/access classifications;
- distribute field-based data gathered from scanners, PDA devices, and other information appliances to multiple users in real time over the portal;
- construct a seamless grid of information on key operational performance areas, such as real time temperature and humidity data for fresh meats, seafood, and other high value perishables transmitted by Radio Frequency sensor tags that emit continuous signals.

The supply chain mega-portal is designed to support a wide range of business functions and supply chain control activities. These include (Boyson et al., 2004):

- ***Workflow automation*** – the portal facilitates workflow automation by providing a common user interface with links to functional databases and applications through the *integration layer*. The key is to successfully pass data to and from the applications and databases to the portal.
- ***Collaborative planning and forecasting*** – the portal allows real-time information sharing to occur among collaborative partners on important scheduling, demand, forecasting, and inventory data.
- ***Asset management; real-time event management*** – the portal's unique technology provides a mechanism for identifying the critical event, developing technical data to support alternative coping strategies, identifying and pulling together a key decision team, providing each member with access to decision-making data, and enabling real-time communication among team members to facilitate this decision making.
- ***Overall decision support and supply chain control*** – the portal provides a mechanism for compiling all key performance indicators and posting this information

at the portal level for supply chain managers to access. In addition, the portal's real-time virtual database could serve as input into real-time optimization models or "what-if" analysis. Further, an effectively designed portal offers control-panel functionality that allows users to convert a stream of transactions from the real-time, virtual database into a visualized flow map that shows the movement of goods and materials throughout the supply chain.

3.5.3 The supply chain planning studio

Jonsson and Lindau (2002) propose a somewhat similar concept to the two previous concepts, but have a different approach and focus. They propose on a conceptual level *The Supply Chain Planning Studio*; a concept for how to plan and control supply chains in global multi stage supply chain network. The concept is based on three main components (ibid):

- *The people and the team* – The objective is to improve the productivity and quality by increasing the autonomy, empowerment and worker satisfaction of a homogeneous shop-floor team, and to increase visibility and common knowledge in design and engineering teams. Due to the geographical constraints in the supply chain, some kind of a virtual team approach may be necessary.
- *The software functionality* – In a studio environment the software supporting the team should be of such a nature that visibility is prioritised; e.g. making the necessary data available and visible for the appropriate people in the relevant decision situations.
- *The studio environment* – An environment is needed wherein the synergetic power of the teams and the information visibility is utilised. The main objective of the studio environment is to have all participating people focusing on exactly the same thing and hereby understand the issue in the same way, and further to make all participants aware of what is the main issue for the moment.

The overall objective of the studio is to benefits form the synergies of these three components. This will result in a planning process working (ibid):

- *in the right way* – use the power of a team based planning
- *with the right issues* – if the team is provided with accurate and timely information about demand and supply, the ability of the team is enhanced dramatically
- *in an alert mode* – the studio environment is built in which the supply chain network is modelled and business issues are listed in a alert mode

To some extended is the supply chain planning studio as much a visualization system as a visibility system. In this sense are the presentation of the supply chain planning studio both appropriate in the current chapter or in chapter 4.6. Of practical reasons are the presentation made in chapter 3.5.3.

3.5.4 Manufacturing execution systems

McClellan (2003) has a broader view, and discusses the use of and specifications of on-line, real-time data sources systems in a Collaborative Manufacturing[43] context. The concept of Collaborative Manufacturing generally focuses on expanding information availability throughout a company's internal operations and supply chain partners (defined as the extended enterprise). The basic assumption behind this is that the use of real-time information

[43] Collaborative Manufacturing is term coined and frequently used by MESA (Manufacturing Enterprise Solutions Association) and McClellan to describe the process were manufacturing enterprises work together for mutual gain. The objectives of Collaborative Manufacturing are to streamline end-to-end business and supply chain processes and provide a more comprehensive and accurate information base from which to make decisions (MESA, 2004.)

in the Extended Enterprise are largely underutilized, and there is a great need for truly accurate and reliable information among the Extended Enterprise partners (visibility). Today there are many different and independent ICT systems used in an enterprise for execution, monitoring and controlling of machines and processes. These systems contain a waste amount of real-time information regarding production and logistics processes and this information is of great value for all members in the Extended Enterprise. Unfortunately, in most cases these systems are not integrated and the information is not accessible for all parts (applies both internal in the individual enterprises as well as in the Extended Enterprise).

According to McClellan (2003) the capabilities of these ICT systems evolved over the past year. Today are ***Manufacturing Execution Systems*** (MES) the dominant o*n-line transaction processing systems* (OLTP), and it is this system that will be the main source for on-line and real-time information in the Extended Enterprise. MES were presented and discussed in 2.6.6.

A MES according to the specifications made above, will be the cornerstone of creating visibility in the Extended Enterprise, where on-line and real-time information are shared among the participants in the Extended Enterprise.

3.5.5 Information visibility system

Balasubramanian et al. (2002) pin point four important functionality for an information visibility system:

- *Web-based* – this will secure a low entry threshold, few technical barriers, compatibility, and low costs.
- *Real-time information* – the information exchange in the visibility systems should be real-time.
- *Backup system* – when the transfer of new data does not work, the system should have a back up functionality. This enables access to the latest data.
- *System automation* – the visibility system should be fully automated, enabling conveying of information both accurately and promptly.

Balasubramanian et al. (2002) information visibility system is perhaps the least formalized approaches, and will not be further discussed.

3.5.6 Pipechain[44]

PipeChain is a software tool that automates the supply chain between customers and suppliers; i.e. a collaborative supply chain solution.

Pipechain's user interface is based on a clear and easy-to-understand metaphor: Water distribution with pipes, tanks and level indicators, see figure 49. Products can be compared to water and stocks to water tanks (Gustafsson and Norrman, 2001). When a customer consumes water (products), the level falls in the tank. As each tank is connected to others, the one with an outflow is automatically replenished. Deliveries are entirely linked to and triggered by consumption so only when a customer consumes (turns the tap), deliveries are forwarded in the system (ibid).

In this way the user obtain an intuitive interface, where graphic images with symbols and color codes enable users to quickly understand the whole process.

[44] The presentation of PipeChain is based on information available on www.pipechain.com

Further, Pipechain can automate most of the routine tasks in order management and delivery monitoring. Integrated monitoring features generate alarms with proposals for corrective actions when irregularities arise. PipeChain also fully support management by exception and drill-down functionality: By clicking on icons, the user can systematically locate the source of the problem.

PipeChain is a visibility system, where the user can always keep track of what's going on, what's on the way to you and what the customers have in stock. Everyone can use the same interface, view the same screens, receive the same warning signals, and have access to the same information on a real-time basis.

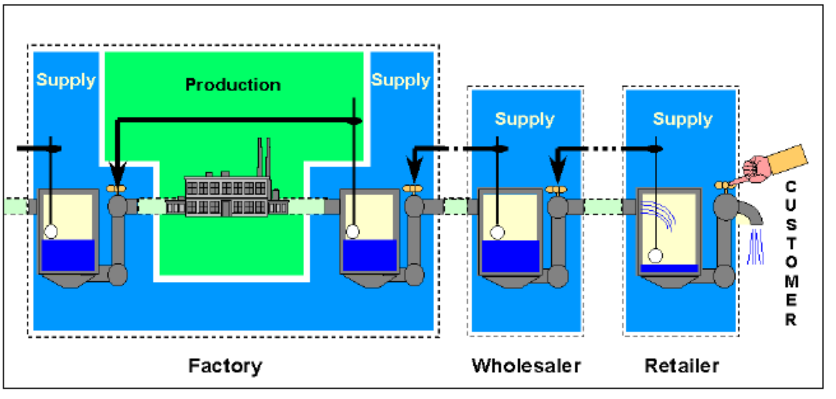

Figure 49 Pipechain's water distribution metaphor

Source: Gustafsson and Norrman (2001)

As it appears from figure 49, PipeChain can also be regarded as an information visualization system. Hence, the presentation of PipeChain could have been done in chapter 4.6.

Sadly the information about PipeChain is limited, and this confines the presentation of the system.

3.6 Summary

This chapter has introduced the concept of information visibility in the Extended Enterprise, and the need for and benefits of sharing information in the value chain. Some key elements in this discussion where:

- The role and power of information and ICT systems in the value chain
- The Bullwhip effect, with causes and methods for coping with it
- The information visibility concept
- Information sharing and information sharing models
- Information visibility systems

Six information visibility systems were presented at the end. These presented proposals for information visibility systems have, as indicated, somewhat different regarding origin, context, approach, and content. It is however possible to identify some common characteristics between some or all of these systems, beside the fact that all address information visibility in the value chain:

- Real time exchange of information between the value chain partners
- An ICT (web) based visibility system

- A collaborative system used among value chain partners
- Automation of processes and workflow
- Planning and control (i.e. decision support) functionality
- Some sort of visualization aspects in most systems
- Add-on to existing ICT systems; relying on existing data bases together with new type of technology (e.g. RFID and sensor) for capturing data.

The bullet list above is not a complete and comprehensive list of all specifications of visibility systems, rather a short summary of some key features in the previous presentation and discussion of visibility systems. The presentation of the information visibility concept, the information visibility systems, the bullets list above, the experience gained through the case studies, will all contribute to the specification made in chapter 5.2.2 for an information visibility and visualization system.

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Chapter 4

Information Visualization

4 Information visualization

Chapter 4 will introduce the concept of information visualization in the Extended Enterprise. The chapter will start with a discussion of the need for information visualization in value chains. Further, the information visualization concept will be defined and explained. Then, the focus will be on how models and other graphical displays can contribute to information visualization. The chapter will end by presenting some of the inspiration sources for developing information visualization in the value chain.

4.1 Introduction

The ever increasing complexity and dynamics of the Extended Enterprises enforce stress, challenges and new requirement for planning and control of operations in the value chains. In this business environment, managers and employees often do not have insight into the ripple effects of their decisions, and effects can also easily get lost in the overwhelming flood of data and information in the value chain (Boyson et al., 2004). The challenges in decision support concern the identification of relevant information, easy access and intelligent use of this information (Kosanke et al., 1999). The only way to understand complex value chain systems is to construct simplified models of them (i.e. visualization), play with the models to see how they work, and then apply what you have learned to the real-world system (Taylor, 2004), see figure 50.

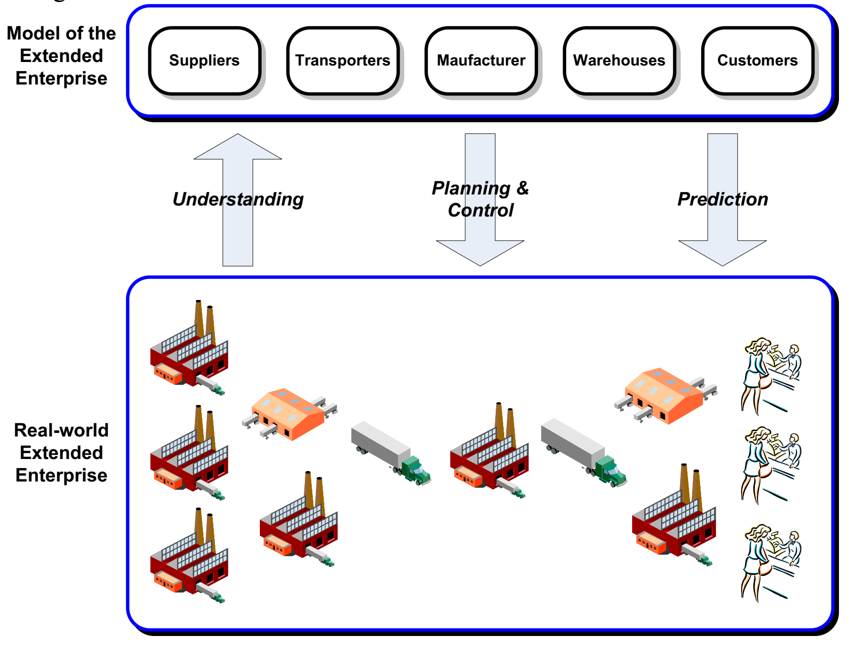

Figure 50 Extended Enterprise visualization

Modified from Taylor (2004)

Value chains are anything but user-friendly, where the behaviour of the chain as a whole can be very difficult to understand; much less predict, plan and control (ibid). Thus, models, particularly those that offer robust visualization tools, can help companies structure and simplify the complex, dynamic structure of their value chain (Boyson et al., 2004). These capabilities help structure, transform, condense, and visually display data from the models or from real-time databases in such a way that mangers can quickly grasp a situation and act upon the present information (ibid).

4.2 The need for information visualization

The rationale for information visualization (directly or indirectly) has to some extent already been mentioned (above and in the previous chapters). The rationale for information visualization is very much in line with the rationale for information visibility, as information visualization enhances the positive effects by information visibility by visualizing the shared information. There is however a need for some further clarifications and specifications. The rationale for information visualization in the Extended Enterprise can shortly be explained through the following arguments:

- ***Information overload***
- ***Holistic thinking***
- ***Dispersed operations***
- ***Speeding up business***
- ***Monitoring***
- ***Prediction***
- ***Decision support***
- ***Fool proofing***

Each of these rationales will be further explained in the subsequent sub-chapters.

4.2.1 Information overload

Information overload occurs when people face so much information that they are unable to attend all of it (Hall, 1998). With the development of Internet technology, raw and unfiltered information is produced in a speed and size that exceeds human cognitive capacity (Ho and Tang, 2001). As a result, both individuals and companies are overwhelmed with information; they have access to more information than they are accustomed to managing (Golicic et al., 2002). However, it is not only the quantity of information which results in information overload. Information format (the multiplicity in information format) and information quality also contribute to the information overload problem as well (Ho and Tang, op cit). Furthermore, overwhelmed information that are irrelevant or of dubious quality can be harmful to employees and their business organizations (Hagel and Singer, 1999). Unfiltered information prevents management at all levels from making well-informed business decisions (Ho and Tang, op cit). There is a need to reduce massive quantities of data into useful information (Davydov, 1999). To be useful, data has to be organized, summarized, and customized. Automatic techniques are needed to transform overloaded and unprocessed information into useful information (Ho and Tang, op cit). Information visualization will help individuals and companies to organize, summarise, customize, and present the information in an easy and recognizable manner for the user.

4.2.2 Holistic thinking

Value chains are complex dynamic systems with people (often with different background, nationality, and culture) from various companies within the value chain that have difficulties to see the big picture; i.e. to understand the total system (value chain), their role in the system, and the consequences of their actions. According to Lofts (2002), people gain a deeper understanding of their business processes when they can visualize them. Information visualization lets people understand in a new way how the value chain operates. Furthermore, information visualization provides the big picture of how your business is linked with others and identifies your business role in the value chain (ibid).

4.2.3 Dispersed operations

Activities such as product design, manufacturing planning and control, sourcing, logistics etc require a number of people to communicate with each other in a shared environment to make joint decisions (Zhang and Zhao, 2005). Globalization of business together with outsourcing of core competences have resulted in Extended Enterprise with dispersed operations. This requires a new communication (virtual) environment where individuals of globally dispersed companies can communicate, collaborate and coordinate their operations. The recent development within ICT (e.g. Internet-based collaboration tools) enables team members of these globally dispersed companies to collaborate electronically by exchanging real-time information and by allowing unparalleled levels of information openness (Lefebvre et al., 2006). Through the use of models, information visualization can overcome some of the barriers of time and space of dispersed operations and improve this virtual coordination and collaboration process. As a result, information visualization can recreate a (virtual) physical feeling for the individuals involved.

4.2.4 Speeding up business

The world of work today is unlike the world of work that our parents faced (Liff and Posey, 2004). The pace of business has considerably increased over the last decades, through advances in automation and robotics, telecommunications, ICT and the Internet, and the globalization of business. The speed with which people must assess and use information that comes to them lead to errors and reduced performance because the information is not available in a quick, focused manner that is easy to access and interpret (ibid). Information visualization can, however, enable people to experience and understand a great deal in a very short time (Lofts, 2002). Information visualization will not only enable a more rapid understanding and response, but also increase the speed of business through the use of models in design, prototyping and testing etc.

4.2.5 Monitoring

It is almost impossible for managers and operators to effectively manage accordingly to the raw data and information streams enabled through information visibility; there is too much information for the parties involved to make sense (Naim et al., 2004). However, information visualization can help monitoring the data and information flow, and detecting trends and anomalies in the data (Brath and Peters, 2004). Further, visualization can aid monitoring of the planned sequence of activities along the value chain and subsequent report any divergence from the plan (Christopher, 2005). With help of exception-based business logic and rules can critical event and exceptions be identified, and alerts can be generated for timely decision support (Buckley et al., 2005). Information visualization may in this manner help the Extended Enterprise to identify and manage events and exceptions in the value chain, and ultimately sense potential problems and respond with flexibility and speed to infrequent or sudden demands.

4.2.6 Prediction

Visualization can help construct models of real-world complex Extended Enterprises. These models (e.g. simulation models) can be used as a test bed to generate predictions about how the system it represented (i.e. the Extended Enterprise) would behave under a variety of conditions (Taylor, 2004). The models can by used to experimenting to either understand the behavior of the system or to evaluate various strategies for the operations of the system

(Boyson et al., 2004). The models can answer these "what if" questions faster, less expensively and with a lot less risk to the company compared to investigating the same questions on the real-world system (Taylor, op cit). Predictions generated by models may increase the understanding of the real-world system, which again can be used to further improve the quality of the model and its predictions (ibid). Hence, information visualization can, through the use of models, generate prediction about the real-world system, saving both time and money and not at least improve the system in it self.

4.2.7 Decision support

While companies have plenty of information in their systems, this information may not be accessible to the parties who need it, or it may not be in a format that is conducive to making business decisions. Similarly, there is a need for tools that allow executives and managers to visualize, understand and plan based on large databases (Simchi-Levi and Simchi-Levi, 2003). Visualization through models can help decision makers to utilize the data/information in order to solve unstructured problems. Information visualization, through the use of models, helps provide common understanding among users about operations and structure, to support analysis or decision-making, or to control operations (Vernadat, 1996).

4.2.8 Fool proofing

Over the last decades both value chains and operations have been under great influence of "new" philosophies from Japan, e.g. Toyota Production System and Lean Production. Japanese techniques such as *pokayoke* and *andon* are visual techniques used to preventing errors by putting limits on how an operation can be performed and signboard incorporating signal lights to indicate which workstation has the problem (Monden, 1998). Similar information visualization can be used in the Extended Enterprise to increase the awareness of process quality and fool proofing the operations.

4.3 Information visualization

The field of visualization is a relatively young filed, and the discipline of visualization was born with the advent of scientific computing and the use of computer graphics for depicting computational data (Hansen and Johnson, 2005). Simultaneously, devices capable of sensing the physical world, from medical scanners to geo-physical sensing to satellite-borne sensing, and the need to interpret the vast amount of data either computed or acquired, have also driven the field (ibid).

4.3.1 Definition and related terms and concepts

Information visualization has become increasingly important in science, engineering and commerce as a tool to convey and explore complex sets of information (Wünsche, 2004). However, the goal of visualization – *the creation of visual representation to help explain complex phenomena* – is certainly not new (ibid). Throughout history, visual abstractions have been developed to aid thinking: Picture from antiquity, maps from ancient Egypt, the geometry diagrams of Euclid, and the statistical diagrams of Playfair (Card, 2004). In fact, disciplines of practice have grown up around how to do these: Cartography, mechanical drawing, electrical schematics, information design for signs, labelling, books, and statistical data graphics (ibid).

In a generic sense, visualization is a method of communication that allows the brain to combine several types of data in the process of understanding and learning. It is an excellent means to communicate overviews, courses of action, coherences, connections and comparisons, (Herskin, 1997). This is in line with the old interpretation of the term (Ware, 2004), where visualization meant constructing a visual image in the mind (Shorter Oxford English Dictionary, 1973). The basic principles of information visualization are illustrated in figure 51.

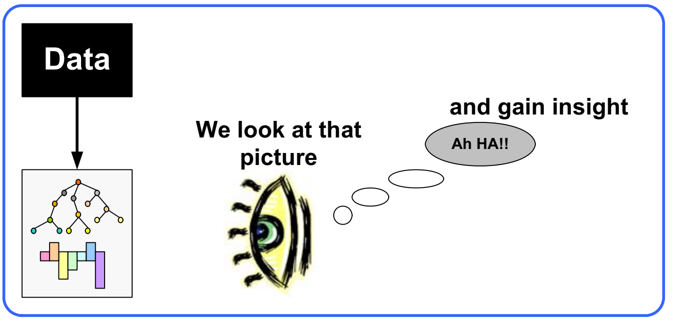

Figure 51 The basic principles of information visualization

Adapted from Spence (2007)

More recent, visualization means something more like a graphical representation of data or concepts (Ware, op cit). Card et al. (1999) stress that visualization is associated with ICT, and defines visualization as: "*The use of computer-supported, interactive, visual representations of data to amplify cognition*". Hansen and Johnson (2005) simply claims that visualization is a method of computing, whereas Gershon et al. (1998) defines *visualization as the process of transforming data, information, and knowledge into visual form making use of human's natural visual capabilities*. With effective visual interfaces it is possible to interact with large volumes of data rapidly and effectively to discover hidden characteristics, patterns, and trends (ibid).

Within the field of visualization there are many sub-branches, such as *product visualization*, *scientific visualization*, *data visualization*, *business visualization* and *information visualization*. Product visualization is concerned with the viewing and manipulation of 3D models, technical drawing and other related documentation of components and products. Scientific visualization is frequently considered to focus on the visual display of spatial data associated with scientific processes (Rhyne, 2003), and tend to be based on physical data (e.g. the human body, the earth, molecules, etc) (Card et al, 1999). Data visualization, business visualization, and information visualization is often used interchangeable (Brath, 1999), and information visualization will be the preferable term in this thesis.

If there were few definitions of information visibility, there are even fewer definitions of information visualization. An interesting observation is that two leading books (*Information Visualization: Design for interaction* by Robert Spence (2007), and *Information Visualization: Perception for design* by Colin Ware (2004)) within the field of information visualization, offer no definition of information visualization! Some key definitions of information visualization are:

- The use of visual means to represent non-spatial, abstract data (Rohrer and Swing, 1997)
- An interactive visual representation that transforms abstract data into a visual representation that is readily comprehended by a user (Brath, 1999).
- The use of computer-supported, interactive, visual representations of abstract data to amplify cognition (Card et al., 1999).

- A computer-aided process that aims to reveal insights into an abstract phenomenon by transforming abstract data into visual-spatial forms (Chen, 2002).
- The use of interactive visual representation of abstract data to amplify cognition (Card, 2004).
- Effective visual representations that present data in a form that allows people to browse the display and understand the inherent information resident in the data (Stasko, 2007).

From the definitions above it is possible to conclude that: 1) Information visualization is about ***representation of data***, and more specific of ***non-spatial and abstract data***; typical financial data, business information, collection of documents, and abstract concepts, etc. The data is typically quantitative or categorical data, but may also include unstructured text, multimedia and structured objects (Brath, 1999). 2) However, information visualization is not only representation of data, but an ***interactive representation*** of data. This implies that the user not only can see and/read the information, but also can interact with the information ***in order to achieve better/further understanding***, ***gain new knowledge***, and ***take the necessary action*** according to the information. 3) The objective of information visualization is to enable an ***easy and readily understanding*** and ***amplify cognition of data,*** that otherwise had been limited or hard accessible. This is achieved by representing the data through models, figures, charts, bars and other means. 4) Information visualization is ***enabled through the use of ICT***. According to Spence (2007) there are three principal reasons for why ICT have been responsible for massive advances in the field of information visualization. First, increasingly inexpensive and rapid access memory makes it possible to store vast amounts of data. Second, increasingly powerful and fast computation allows the rapid interactive selection of subsets of the data for flexible exploration. Third, the availability of high-resolution graphic displays ensures that the presentation of data matches the power of the human visual and cognitive systems.

Based on these observations, the following definition of information visualization will be used in this thesis: ***Information visualization is the use of computer-supported, interactive, visual representations (i.e. models) of abstract and complex data and information for gaining new knowledge, amplify cognition, and rapid and action-oriented understanding.***

4.3.2 The information visualization concept

The value of visualization as a tool for understanding and controlling the value chain is growing as the value chains grow in complexity. The only way to understand complex systems (such as Extended Enterprises) is to construct simplified models of them, play with the models to see how they work, and then apply what have been learned on the real-world system (Taylor, 2004).

Figure 52 illustrates information visualization in the value chain.

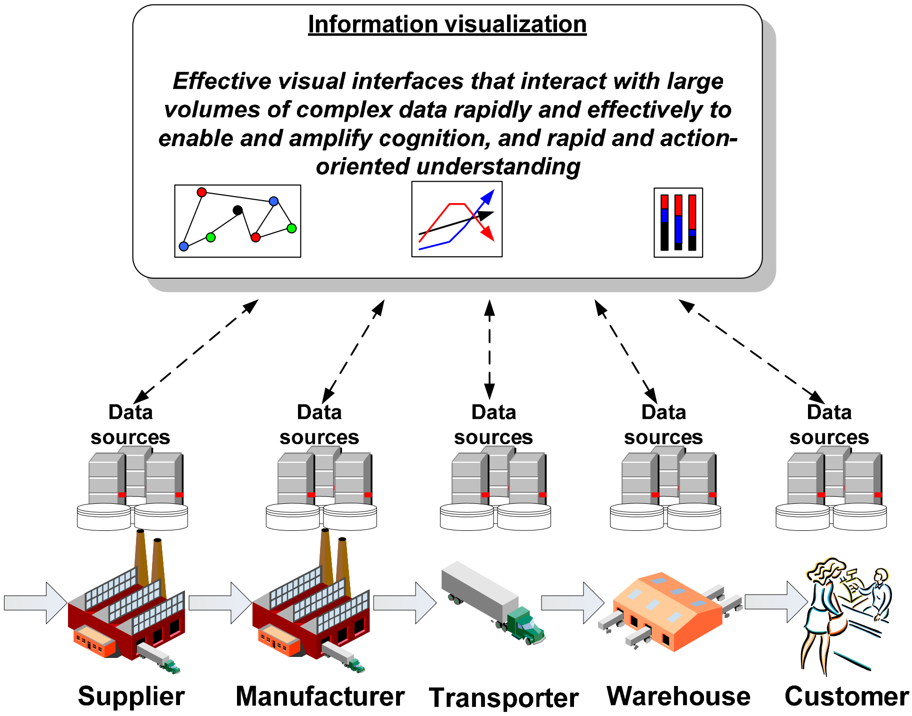

Figure 52 Information visualization in the value chain

Figure 52 illustrates how information from the value chain is presented in a visual intuitive form that permits easy understanding, enable interaction with the information, and ultimately support decision making (i.e. planning and control of operations).

4.3.3 Benefits of information visualization

Figure 51 indicates that models can help and enable understanding, prediction and planning and control of the system. According to Card et al. (1999), information visualization serves two related but quite distinct purposes:

- The use of visual means for communication of information and knowledge (a picture is worth more then ten thousand words).
- The use of graphical means to create or discover the information and/or knowledge (using vision to think).

However, when discussing the applications and implications of information visualization, Card et al. (1999) point out that information visualization have three goals:

- Discovery – powerful visual tools can support discovery (e.g. visual data mining).
- Decision making – information visualization applications support decision making on both a personal level and at the business level.
- Explanation – to explain processes in ways that may lead to better predictions or to provocative insights, which can become the basis for action.

The two bullet lists are to some extent concurrent and simultaneous supplementary. Decision making is missing in the first bullet list, and communication is missing in the second bullet list.

Several other authors have addressed the issue of benefits, applications, and or/advantages of information visualization, see among others Spence (2007), Brath and Peter (2005), Ware (2004), Brath (1999), and Gershon et al. (1998). The following bullet list summarizes some of this discussion:

- Information visualization is a powerful tool for monitoring, e.g. see trends and anomalies in data (Brath and Peters, 2005).
- Information visualization is extremely powerful for analysis, e.g. a tool that can navigate through a rich, complex data set, with faster access and utilization of the data available and a higher degree of confidence in the analysis (ibid).
- Information visualization can help companies building direct relationships with new customer through the use of integrated display customised to the customer (ibid).
- Information visualization provides an ability to comprehend huge amounts of data (Ware, 2004).
- Information visualization allows the perception of emergent properties that were not anticipated (ibid).
- Information visualization often enables problems with the data itself to become immediately apparent (ibid).
- Information visualization facilitates understanding of both large-scale and small-scale features of the data (ibid).
- Information visualization facilitates hypothesis formation (ibid).
- Information visualization may be used for tasks such as identification, multivariate correlation, search, query, exploration and communication (Brath, 1999).

Based on this discussion and the three bullets list above, it is possible to conclude that information visualization can:

- ***be a powerful mean for communication of information and/or knowledge***
- ***includes graphical means to create or discover the information and/or knowledge***
- ***be used for monitoring and analysis of huge amount of data and information***
- ***support decision making on both a personal level and at the business level***
- ***explain processes in ways that may lead to better predictions or to provocative insights, which can become the basis for action***

All these purposes will be included in this thesis. Information visualization will be used for improving the communication within and between the members of the Extended Enterprise. Further, information visualization will be used for monitoring (supervision), early problem detection, analysis and decision making/support of the production and logistics processes within the Extended Enterprise. Combined these will be a powerful mean for planning and control of manufacturing and logistics processes in the Extended Enterprise.

4.4 Models and visualization

Models can be powerful means for enabling information visualization. This is reflected in the old proverb: A picture is worth more than a thousands word. Models can take a system that may be hard to understand or dangerous to manipulate, and render it in a form that is easier to understand and safer to play with (Taylor, 2004).

Building a model of a system (i.e. modeling) requires an analysis of the system to identify its key components, figure out how those components work, and then reassemble them in a way that replicates the essential behavior of the system (ibid). The basic sequence of analysis and synthesis is the surest way to understand complex systems (ibid). The prime and major advantage of modeling that have often been observed in industry relies in its ability in building a common view of the enterprise which can be shared by the various actors, i.e. building consensus that enforces the enterprise culture (Berio and Vernadat, 2001). Hence, models may enable understanding, consensus, communication and decision support in and between organizations regarding various aspects (i.e. operations, processes, control, structure etc).

As already indicated in figure 6, models come in many variants. Chapter 4.4 will address several issues of models and modeling in the Extended Enterprise, and how these can contribute to information visualization. The assumption is that on one hand there ***is a need for holistic, consistent and comprehensive Extended Enterprise models***, and on the other hand these models need to be ***simple, easy to use and time saving, intuitive and easily recognizable*** for the user.

4.4.1 Models

A model is a simplified representation or abstraction of reality. It is usually simplified because reality is too complex to describe exactly and because much of the complexity is actually irrelevant in solving the specific problem (Turban and Aronson, 2001). The degree of simplification and abstraction depends on the interest of the targeted audience. A model is always expressed in terms of a language (mathematics, natural languages, symbols etc) (Vernadat, 1996). According to Turban and Aronson (op cit), models can be classified into three categorizes according to the degree of abstraction: Ionic (e.g. prototypes), ***analog*** (charts, diagrams etc) and mathematical (e.g. algorithms). This is a similar, and also broader, classification than the one made by Taylor (2004), see chapter 1.3.3 and figure 6. Taylor (op cit) divides between ***conceptual***, mathematical and simulation models. Analog and conceptual models are identical, and it is just a semantic difference between those two. The focus in this dissertation is on conceptual models, which is a symbolic representation of reality.

According to Delen and Benjamin (2003), conceptual models are formal or informal abstractions of a system that are expressed using special-purpose modeling constructs. As part of a modeling language's syntax, these constructs include simple graphical elements such as circles, boxes and arrows.

Another classification of models is given by Brathaug and Evjen (1996):

- ***Improvements models*** – are methodology models for improvement processes (e.g. help BPR etc). Improvement models also comprise models of the areas to change and the wanted changes. The "as-is" model and the "to-be" model help managing the following change. These models are as a rule only visual, or in other words, there are no flows of data.
- ***Operative models*** – are more than just visual models; they are capable of doing "work". They contain methods that manipulate and perform calculations on the structures in the model.
- ***Knowledge models*** – might comprise methods, but are more a knowledge repository, and comprise models like enterprise models, project models or process models.

When relating this classification to the prior classification, we can conclude that both improvements and knowledge models are analog/conceptual models, whereas the operative models can be viewed as both an analog and mathematical model depending on the degree of "functions" included in the model.

Senge (1990) uses the term *mental models* to describe the deeply ingrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how the take action. However, such models are not often shared by all the different stakeholders in a business, which may result in dysfunctional and provincial attitudes and behavior. It is therefore essential to develop a sheared mental model of the organization and its environment if we are to gain and benefit from new insights and to develop real consensus (Marshall, 2000). In this sense a mental model can be seen as an analog/conceptual model.

Some authors and practitioners use the term ***map*** instead of models. A map is a spatial representation of the environment. Representation in this sense means something that stands for the environment that it portrays, and is both likeness and a simplified model (Muehrecke and Muehrecke, 1992 in Gardner and Cooper, 2003). From this definition we can conclude that maps are a sub-group of analog/conceptual model, where maps are those conceptual models which have a high degree of recognition (in the meaning of resemblance with the system is represent). When there is a need for complex and comprehensive models (e.g. high degree of details etc) of systems, it is in many cases no longer feasible to do this with maps and more traditional conceptual models that are used (such as IDFO etc).

According to Vernadat (1996) there are three levels of generalization of models:

- ***A particular model*** is a dedicated model for some aspects of a given enterprise or a system.
- ***A partial model*** is a model which is not fully instantiated, and which can be reused and customized by business users for building their particular models.
- ***A reference model*** is a (partial) model which can be used as a basis for particular model developments or evaluation of particular models (ibid). The rationale for developing reference and partial models are to provide standardization, user-friendliness and equally important save time and cost (due to the reuse of the model).

As described there exists various types and classifications of models. This dissertation will focus on analog (conceptual) models, which serves as improvement, knowledge and to some degree as an operative model within the Extended Enterprise. These models should be developed with as much resemblance to maps as possible, i.e. with high degree of recognition of the systems it represents. And further, the models should include reference, partial models and particular models.

4.4.2 Conceptual models related to business

Within the conceptual models heading there are a variety of different models and areas of application for such models. If the conceptual models are related to business, models such as business models, enterprise models, product models, process models, organizational models, etc are quite common.

Table 17 gives an introduction and short description of some types of models. Other models clearly exist, but the ones highlighted are the ones with most relevance to the thesis.

Type of model	Description
Business model	A business model is a representation of a firm's underlying core logic and strategic choices fro creating and capturing value within a value network (Shafer et al., 2005); i.e. a term which simply refer to way a company does business (Osterwalder et al., 2005). A definition which put more emphasis on the modeling aspects of business models are (Osterwalder, 2004): "A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning

Type of model	Description
	money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners fro creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams." Further, business models can be viewed as a business layer between business strategy and processes (ibid).
Enterprise model	An enterprise model is one representation of a perception of an enterprise (Vernadat, 1996). It can be made of several sub models including (but not limited to) process models, data models, resource models and organization model (ibid). The content of an enterprise model is whatever the enterprise considers important for its operations. Delen and Benjamin (2003) use the term enterprise model set to refer to a group of conceptual models built to obtain a coherent and comprehensive picture of an enterprise (the models within the model set are equivalent to the views used within enterprise modeling (functional, information, resource and organization view). This set includes models of various types, and each type of model defines a "perspective or viewpoint from which the system is considered for a given purpose, concentrating on some aspects and hiding irrelevant ones to reduce complexity" (Vernadat, 1996).
Control model	A control model is a representation of how operations are organized and controlled in manufacturing (Andersen et al., 1998; Alfnes and Strandhagen, 2000).
Process model	Process models are visual depictions of the steps and flows of a process, and such pictures make understanding and communication about the process much easier (Andersen et al., 2008). Kosanke et al. (1999) relates the process models to the enterprise, and define process model as a model that describes both the functionality and the dynamics of the enterprise.
Operating model	An operating model is the necessary level of business process integration and standardization for delivering goods and services to customers (Ross et al., 2006). Further, an operating model describes how a company wants to thrive and grow. By providing a more stable and actionable view of the company than strategy, the operating model drives the design of the foundation for execution (ibid).
Operational model[45]	An operational model exists as a way of defining the business in which we work (Meaneaux, 2000). It outlines at a high level, without details, the key functions within an organization in terms of roles and responsibilities (ibid).
Operations model	An operations model is some sort of representation of operations in the enterprise and/or the value chain. In it simplest form it is just a picture of the processes and/or the structure of the network. See chapter 7.2 for more information regarding operations models.

Table 17 Key conceptual models used in business

The following reflection can be made from reading table 17 and comparing the various models:

- Business models are the most used[46] of the models listed in table 17, but still less formalized of than for example enterprise and process models. Within the domain of enterprise and process models a multitude of tools and concepts exists (see table 18 and 19), whereas few concepts and tools exist which may help companies and their managers to specify conceptual business models (Osterwalder, 2004).
- Enterprise models and business models differ even though they are conceptually relatively close (Osterwalder et al., 2005). Enterprise models are mainly concerned with processes and activities, while business models essentially focus on value creation and customers (ibid). Similar, the main role of enterprise models inside a firm

[45] Christensen et al. (1995) list operational models as one of three types of enterprise models, where conceptual models and analysis models are two the others. In this respect the operational model is a computer enactable enterprise model, integrated into the enterprise wide ICT system (Alfnes, 2005). Thus the operational model by Christensen et al. (1995) is not a conceptual model, and thereby omitted from the discussion in this chapter.

[46] A search a www.google.com (27.11.2008) gives the followings hits: Business model (11 300 000), Enterprise model (126 000), Control model (837 000), Process model (1 180 000), Operating model (302 000), Operational model (161 000) and Operations model (62 400).

is to improve efficiency, whereas the main role of business models is to find and design a promising business concept (ibid).

- Sometimes there can be some confusion between business models and (business) process models. Part of the confusion comes from the expression “business modeling”, which are mainly used for the activity of business process modeling (i.e. the activity of modeling processes), and not business models (ibid).
- Operating model, operational model and operations model are very similar, with slightly differences. These three models will in this thesis be treated as on group of models under the heading operations model.
- The operations model can be viewed as a high level conceptual enterprise model.
- As already mentioned, control models and process models may be viewed as sub-models of enterprise models (and thereby also of operations models).

Enterprise models will be used as examples throughout chapter 4.4, due to the fact that these are the conceptual models that are most formalized and have most resemblance to the way models are used in this dissertation.

4.4.3 Modeling

Creating a model requires methods and tools for abstraction, representation and model manipulation. Modeling methods will guide the total modeling process from the observation of a reality to model use and maintenance (Kosanke et al, 1999).

The modeling process is the set of activities to be followed for creating one or more models of something (defined by its universe of discourse) for the purpose of representation, communication, analysis, design or synthesis, decision-making, or control (Verndat, 1996).

As indicated earlier, some authors use the term map instead of models, and consequently use the term mapping instead of modeling (see among others Hunt (1996), Andersen (1999), Rother and Stock (1999) and Jacka and Keller (2002)).

Any modeling technique is characterized by (Ross, 1977, and Vernadat, 1996):

- The definition of the purpose of the model, i.e. what is it aimed at
- The range of the model, i.e. the scope or domain covered by the model (also called the universe of discourse)
- The viewpoint on the model, i.e. which aspects are covered and which are left out by the model
- The detailing level of the model, i.e. the level of precision or granularity of the model regarding the reality model.

Throughout the last two decades several efforts and initiatives have been carried out within the development of enterprise models (maps) and modeling (mapping). Some of these efforts and initiatives resulted in well-known enterprise modeling frameworks (architectures, languages and methodologies) such as CIMOSA, PERA, GIM (see Vernadat (1996), Bernus and Nemes (1996), Rolstadås and Andersen (2000) and Chalmenta et al. (2001) among others). Most of these modeling frameworks are developed for Computer Integrated Manufacturing (CIM) enterprises in supporting their enterprise integration efforts (Delen and Benjamin, 2003).

Similar, a wide range of enterprise modeling approach have also been developed. These modeling approaches, in comparison to architectures, do not provide a comprehensive picture but they address a particular problem area (Gastinger and Szegheo, 2000). Table 18 gives a brief introduction to some of the modeling approaches available today. The list outlined in table 18 is not a complete list of modeling approaches, but rather a collection of some of the most used methods.

Other efforts and initiatives have approached a more narrow and specific aim and application. Examples of such efforts are process modeling for ERP implementation and BPR projects (see among others Hammer and Champy (1993), van der Aalst et al. (2000) and Becker et al. (2003)), the SCOR model (www.supply-chain.org) for supply chain modeling and performance measurement, and Value Stream Mapping (VSM) (Rother and Shook, 1999) for eliminating waste and creating continuous flow within enterprises and Extended Enterprises. The latter approaches (e.g. SCOR and VSM) offer only a limited focus and do not attempt to give a holistic view of the (extended) enterprise, compared to the more complex and comprehensive enterprise modeling techniques.

Table 18 and 19 give an overview of these modeling frameworks, reference architectures, and modeling approaches, whereas the value chain models will be presented in chapter 4.4.9.

Reference Architecture	Full name	Description	Origins	Source of information
CIMOSA	Computer Integrated Manu-facturing Open System Architecture	Its aim is to provide the manufacturing industry with 1) an Enterprise Modeling Framework (EMF), which can accurately represent business operations, support their analysis and design, and lead to executable enterprise models; 2) an Integrated Infrastructure (IIS), used to support application and business integration as well as execution of the implementation model to control and monitor enterprise operations; and 3) a methodology to be used along the System Life Cycle (SLC) to assist users in applying CIMOSA principles (Vernadat, 1998)	Developed under the framework of the European Union ESPRIT research programme. CIMOSA resulted from the consortium AMICE (European CIM Architecture) that participated in the ESPRIT projects numbers 688, 2422, and 5288. The work was initiated in 1984.	Kosanke (1991), Russel (1991), Querenet (1991, AMICE (1993), Kosanke et al. (1995), Vernadat (1996), Kosanke and Zelm (1999), Berio and Vernadat (1999), Berio and Vernadat (2001)
PERA	The Purdue Enterprise Reference Architecure	It has designed to assist industry in its effort to develop and implement integrated manufacturing systems. It is a complete and largely documented methodology to define, design, construct, install, and operate an integrated enterprise system (Vernadat, 1996). It covers the full enterprise life cycle from inception and mission definition down to its operational level and final plant obsolescence.	Developed at the University of Purdue since 1989, led by Prof. Williams at the Purdue Laboratory for Applied Industrial Control	Williams (1992), Williams (1994), Vernadat (1996), Williams (1998)
GIM/GRAI	GRAI Integrated Meth-odology	The objective is to allow various improvements actions such as re-engineering (e.g. BPR), choice and implementation software package (e.g. ERP) or advanced IT applications (e.g. workflow), definition and implementation of performance indicators, or benchmarking, by always using the same model, the same formalisms and the same generic structured approach (Doumeingts and Ducq, 2001). The methodology includes four phases: initialization, analysis, design and implementation.	Both GRAI and GIM have been developed at the University of Bordeaux, France. GIM has its origins in GRAI (Graphes a Resultates et Activites Interrelies, a method to model and analyze automated manufacturing systems) and in Merise (an information system design and analysis methodology)	Doumeingts et al. (1992), Vernadat (1996), Doumeingts and Ducq (2001)
ARIS	Architecture of Integrated Information Systems	The focus of ARIS is on software engineering and organizational aspects of integrated enterprise system design, and deals with more traditional business-oriented issues of enterprises (such as order processing, production planning and control, inventory control, etc). The ARIS House of business engineering (HOBE) provides a framework for managing business processes – from organizational engineering to real-world IT implementation, including continuous adaptive control.	Developed by Prof. Scheer at the University of Saarbrucken in Germany	Scheer (1992), Vernadat (1996), Scheer (1998), Scheer and Nuettgens (2000)

Table 18 Enterprise modelling frameworks/reference architectures

Modeling Approach	Description	Source of information
UML	UML, Unified Modeling Language, is a language for specifying, visualizing, constructing, and documenting software systems, as well as for business modeling and other non-software systems. UML represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems. It is a visual modeling language of choice for building object-oriented and component-based systems. It is a visual language capable of representing the structure and behavior of product information from conception to implementation and can be used to hierarchically define "business processes". UML focuses on a standard modeling language, not a standard process. UML is developed by Object Management Group (OMG, www.omg.org)	Booch et al. (1999), Marshall (2000), Martin and Kendall (2000), UML (2005)
BPMI	BPMI, Business Process Management Initiative, is a non-profit corporation, which aims to promote and develop the use of Business Process Management (BPM) through the establishment of standards for process design, deployment, execution, maintenance, and optimization. BPMI defines open specifications such the BPML (Business Process Modeling Language) and BPMN (Business Process Modeling Notation). The BPML is a meta-language for the modeling of business processes. BPML defines a formal model for expressing abstract and executable processes that address all aspects of enterprise business processes, including activities of varying complexity, transactions and their compensation, data management, concurrency, exception handling and operational semantics (Arkin, 2002). BPMN specification provides a graphical notation for expressing business processes in a Business Process Diagram (BPD) (BPMI, 2002).	Burlton (2001), Arkin (2002), BPMI (2002), BPMI (2005)
PetriNets	Petri Nets is a graphical oriented language for design, specification, simulation, and verification of systems. Perti Nets are especially convenient to analyze manufacturing systems and information networks since their qualitative properties perfectly reflect properties of these systems (Bernus et al .,1998). Perti Nets has its origin in Carl Adam Petri's dissertation Kommunikation mit Automaten in 1962.	Pertri (1962), Peterson (1981), Proth (1998),
WfMC	Workflow is concerned with the automation of procedures where documents, information or tasks are passed between participants according to a defined set of rules to achieve, or contribute to, an overall business goal. WfMC, Workflow Management Coalition, is an non-profit organization (founded in 1993) with the objectives of advancing the opportunities for the explotation of workflow technology through the development of common terminology and standards. The has proposed a framework for the establishment of workflow standards, which includes five categories of interoperability and communication standards and the development of a common terminology in a glossary of workflow terms (Carlsen, 1997).	Hollingsworth (1995), Carlsen (1997), Weske and Vossen (1998), van der Aalst et al (2000), Fischer (2005), WfMC (2005)
IDEF	The IDEF, Integration DEFinition language, arose in the 1970s out of the U:S Air Force Integrated Computer Aided Manufaturing (ICAM) program. The IDEF suite covers several different manufacturing aspects and consist of the following approaches (Szegheo, 2000b): • IDEF0 - used to build functional models • IDEF1 - used for the information model • IDEF1X - a method for designing relational databases • IDEF3 - complements IDEF0 by modeling the flow of control and objects within business processes	Menzel and Mayer (1998), Gastinger and Szegheo (2000), Szegheo (2000b), IDEF (2005)

	• IDEF4 - an object-oriented design method • IDEF5 - an ontology description capture method	
STEP	STEP, the STandard for the Exchange of Product model data, is a comprehensive ISO standard (ISO 10303) that describes how to represent and exchange digital product information. Digital product data must contain enough information to cover a product's entire life cycle, from design to analysis, manufacture, quality control testing, inspection and product support functions. STEP is built on a language, EXPRESS, that can formally describe the structure and correctness conditions of any engineering information that needs to be exchanged.	Watson (1995), Anderl et al. (1998), Eastman (1999), Molin (2000)
Flow-charts	Flowcharts are maps or graphical representations of the flow of activities in a process. There are many ways of drawing a flow chart, and the basic way is simply using different symbols to represent activities and arrows to illustrate the connections between the activities (Andersen and Pettersen, 1996). Flow charts have been used for a long time, and no individual/organization is specified as the "founder" of flow charts. However, flowcharts became popular in the 1960s through extended use within computers programmers and later in the field of quality management.	Andersen (1999), Andersen (2000), Gastinger and Szegheo (2000)

Table 19 Various modeling approaches

4.4.4 Purpose of modeling

In line with the characteristics outlined by Ross (1977) and Vernadat (1996) in the prior sub-chapter, it is important to keep in mind that the purpose of modeling is very much depended on what kind of models that are being developed. Modeling itself is very seldom discussed in literature, but rather in connection with various types of models; i.e. business models, enterprise models, data models, process models, mathematical models, molecular models, supply chain maps (models), value stream map (model) etc.

Take for example enterprise models. The purpose of these models is to provide common understanding among users about Extended Enterprise operations and structure, to support analysis or decision-making or to control operations of the Extended Enterprise (Vernadat, 1996). Such models are capable of assisting the managing task in the operations by providing decision support for long term and short term planning, as well as for exception handling (Kosanke and Zelm, 1999).

Any enterprise model serves a purpose. There may be many different purposes, but fundamentally any enterprise model aims at making people understand, communicate, develop, and cultivate solutions to business problems (Szegheo, 2000b). An Enterprise Model can be created to serve one purpose, but it could as well be used for several purposes. Christensen et al. (1995) divide the propose of models into three categories:

1. Human sense making and communication, where the main purpose of Enterprise Modeling is to make sense of aspects of an enterprise and communicate with others.
2. Computer assisted analysis, where the main purpose of Enterprise Modeling is to gain knowledge about the enterprise through simulation or deduction.
3. Model deployment and activation, where the main purpose of enterprise modeling is to integrate the model in an enterprise-wide information system and thereby actively take part in the work performed by the organization.

Vernadat (1996) has a somewhat more complementary and detailed list of purposes for enterprise models:

- To better represent and understand how the enterprise (or some part of it) works
- To capitalize acquired knowledge and know-how for later reuse
- To rationalize and secure information flows
- To design (or redesign) and specify a part of the enterprise (functional, behavioral, informational, organizational, or structural aspects)
- To analyze some aspects of the enterprise (economic analysis, organization analysis, qualitative analysis, quantitative analysis, facilities layout etc)
- To simulate the behavior of some part(s) of the enterprise
- To make better decisions about enterprise operations and organizations
- To control, coordinate, or monitor some part of the enterprise (i.e. some processes)

Bernus (2001) points out that models can be used throughout the life cycle of a system – in concept development, specification, design, construction and operation – for experimentation, analysis, decision making, communication and learning. He further argues that enterprise models may be used to externalize (make explicit) individual understanding and to negotiate a shared one, alleviating the problem presented (ibid).

The key message is that modeling can serve many purposes and models have a wide area of applications within enterprises and Extended Enterprise. And it is important to keep in mind that a model can be created to serve one purpose, but it could as well be used for several purposes.

4.4.5 Content of models

An enterprise can be view from different aspects. Due to its complexity and size, an enterprise model is made of several viewpoints or angles from which one can look at an enterprise resulting in a variety of models suited for different purposes (Vernadat, 1996). The content of an enterprise model is whatever the enterprise consider important for its operations. In a manufacturing context usually the following aspects are modeled (Szegheo, 2000a):

- ***Processes*** – that refers to manufacturing and business processes (administrative, management, finance, etc)
- ***Products*** – product related information, all technical data of data of a product and the manufacturing processes, that are necessary to produce the product
- ***Resources*** – physical machines and devices, applications (software packages), raw material, etc
- ***Information*** – anything that can be represented by data
- ***Organization and management*** – organizational charts, goals and objectives
- ***Environment of the enterprise*** – business constraints, legal issues, government regulations, competitors and business partners

4.4.6 Benefits of modeling

When addressing the benefits of using models, it is important to relate this discussion to the prior presentation of the purpose of modeling. Of obvious reasons benefits and purposes are very close connected.

Enterprise modeling requires several, often somewhat cumbersome, tasks to capture both contents and behavior of the enterprise. However, modeling has several benefits for the enterprise. Delen and Benjamin (2003) group the benefits of use of enterprise models into three categories:

- First, conceptual models provide decisions makers with a consistent and coherent view of the current and future state of the Enterprise, and enable managers to design and analyze operations at the macro level.
- Second, they can be used to transfer enterprise-specific knowledge among domain experts, system analysts, and other stakeholders. The time and associated costs of knowledge transfer activities is significantly reduced.
- Third, high-level enterprise models can be reused by a number of analysis method specialists to build a variety of analysis models.

Similar do Kosanke et al. (1999) identify four benefits, when discussing modeling in a (enterprise/information) integration context (i.e. enabling information sharing):

- Enterprise knowledge and business processes become much more transparent with an explicit, commonly understood representation and documentation
- Intra and inter enterprise communication is based on easily accessible real-time information and common understanding and thereby greatly increased
- Decision support for the evaluation of operational alternatives, business process re-engineering projects, exception handling and problem solving on all levels of the decision hierarchy can be easily based on real time information and thereby enhances significantly the decision quality

- Management of change becomes possible through the ease of access to information, the ease of adoption of the decision support base, i.e. the business process model and the visibility of impact of proposed changes prior to their implementation.

As we can see the two lists are in accordance with each other and at the same time supplement each other. According to the lists benefits like enabling understanding, consensus, communication and decision support are agreed upon. In addition, the last point in the list of Delen and Benjamin is of utter importance; the aspect of reuse (see also chapter 4.4.7).

4.4.7 Pitfalls of modeling

Unfortunately, modeling of enterprises is a complex, difficult, time-consuming process and prohibitively expensive (Reyneri, 1999), and have yet to make a significant impact on the decision-making of most companies and organizations (Delen and Benjamin, 2003). The primary reason for the limited success of these enterprise modeling and analysis methods on a large industrial base is that the methods are generally very elaborate and require acute expertise to be used effectively (ibid).

Bernus et al. (1996) claims that although the economic return from producing high quality enterprise models in the process of enterprise engineering can be significant, model building from scratch remains unacceptable expensive for a large part of industry (especially small and medium sized enterprises), and there is a recognized need to share and reuse previously produced models.

Gardner and Cooper (2003) point out that there are some concerns that companies must address before publishing models, either internally or externally in the value chain. These concerns or risks include giving away competitive information, changing the chain dynamics, getting lost in too many details, and providing an ineffective perspective for management use (ibid).

4.4.8 Need for standardization within modeling

The efficiency of the modeling process can be significantly enhanced by employing reusable building blocks, rather than to start on scratch every time a model is being created or modified. One important element in achieving reuse of models is standardization. To take full advantage of modeling of enterprises, a standardized modeling methodology is needed, which enables the definition of business process for different types of enterprises, in different operative contexts and at the necessary level of detail (Reyneri, 1999).

Kosanke and Nell (1999) points out that standardization can contribute to benefits in wide range of areas within modeling. Firstly, standardization will determine, in specific and generic ways, what characteristics in an enterprise are necessary to analyze or model. Secondly, standardization will ensure a common understanding of the enterprise (e.g. processes etc), through the key aspects define within the standardization. Thirdly, standardization will enable linking of models from different sources in order for these models to behave as a common model. Fourthly, standardization will simplify exchange of models between partners. And finally, standardization will allow reuse of models or elements of models.

Various initiatives have been done in order to achieve standardization. As far as the Enterprise Modeling and Integration community is concerned; research and standardization activities are coordinated by the IFAC-IFIP (International Federation Automatic Control International Federation Information Processing) Task Force on Architectures for Enterprise Integration and ISO TC 184 SC5 WG1 in connection with CENT C 310, its European counterpart (Vernadat, 2001). See among others Kosnake and Nell (1999), Shorter (1999) and Vernadat (2001) for more information among the various standardization efforts. ARIS, CIMOSA, PERA and GIM/GRAI are enterprise modeling approaches which fulfils these standards. These approaches will be presented and discussed in more detail in chapter 4.3.

Other initiatives worth mentioning are among others UML (Unified Modeling Language), BPMI (Business Process Management Initiative), WfMC (Workflow Management Coalition), and SCOR (Supply Chain Operations Reference) model (see table 4.3 and chapter 4.4.8 for more information).

However, for value chains there are not yet a universal set of modeling conventions to represent a value chain (Gardner and Cooper, 2003). There needs to be developed a well-established process for modeling so that knowledge is easily transferable and exchangeable among managers and organizations as appropriate (ibid).

4.4.9 Value chain models

Still, there have been a few attempts to systematize the activities and process into a holistic framework or model of the value chain over the last 20 years or so. An early attempt was the value chain/value system model by Porter (1985) (see chapter 2.3.1 and figure 16). In addition to this effort, are the following four frameworks/models perhaps the most known:

- ***The SCOR (Supply Chain Operations Reference) model*** by the Supply-Chain Council
- ***The Extended Enterprise model*** by Browne and Zhang (1999)
- ***The Supply Chain Management model*** by Lambert et al. (1998)
- ***Value Stream Mapping*** by Rother and Shook (1999)

The Supply Chain Operations Reference-model (SCOR) has been developed and endorsed by the Supply-Chain Council (SCC), an independent not-for-profit corporation, as the cross-industry standard for supply-chain management (SCC, 2006). The SCOR model, see figure 53, is a reference model that allows companies to introduce standards to business process re-engineering, benchmarking and process management. It is further a tool that enables users to address, improve and communicate supply chain management practices within and between actors. The SCOR Model is based on five distinct management processes (ibid):

- ***Plan*** – Processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production and delivery requirements
- ***Source*** – Processes that procure goods and services to meet planned or actual demand
- ***Make*** – Processes that transform product to a finished state to meet planned or actual demand
- ***Deliver*** – Processes that provide finished goods and services to meet planned or actual demand, typically including order management, transportation management, and distribution management
- ***Return*** - Processes associated with returning or receiving returned products for any reason. These processes extend into post-delivery customer support

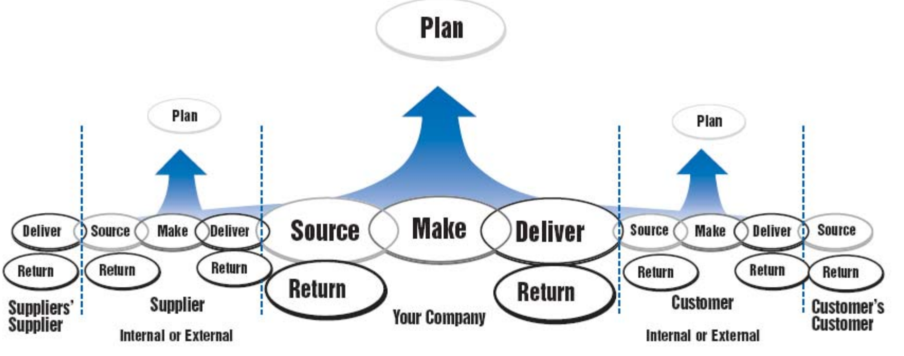

Figure 53 The SCOR Model

Source: SCC (2006)

The Extended Enterprise model (see figure 54) identifies five high-level macro business processes. Each of these macro business processes can be decomposed further to show in greater detail the sequence of activities within the process. The identified macro processes are directly related to the operational activities of the manufacturing enterprise. The five macro business processes, and their associated definitions, identified using the business model shown in figure 54, are as follows (Jagdev and Browne, 1998):

- ***The Customer Order Fulfillment*** process includes all of the activities directly involved with the planning, control and co-ordination of customer requirements with the manufacturing process and the delivery of the product to the customer.
- ***The Supply Chain Management*** process includes all of the activities directly involved in the co-ordination of supplier capabilities, the planning of supplies requirements and the delivery of these requirements to the manufacturing process.
- ***The Manufacturing*** process contains all of the activities directly involved in the physical production of the product.
- ***The Customer Driven Design*** process includes all of the activities directly involved in the design and development of a product (and its associated manufacturing process) subject to customer requirements and its release to manufacturing.
- ***The Co-engineering and Co-Design*** process includes all of the activities directly involved with the co-ordination of supplier capabilities into the product design process.

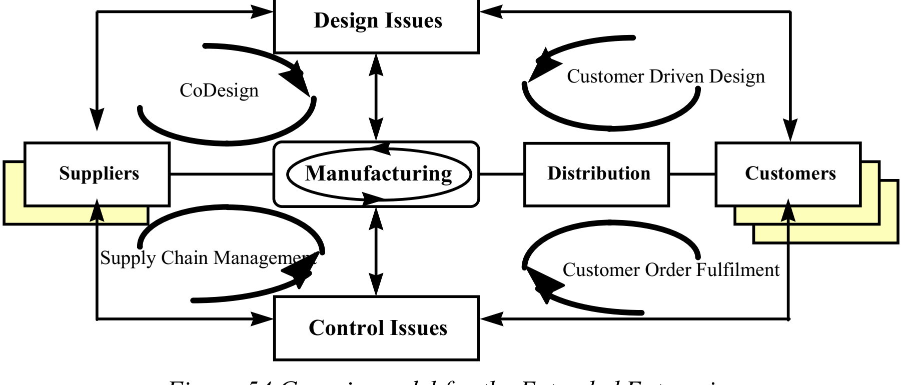

Figure 54 Generic model for the Extended Enterprise

Source: Browne and Zhang (1999)

The SCM model (see figure 55) depicts a simplified supply chain network structure, the information and product flows, and key supply chain business processes penetrating functional silos within the company and the various corporate silos across the supply chain (Lambert et al., 1998). The SCM model identified eight key business processes that make up the core of supply chain management (ibid):

- ***Customer Relationship Management*** process provides the structure for how the relationship with the customer is developed and maintained.
- ***Customer Service Management*** process is the firm’s face to the customer. It provides the single source of customer information, such as product availability, shipping dates and order status.
- ***Demand Management*** process needs to balance the customer’s requirements with the firm’s supply capabilities.
- ***Order Fulfilment*** process involves more than just filling orders. It includes all activities necessary to define customer requirements, design a network and enable a firm to meet customer request while minimizing the total delivered cost as well as filling customer orders.
- ***Manufacturing Flow Management*** process deals with making the products and establishing the manufacturing flexibility needed to serve the target markets.
- ***Procurement*** is the process that defines how a company interacts with its suppliers.
- ***Product Development and Commercialization*** is the process that provides the structure for developing and bringing products to market jointly with customers and suppliers.
- ***Returns*** is the process by which activities associated with returns, reverse logistics, gatekeeping, and avoidance are managed within the firm and across key members of the supply chain.

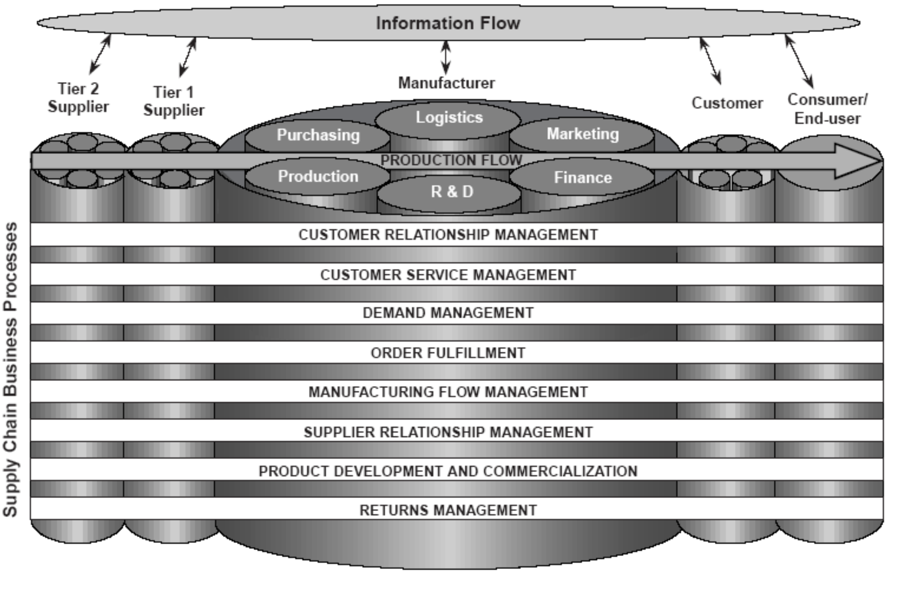

Figure 55 Supply Chain Management Model

Source: Lambert et al. (1998)

Value stream mapping is not a model, but rather a modeling approach commonly used within Lean Production to identify and eliminate waste. Value stream mapping is a pencil and paper tool that helps companies to see and understand the flow of material and information as a product makes its way through the value stream (Rother and Shook, 1999) (see chapter 2.3.1 for discussion of value stream vs. value chain). The value stream mapping process is simple (ibid): Follow a product's production path from customer to supplier, and carefully draw a visual representation of every process in the material and information flow. Then ask a set of key questions and draw a "future state" map of how value should flow (ibid). An example of a value stream map is given in figure 56.

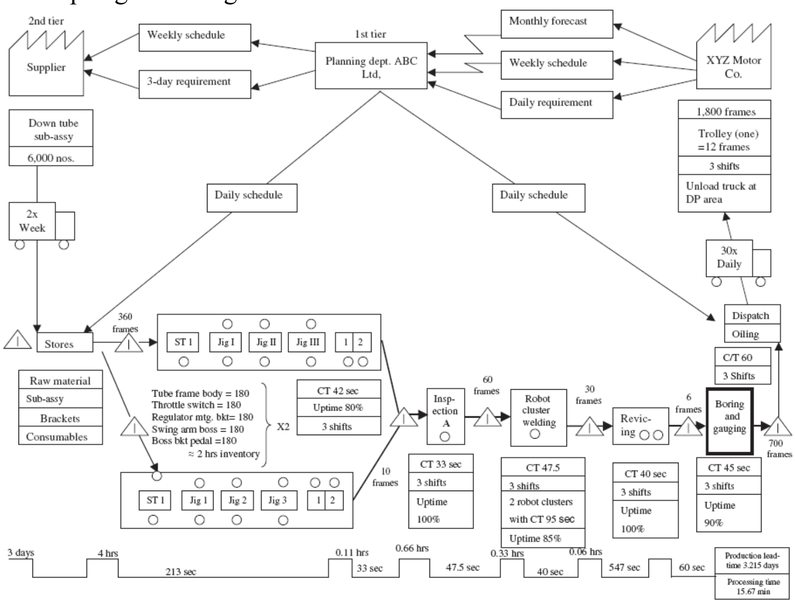

Figure 56 Example of value stream mapping picture

Source: Seth and Gupta (2005)

4.4.10 Models in the Extended Enterprise

Throughout chapter 4.4 various models and modeling approaches has been presented and discussed. Enterprise modeling has been the prominent part of this discussion, but there are other approaches as well; ranging from the primitive flowcharts, via various mapping initiatives (e.g. VSM), to more rigid and formal frameworks like the SCOR model and business process modeling for ERP implementation (e.g. the SAP R/3 Blueprint).

As already indicated the success and application of these models and modeling approaches have been limited (see chapter 4.4.7), perhaps with exception of the SCOR model. However, the SCOR model is yet in its infancy and has not been accepted as an industry standard (Huan et al., 2004).

Further, even though there are numerous enterprise modeling approaches and tools available, many organizations prefer to develop their own enterprise modeling approach or tool (Szegheo, 2000b). She argues that there are at least three reasons for this (ibid):

- o Existing solutions are developed for another purpose than the one in mind
- o Existing solutions can not provide desired flexibility

- Reluctance in companies to use new tools and techniques

Thus, there is a lack of holistic, consistent and comprehensive models that at the same time are simple, easy to use, time saving, intuitive, and easily recognizable for the user. This is particularly true for the Extended Enterprise.

Figure 57 illustrates how Extended Enterprise can address this challenge and generate simple, easy, low cost, holistic, consistent and comprehensive Extended Enterprise models, which at the same time are easily recognizable for the users.

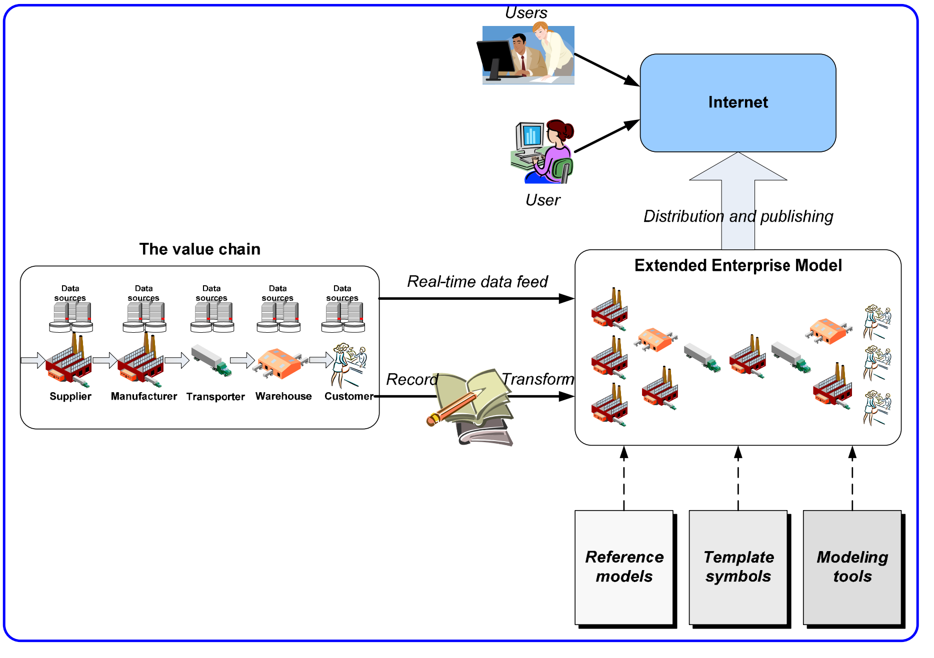

Figure 57 Modeling in the Extended Enterprise

Modified from: Kalpic and Bernus (2002)

4.5 Other graphical displays enabling visualization

Models are not the only means for enabling information visualization. For some types of data/information models are not the appropriate means for visualization. This is typically for statistical data and/or performance related data. Table 20 summarizes some of the most common graphical displays used to enable information visualization.

Graphical displays	Description
Line and bar graphs	Both line and bar graphs are in general the most effective display media for many reporting applications. They serve different purposes: A line graph provides an overall view of the entire data set, showing the variations in the values, while a bar graph focus on the local details, facilitating comparisons between individual values (Few, 2006).
Pie harts	The fundamental purpose of a pie chart is to facilitate part-to-whole comparisons, i.e. judging the proportion of each slice compared to the total, which is represented by the full circle.
Sparklines	Sparklines can be defined as data-intense, design-simple, word-size graphics that are usually embedded in a context of words, numbers and images (Tufte, 2006).

Graphical displays	Description
	The idea behind sparklines is very simple: When the graph is compressed in a very small space, it can be used like a word and placed immediately next to numbers that provides more details about the data.
Gauges and bullets graphs	By far the most popular graphical display for KPIs is a gauge. Very often the gauge is designed to look like a speedometer in a car (i.e. dashboard) and usually the collars of the qualitative levels are encoded with “traffic lights”, i.e. red, yellow, and green. An alternative for a gauge that performs the same function is a bullet graph (Few, 2006). It displays the actual and target values of a performance measure and a qualitative range in a smaller space than a gauge and without any unnecessary decoration.

Table 20 Graphical displays for visualizing of data

Adapted from: Ahokas (2008)

The graphical displays listed in table 20 are well-know techniques, which most people are familiar with. Thus, the graphical displays will not be further discussed.

4.6 Visualization system

Similar to chapter 3.5 where various information visibility systems were presented, will chapter 4.6 present some information visualization system or areas where information visualization is used for planning and control of operations. This as inspiration for the development of an information visibility and visualization system in chapter 5.

The succeeding part of this sub-chapter will presented and discuss six different information visualization systems and/or concepts:

- Visual factory, system, management and control
- Operational monitoring and control in the Process Industry
- Control centre/towers
- Dashboards
- Collaborative virtual environment
- Advances in ICT

Some of the systems/concepts above may be regarded as information visibility systems, similar to some of the information visibility systems presented in chapter 3.5 which may be regarded as information visualization systems. However, the six systems/concepts presented in chapter 4.6 have a main focus on visualization; hence it is natural that the presentation is given in this chapter.

4.6.1 Visual factory, system, management and control

A key inspiration source for information visualization in the Extended Enterprise is the concept of *visual factory, management and control* in lean production. This chapter will give a brief introduction to those concepts, and how these concepts can be utilized in an information visualization system for the Extended Enterprise.

One of the cornerstones in Lean Production is the principles of the 5 Ss or visual factory. The term 5 S is derived from five Japanese words (starting with the letter S) describing the elements in achieving a workplace characterized by cleanliness and orderliness. The logic behind the 5 Ss is that *Proper arrangement and organization*, *Orderliness*, *Cleaning up, Cleanliness,* and *Discipline* at the workplace are basic requirements for producing high quality products and services, with little or no waste, and with high quality. Table 21 gives an introduction to the 5 S’s and its meaning.

Japanese	English	Meaning
Seiri	Proper arrangement and organization	Do things in the proper order; eliminate unnecessary things
Seiton	Orderliness	Specify a location for everything; designate location by number, color coding, name, etc; put things were they belong
Seiso	Cleaning up	Specify recommended procedures for cleanup; follow the procedures; check over all work
Seiketsu	Cleanliness	Dust, wash, and maintain equipment; keep equipment and the workplace in the best possible condition
Shitsuke	Discipline	Scrutinize practice; expose the wrong ones; learn correct practices and be careful to use them

Table 21 Explanation of the 5 Ss concept

Adapted from Nicholas (1998)

The visual factory is a factory run and managed accordingly to the 5 Ss. The intent of the visual factory concept is that the whole workplace is set-up with signs, labels, color coded markings etc such as anyone unfamiliar with the process can, in a matter of minutes, know what is going on, understand the process, and know what is being done correctly and what is out of place (MAMTC, n.d.). There are two types of applications in visual factory (ibid):

- A visual display relates information and data to employees in the area
- A visual control is intended to actually control or guide the action of the group members

Figure 58 illustrates a visual display, taken from a company that has implemented Lean Production and 5 Ss. The display gives information for and about several teams associated with a set of predefined processes (in this case all processes within a small factory) within the factory.

Figure 58 Example of Visual Display

(printed with permission of Hydro)

Visual control is control by visualization, meaning acting on the basis of what one sees. It is important to remember that even though the person will act accordingly to what he sees; this is possibly because there has been done a tremendous job in advance with standardization, simplification and break-down of processes. Kanban is a good example of visual control, where prior to the daily operations there has been standardization, decentralization of decision making, introduction of Kanban loops, calculation of Kanban cards and size etc.

Visualization in visual factories is represented by visual systems. A visual system is a group of visual devices designed to share information at a glance and visual information is presented in an interpretive environment to enable fast and valid decision support (Galsworth, 1997). A visual device is a mechanism that is intentionally designed to share information vital to the task at hand at a glance (ibid). Accordingly to Galsworth (ibid) there are four types of visual devices:

- Visual indicators – it shares information by displaying or showing; are used when compliance or adherence is voluntary
- Visual signals – is slightly more powerful than an indicator; it first catches our attention and than delivers its message
- Visual controls – cross the line from optional to required behavior; adherence beings to get built in
- Visual guarantees – is designed to make sure that only the right things happen; prevention information is design into the device

However, visualization in organization is not limited to factories and shop floors, but can be applied in all areas of the organizations; visual management. Visual management is a system for organizational improvement that can be used in almost any type of organization to focus on what is important and to improve performance across the board (Liff and Posey, 2004). It adds a new dimension to the processes, systems, and structures that make up the existing organization by utilizing strong graphic visualization techniques to heighten its focus on performance (ibid). Visual management is a system that helps organizations create and sustain competitive advantage in two significant ways (ibid):

1. It ensures that an organization's internal structure, management systems, work environment, and culture are aligned with its mission and values.
2. It focuses employees' attention on critical performance goals, making sure that the employees know what is expected of them at all times and are committed to the organization's success.

It is further a holistic and systemic approach to improvement of individual and organizational performance (ibid).

Accordingly to Greif (1991) there are three types of visual information:

1. Methods and organization – this is mainly information regarding overall processes and procedures within the organization
2. Resources and technology – this is information more specific to individual processes (e.g. machines etc) and some information regarding the manufacturing process
3. Product and materials – this is product and material specific information

The concept of visual management has achieved massive recognition outside the traditional Lean Production boarders. Its principles are suitable for almost all kind of business, and sectors like service, healthcare, administration, government etc has lately adapted and implemented ideas from visual management.

According to the ”rules” of Lean Production, visual factory and visual management, is the placement and the medium of the information of utter importance. Selecting the location for a visual message is fundamental. Information must be organized hierarchically, keeping permanent or important information close the process, and storing other information nearby (Greif, 1991). In selecting the medium, it is important to understand the way the user perceives the communication problem, and look for alternative ways of presenting the information. Galsworth (1997) is in line with the traditions within Lean Production, and claims that computers are not the solution. She argues that computers will not provide the information fast enough and they store the information at wrong locations. Greif (1991) on the other hand points out that when computers can offer expanded visibility (in the meaning group communications; displaying data on illuminated boards, graphic displays for inventories and flows), they will play a lager role in visual control for production units.

This thesis will be in line with Greif’s argument, and the ideas from the visual factory and visual management will be conveyed into the value chain and the Extended Enterprise with the support of ICT.

4.6.2 Operational monitoring and control in the Process Industry

A second source of inspirations for information visualization in the Extended Enterprise is the concept of operational monitoring and control in the process industry.

Within the process industry[47] the ideas of visual monitoring and control has been applied for several decades. This tradition has developed separately from the Lean Production tradition, and has had a strongly technology foundation. The key element is process control of operations; meaning monitoring quality while the product is being produced. The objective is to provide timely information on whether current produced items are meeting design specifications and to detect shifts in the process that signal that future products may not meet specifications (Chase et al., 2004). Another important incentive for using process control is that the operations within the process industry in many cases are dealing dangerous materials or the process it self is dangerous (e.g. toxic, explosive etc). In this sense it becomes extremely important to monitor the process and become aware of dangerous situations.

In order to be able to monitor and control the operations, different kinds of (information) technology is needed. Greeff and Ghoshal (2004) gives an overview of the evolution of measurement instruments, control systems, visualization systems and execution system within manufacturing, and particularly within process industry. All these systems are presented in chapter 2 in this thesis, and will thus not be presented in this section.

By using these systems companies are able to measure performance of the processes, and thereby control and visualize (supervision) the processes, and when necessary execution. Figure 59 is an example of visual monitoring and control in the process industry. The illustration in figure 59 is taken from an MES/SCADA system.

[47] Process industry is a part of manufacturing industry using (raw) materials to manufacture non-assembled products in a production process where the (raw) materials are processed in a production plant where different unit operations often take place in a fluid form and the different processes are connected in a continuous flow (Promote, 2004).

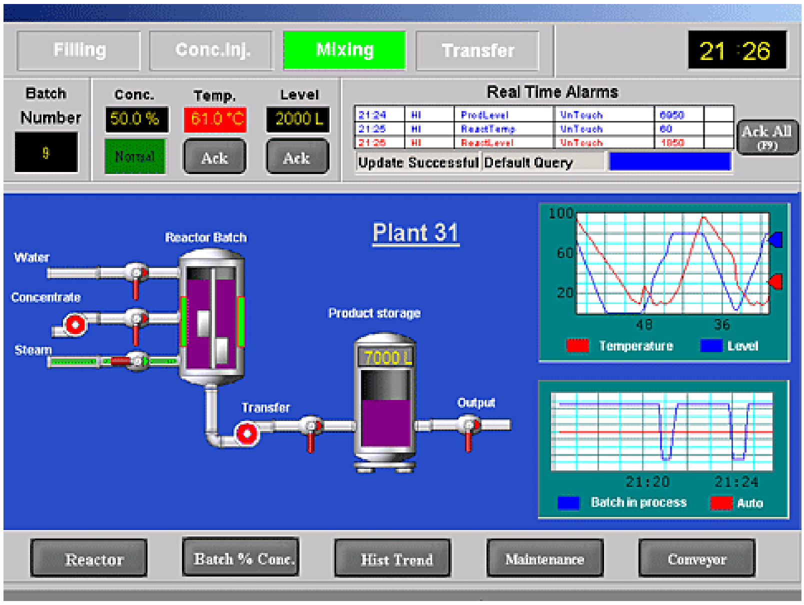

Figure 59 Example of visual monitoring and control in the process industry

Source: Wonderware (n.d.)

There are mainly three reasons why process monitoring and control are more applied within the process industry compared with more traditionally industry (Bolseth, 2004):

- High degree of automation of processes – allows a high degree of automated data collection from the processes which can be populated into the monitoring and control systems
- Easy-to-follow material flow (continuous flow) through the processes – allows simple and comprehensive visual presentation of the processes and the material flow
- Dangerous and critical processes – justifies large investments in visualization and control and monitoring tools

The intention of this thesis is to expand the ideas of visual monitoring and control in the process industry into the value chain and the Extended Enterprise, and to other type of manufacturing. The aim is to give the same type of insight of each process in the Extended Enterprise, as in figure 59, and an overview of how the individual processes are connected throughout the Extended Enterprise.

4.6.3 Control centres/towers

A third source of inspiration for information visualization in the Extended Enterprise is how control centres/towers are used to support and monitor operations in military, aerospace, aviation, etc.

Most people are familiar with the phrase "Houston, we have a problem". This refers to the Apollo 13 mission, which experienced a problem and needed to consult the mission control centre of NASA in Houston. These mission control centres, also called flight control room, are the ground control of the mission, and control, monitor and support all aspect of the mission using some of the most sophisticated information and communication technology and data displaying equipment available, see figure 60a.

a) b)

Figure 60 Control centre at NASA and Statoil

In these control centres are teams of experienced engineers and technicians, and even physician/surgeon, gathered together to control and monitor every second and detail of the mission, and not at least provide support and expertise to deal with unexpected events.

Similar control centres could be found in other space agencies like ESA (European Space Agency) and FKA (Russian Federal Space Agency). Further, smaller (and perhaps not that advanced) version of the aerospace mission control centres are applied within traffic control, railway control, air traffic control, and within the military, etc. Figure 60b is taken from a control centre of an offshore installation in the North Sea. In this example there are two persons present and they have access to several multi-screen control and monitoring views.

Figure 61a is taken from the control centre of the Norwegian Public Roads Administration in Oslo, and figure 61b is a picture of the control tower at the Oslo International Airport.

a) b)

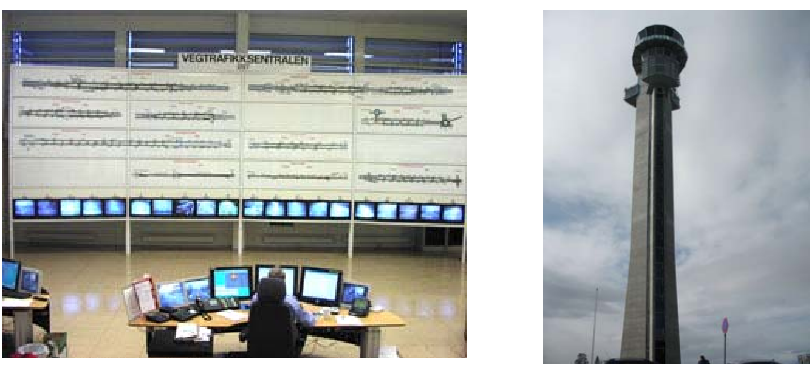

Figure 61 Traffic control centre in Oslo and control tower at Oslo Airport

The vision in this thesis is to create some sort of control centre of the Extended Enterprise, similar to those described in this chapter.

4.6.4 Dashboards

A fourth source of inspiration for information visualization in the Extended Enterprise is the dashboard concept. The term dashboard brings to mind that panel under the windshield of a vehicle that contains indicators dials, various compartments, and control instruments (Malik, 2005). Its beauty lies in its functionality. It brings together all of the relevant data and functions within easy accessibility to the driver. It allows the driver to monitor important, even lifesaving data while performing the vital day-to-day task of driving. In addition, it provides an ease of use and comfort so as to make the multitude of decisions necessary during the driving task almost automatic, and certainly effortless (ibid).

The dashboards within an automobile (or aircraft, boats, etc) has inspired the concept of dashboard within information management, performance measurement and management, and business intelligence. The purpose of the dashboard in all these settings is the same; ***to monitor and drive a complex and interdependent system*** (ibid). Kaplan and Norton (1996) draw the analogy between an aircraft dashboard on an organizational need for similar information tools: "*Skilled pilots are able to process information from a large number of indicators to navigate their aircraft. Yet navigating today's organizations through complex competitive environments is at least as complicated as flying a jet. Why should we believe that executives need anything les than a full battery of instrumentation for guiding their companies? Managers, like pilots, need instrumentation about many aspects of their environment and performance to monitor the journey toward excellent future outcomes*". Figure 62 illustrates a flight cockpit and dashboard for enterprise.

Figure 62 Flight cockpit and supply chain dashboard

(The flight cockpit is a cockpit from F-15e strike eagle, whereas the supply chain dashboard is taken from http://www.supplyanalytics.com/monitoroview.htm)

The term dashboard has acquired a vibrant new meaning in the field of information management and performance management, as leading organizations worldwide embrace the idea of empowerment through improved real-time information systems. In the current corporate vocabulary, *a dashboard is a rich computer interface with charts, reports, visual indicators, and alert mechanisms that are consolidated into a dynamic and relevant information platform* (Malik, 2005). Other authors offer similar definitions:

- A dashboard is a visual display of the most important information needed to achieve one or more objectives; consolidated and arranged on a single screen so the information can be monitored at a glance (Few, 2006)

- A performance dashboard is a multilayered application built on a business intelligence and data integration infrastructure that enables organizations to measure, monitor, and manage business performance more effectively (Eckerson, 2006)

However, dashboards are not a new phenomenon. According to Few (op cit) dashboards is simply a new name for the Executive Information Systems (EISs) first developed in the 1980s. These systems were however ahead of its time. Back then, before data warehousing and business intelligence had evolved the necessary data handling methodologies and given shape to the necessary technologies, the vision simply wasn't practical; it couldn't be realized because the required information was incomplete, unreliable, and spread across too many disparate sources (ibid).

Dashboards can help to aggregate and synchronize enterprise information and enable workflow-based information display for users based on their roles and needs. Dashboards support the presentation of performance and supporting information in standard formats for aggregation and analysis (Buckley et al, 2005). Transactional visibility and dashboard displays of information can be enhanced with well-defined business logic. Alerts can be generated for timely decisions support.

According to Eckerson (2006), organizations really need a performance dashboard that translates the organization's strategy into objectives, metrics, initiatives, and tasks customized to each group and individual in the organization. A performance dashboard is really a performance management system (ibid). It communicates strategic objectives and enables business people to ***measure, monitor, and manage*** the key activities and processes needed to achieve their goals (ibid):

- ***Monitor*** – critical business processes and activities using metrics of business performance that trigger alerts when potential problems arise.
- ***Analyze*** – the root cause of problems by exploring relevant and timely information from multiple perspectives and at various levels of detail.
- ***Manage*** – people and processes to improve decisions, optimize performance and steer the organization in the right direction.

Table 22 illustrates the application of the performance dashboards.

	Monitoring	**Analysis**	**Management**
Purpose	Convey information at a glance	Let users analyze exception conditions	Improve alignment coordination and collaboration
Components	Dashboard Scorecard BI portal Right-time data Alerts Agents	Multidimensional analysis Time-series analysis Reporting Scenario modelling Statistical modelling	Meetings Strategy maps Annotation Workflow Usage monitoring Auditing
A performance dashboard consists of three applications (monitoring, analysis, and management) that deliver related sets of functionality and consist of multiple components.			

Table 22 Performance dashboard applications

Source: Eckerson (2006)

According to Eckerson (2006), there are three major types of performance dashboards. Each type of performance dashboard emphasizes three different layers (summarized graphical view, multidimensional view, and detailed reporting view) and the three different applications described above to different degrees (ibid):

- ***Operational dashboards*** monitor core operational processes and are used primarily by front-line workers and their supervisors who deal directly with customers or manage the creation or delivery of the organization's products and services. Operational dashboards primarily deliver detailed information that is only lightly summarized. As a result, operational dashboards emphasize monitoring more than analysis and management.
- ***Tactical dashboards*** track departmental processes and projects that are of interest to a segment of the organization or a limited group of people. Managers and business analysts use tactical dashboards to compare performance of their areas or projects, to budget plans, forecast, or last period's results. Tactical dashboards are usually updated daily or weekly with both detailed and summary data. They tend to emphasis analysis more than monitoring or management.
- ***Strategic dashboards*** monitor the execution of strategic objectives and are frequently implemented by using a Balanced Scorecard approach, although Total Quality Management, Six Sigma, and other methodologies are used as well. The goal of a strategic dashboard is to align the organization around strategic objectives and get every group marching in the same direction. To do this, organizations roll out customized scorecards to every group in the organization and sometimes to every individual as well. Strategic dashboards emphasize management more than monitoring and analysis.

To conclude the discussion of dashboards, we will use Malik's (2005) requirements and specifications of elements of dashboards. Table 23 summarizes these requirements and elements.

A dashboard must contain the following underlying elements	***A dashboard should have also have some of the following advanced elements***
Synergetic. Must be ergonomically and visually effective for a user to synergize information about different aspects within a single screen view.	**Interactive**. It should allow the user to drill down and get details, root causes and more.
Monitor KPIs. Must display critical KPIS required for effective decision making for the domain to which a dashboard caters.	**More data history**. The dashboard should allow the users to review the historical trend for a given KPI.
Accurate. Information being presented must be entirely accurate in order to gain full user confidence in the dashboard. The supporting dashboard data must have been well tested and validated.	**Personalized**. The dashboard presentation should be specific to each user's domain of responsibility, privileges, data restrictions, and so on.
Responsive. Must respond to predefined thresholds by creating alerts in additions to the visual presentation on the dashboard (e.g. sound alarms, e-mails, pagers, blinkers, etc) to draw immediate user attention to critical matters.	**Analytical**. It should allow the users to perform guided analysis such *as what-if* analysis. The dashboard should make it effortless for a user to visually navigate through different drill-down paths, compare, contrast, and make analytical interfaces. In this way, the dashboard can facilitate better business comprehension within a set of interdependent business variables.
Timely. Must display the most current information possible for effective decision making. The information must be *real-time* and *right-time*.	**Collaborative**. The dashboard should facilitate users' ability to exchange notes regarding specific observations on their dashboards.

	Trackability. It should allow each user to customize the metrics he or she would like to track. Such customized tracking could then be incorporated within the default dashboard view presented to the user after login.

Table 23 Requirements and elements of dashboards

Adapted from Malik (2005)

4.6.5 Collaborative virtual environment

A fifth source of inspiration for information visualization in the Extended Enterprise is the concept of collaborative virtual environment.

As perviously indicated in this thesis, companies are increasingly forced to engage in collaboration with its customers and suppliers. With the development of new technologies, and particularly within ICT, this collaboration now takes the form of global virtual teams (Rutkowski et al., 2002). Activities such as product design, production and inventory control, and transportation planning require a number of people to communicate with each other in a shared environment to make joint decisions (Zhang and Zhao, 2005). This requires a new communication environment where several groups can be involved to manipulate the activities of an environment according to different demands. A collaborative virtual environment is such an environment. Virtual environment is an interactive, spatial, real-time medium that can represent complex data and information in a vivid and easy to understand way (ibid).

For example in product design, designers and engineers can use this virtual environment to share their work with globally distributed colleagues. Furthermore, these collaborative systems also allow designers to work closely with suppliers, manufacturing partners, and customers to get valuable input into the design chain (Li et al., 2005), see figure 63.

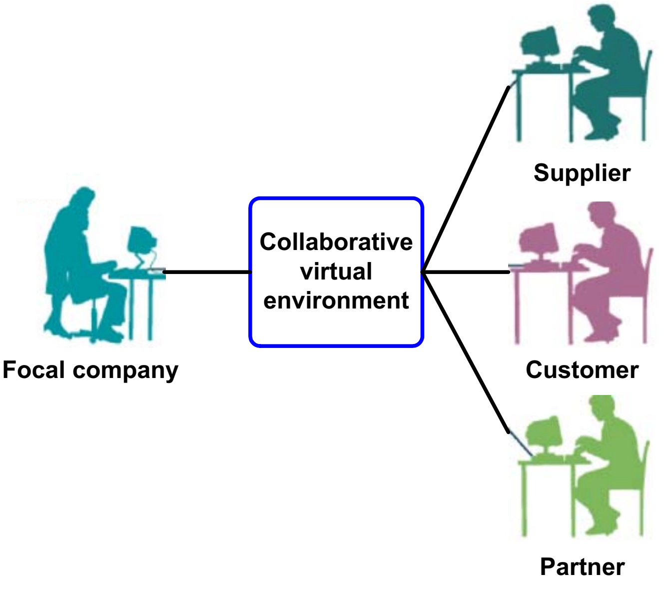

Figure 63 Collaborative virtual environment

According to Zhang and Zhao (2005) there are four areas in the Extended Enterprise that may benefit from the use of virtual environment (VE) technology:

1. *In designing a new supply chain*, VE enables new products or technology characteristics to be verified, and the processes of their construction and operation to be simulated without any physical investment, such as material, equipment, and human resources.
2. *For specific problems*, such as process planning and machine scheduling, VE enables greater understanding of the problem from different perspectives; as virtual environments are flexible and interactive so that users can move between different views of a model to facilitate their thinking.
3. *For material and information flow in supply chains*, VE enables users to visualise and simulate production and workflow, which increases clarity in production cycles, allowing problematic areas to be identified.
4. *For training value chain practitioners*, VE changes the way people learn about specific objects, and the way in which people communicate their insights to others. It promises to facilitate wider understanding of the built VE environment, and to enable clients, managers, and end users to contribute their experience (Whyte, 2002).

Particularly area 2, but also area 3 and 4, will be in focus in this thesis. The intention is to create a collaborative virtual environment for planning, control and monitoring operations in the Extended Enterprise.

4.6.6 Advances in ICT

A six, and final, source of inspiration for information visualization in the Extended Enterprise is the recent advances in ICT.

In chapter 1 the rapid development and evolution of Information and Communication Technology was introduced as one of five key trends within today's business environment. A wide variety of these ICT systems were introduced in chapter 2. In this regard it is important to stress four facts:

- ICT itself will not contribute in value adding
- ICT implementation has to be aligned with business strategy and operations capabilities
- The challenge is to combine different ICT tools into a connected and holistic tool for the whole business, and by doing it correctly it can give great competitive advantages
- It is not only the availability of new ICT that drive the development, but equally important the decreasing cost of this ICT tools; ICT is becoming a commodity

In autumn 2003 SINTEF conducted a study of supply chain management tools for production and logistics, and made the following conclusion for the future ICT systems in the value chain (Borgen et al, 2003):

- ICT systems must be able to give instantaneous correct, updated and available information, not only from production equipment (e.g. machines) but also from the material and information flow in the value chain
- ICT systems must be able to visualize the information and transform it into knowledge in order to enable a quick and correct decisions making
- ICT systems must as fare as possible offer self-correcting systems where the need for re-planning is mineralized
- ICT systems must utilize the traceability possibilities that are offered within several ICT systems in the value chain

- ICT systems must be able to use all the historical information which are collected and use this information for improvement purpose
- New types of Key Performance Indicators has to be developed, in order to unveil occurrence in advanced

This thesis will try to develop information visualization (and visibility) system according to the conclusion made in the SINTEF study.

4.7 Summary

Throughout chapter 4, both the rationale and inspiration for information visualization in the Extended Enterprise have been outlined. Due to the presentation and discussion made in chapter 4 it is possible to make the following summary of information visualization in the Extended Enterprise:

- Information visualization can help to overcome the situation of information overload that many companies and individuals are experiencing. Information visualization will help individuals and companies to organize, summarise, customize, and present the information in an easy recognizable manner for the user.
- Information visualization can through the use of models enable holistic thinking in the Extended Enterprise. Information visualization lets people understand in a totally new way how the value chain operates, and provides the big picture of how your business is linked with others and identifies your business role in the value chain (Lofts, 2002).
- Information visualization can through the use of ICT and models create a collaborative virtual environment enabling dispersed operations. Through the use of models, information visualization can overcome some of the barriers of time and space of dispersed operations and improve this virtual coordination and collaboration process. As a result, information visualization can recreate a (virtual) physical feeling for the individuals involved
- Information visualization can help speeding up processes. Information visualization can enable people to experience and understand a great deal in a very short time (Lofts, 2002). Information visualization will not only enable a more rapid understanding and response, but also increase the speed of business through the use of models in design, prototyping and testing etc.
- Information visualization can be powerful as decision support. Information visualization, through the use of models, helps provide common understanding among users about operations and structure, to support analysis or decision-making, or to control operations (Vernadat, 1996).
- Information visualization can take advantage of the recent and rapid advances within ICT, and inspiration form visual factory and management, control centre, and process control and monitoring within the process industry in order to create a powerful solution for efficient and effective planning and control of operations in the Extended Enterprise.

The bullets above are not a complete and comprehensive list of all benefits, specifications and applications of information visualization in the Extended Enterprise, but rather a short summary of some key features in the previous presentation and discussion of information visualization.

The presentation of the information visualization concept, with its rationale and inspirations, the bullets list above, the experience gained through the case studies, will all contribute to the specification made in chapter 5 for an information visibility and visualization system.

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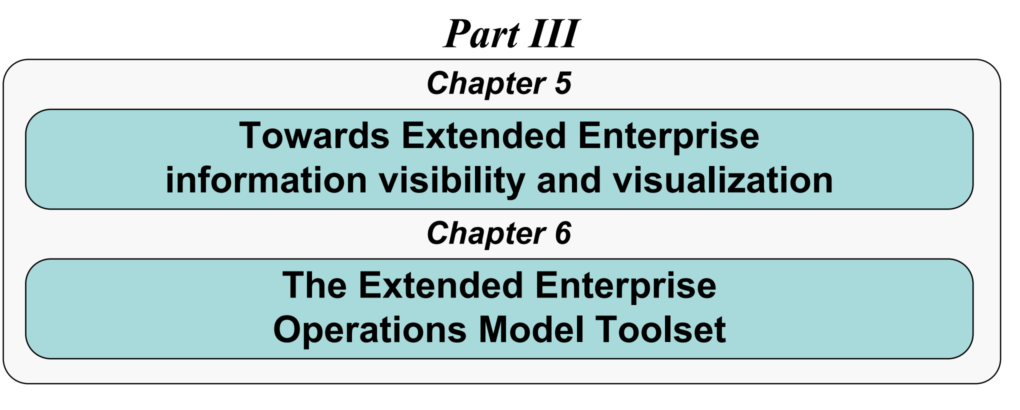
PART III

Synthesis and results

This main objective of Part III is to ***present the analysis, findings and results*** *of this thesis. In this part the* ***literature review*** *presented in Part II (chapter 2-4) is* ***merged*** *with the* ***experience gained in the field studies****. The field studies are however not presented in this part, but rather in Part IV (chapter 7-8). The underlying assumption in this thesis is that* ***information visibility*** *and* ***visualization*** *can contribute to* ***powerful and efficient support in control and planning of operations in the Extended Enterprise****, and thereby* ***improved material and information flow throughout the value chain****, and ultimately* ***operational excellence****.* ***The Extended Enterprise Operations Model Toolset*** *is a set of tools providing* ***information visibility*** *and* ***visualization*** *in the value chain.*

Chapter 5 *is devoted to the combined concept of information visibility and visualization in the Extended Enterprise. The concept of information visibility and visualization rely greatly on the theoretical fundament brought on in the literature presented in Part II (chapter 2-4), together with the needs/lacks identified in literature and in the field studies. The objective of this chapter is to introduce the concept of information visibility and visualization in the Extended Enterprise, together with functionalities for an information visibility and visualization system, and ultimately information sharing requirements in the Extended Enterprise.*

Chapter 6 *will introduce and present the Extended Enterprise Operations Model Toolset. The Extended Enterprise Operations Model Toolset is an information visibility and visualization system; i.e. a system enabling information visibility in the value chain and providing powerful and rich visualization of the shared information. The objective of the EE Operations Model Toolset is to provide a powerful set of tools as decision support for planning, control and monitoring of operations in the Extended Enterprise. Each tool within the toolset will be thorough debated, together with the holistic view of the toolset.*



Chapter 5

Towards Extended Enterprise Information Visibility and Visualization

5 Towards Extended Enterprise Information Visibility and Visualization

Chapter 5 is devoted to the combined concept of information visibility and visualization in the Extended Enterprise. The concept of information visibility and visualization rely greatly on the theoretical fundament brought on in the literature presented in Part II (chapter 2-4), together with the needs/lacks identified in literature and in the field studies. The objective of this chapter is to introduce the concept of information visibility and visualization in the Extended Enterprise, together with functionalities of an information visibility and visualization system, and ultimately information sharing requirements in the Extended Enterprise.

5.1 Introduction

The focus in this thesis is to manage and control the *virtual value chain*, i.e. the flow of information, to support, improve and enhance the *physical value chain* of the Extended Enterprise. It is basically a question of exploring and exploiting the unreleased power of the information.

5.1.1 The virtual value chain

Every business today competes in two worlds (Rayport and Sviokla, 1995): ***A physical world of resources*** that managers can see and touch and a ***virtual world made of information***, see figure 64.

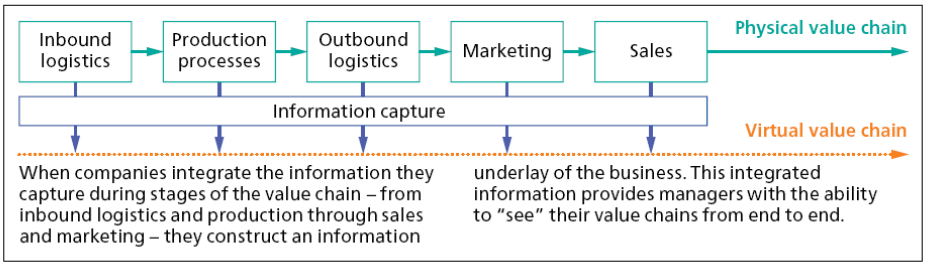


Figure 64 Building the virtual value chain

Source: Rayport and Sviokla (1996)

The challenge is to manage and control the *virtual value chain*, i.e. the flow of information (see figure 64), in such a manner that it supports, improves and enhances the *physical value chain*. This challenge can be broken into two distinctive sub-challenges:

- ***Enabling and securing a seamless, accurate and timely flow of information*** between all value chain actors (i.e. information visibility; see chapter 3).
- ***Exploiting the available information*** to a competitive advantage for the value chain, and its participating companies, and to provide a greater value proposition to the customer (among other information visualization; see chapter 4).

The challenge of managing and controlling the virtual value chain is the underlying basis of this thesis. Chapter 5 is therefore devoted to how Extended Enterprises can improve their business by sharing information and exploiting this information in a way that provide increased value for the customers and themselves.

5.1.2 Background and motivation

The underlying assumption in this thesis (see chapter 1.4.2) is that information visibility and visualization can help Extended Enterprises to overcome many of the problems that they are facing (see chapter 1 – 4, particular chapter 1.4.3). This is enabled through:

- Integration of ICT systems within and between companies in the Extended Enterprise, and information sharing between these systems.
- Providing (proactive) principles, tools and methods supporting planning and control of operations in the Extended Enterprise.
- Introducing holistic thinking regarding operations in the Extended Enterprise, i.e. make it possible for every member (e.g. employee, company, etc) to see the *big picture*; how its own activities/processes are only a fraction of a larger system (the value chain), and highlight the cause and effect relationships of its action in this system.
- Developing uniform modeling techniques and construct for operations in the Extended Enterprise, enabling holistic thinking and decision support.

And further, information visibility and visualization may help Extended Enterprises to improve their operations and gaining a competitive advantage in today's business environment:

- By ***reducing system demand variation*** (how small changes in customer demand are dramatically amplified upstream in the value chain)
- ***Speeding up processes***, and enable a more responsive and adaptive Extended Enterprise; i.e. enabling a demand driven Extended Enterprise
- ***Reducing costs***, by eliminating or lower inventory along the value chain, avoiding obsolete inventory, avoiding stock–outs and rush orders, etc
- ***Improving and simplify the planning and control process*** of operations in the Extended Enterprise, by visual access to timely and accurate information.
- ***Reducing risks*** in the Extended Enterprise, by streamlining the information flow throughout the value chain
- ***Synchronizing the Extended Enterprise***, enabling a nearly continuous demand driven flow of product along the value chain

Information visibility is about ICT integration along the value chain, and information exchange between the partners in the Extended Enterprise. Information visualization on the other hand, is about how the exchanged information is presented to the user. Whereas information visibility deals with how various ICT systems are able to communicate with each other (see chapter 3) and what type of information that is exchanged between these systems, are the major concerns of information visualization how different models (see chapter 4) and other graphical interfaces can be used in order to enable and amplify cognition and rapid and action-oriented understanding.

5.1.3 Focus

The information visibility and visualization concept are tight connected with the ***flow of information and materials along the value chain***, and not at least how to improve and make this process more efficient and responsive. The information flows have a direct impact on the production scheduling, inventory control and delivery plan of individual members of the value chain (Lee et al., 1997a). The information visibility and visualization concept address the essence of logistics; providing the right product (in the right quantity, at the right time, at the right location, for the right price) for the customer.

The information visibility and visualization concept ***seeks to improve the material flow*** in the Extended Enterprise, ***by visualizing, simplifying and streamlining the supporting information flow***, ***connecting the material flow to the actual demand from the customers***, and ***enhancing the planning and control process of the material flow*** (i.e. manufacturing and logistics operations).

The information visibility and visualization concept have limited focus on physical re-design of the material flow (e.g. new layout, locations, etc) throughout the value chain. This does not imply that such a physical re-design is not regarded as important! The focus is determined by the scope (see chapter 1.3.5) and limitations (see chapter 1.7) made in this thesis.

The remaining part of this chapter will focus on how the concepts of information visibility and information visualization can be merged into a concept for information visibility and visualization in the Extended Enterprise.

5.2 The Information visibility and visualization concept

The aim of chapter 5.2 is to introduce and present the concept of information visibility and visualization in the Extended Enterprise, to specify functionalities of an information visibility and visualization system, and information sharing requirements in the Extended Enterprise.

5.2.1 Introducing the information visibility and visualization concept

The first purpose of chapter 5.2 is to introduce the information visibility and visualization concept for Extended Enterprises. So far information visibility and information visualization have been described and discussed separately. The two concepts have separately been defined as (recapitulation from chapter 3.3.1 and chapter 4.3.1):

- Information visibility is the ability to "see" (i.e. access) all relevant information, on-line and in real time, in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. This is achieved through a seamless flow of accurate and timely information (e.g. customer demand information and other operational, tactical and strategic information influencing the operations) within and between companies in the value chain.
- Information visualization is the use of computer-supported, interactive, visual representations (i.e. models) of abstract and complex data and information for gaining new knowledge, amplify cognition, and rapid and action-oriented understanding.

The objective of this thesis is how to combine these two concepts into a powerful toolset for the Extended Enterprise. The basic logic of combining these two concepts is obvious: Information visibility will provide access to all relevant information in the Extended Enterprise, whereas information visualization will support communication, monitoring, analysis, and decision making on the basis of this information. In this thesis the information visibility and visualization concept will be related manufacturing and logistics processes in the Extended Enterprise, and the management of those.

Information visibility and visualization can be defined as: ***The ability to visually access (on-line and in real time) all relevant information in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. The visualization of information is enabled through the use of computerized models and other graphical interfaces. These computerized models are supported and linked to a flow of accurate and timely information spanning the value chain***.

The information visibility and visualization concept is illustrated in figure 65. Figure 65 is a fusion of figure 42 (information visibility in the Extended Enterprise) and figure 52 (information visualization in the Extended Enterprise), where the aim has been to take the essence of each figure and concept and merge them into figure 65.

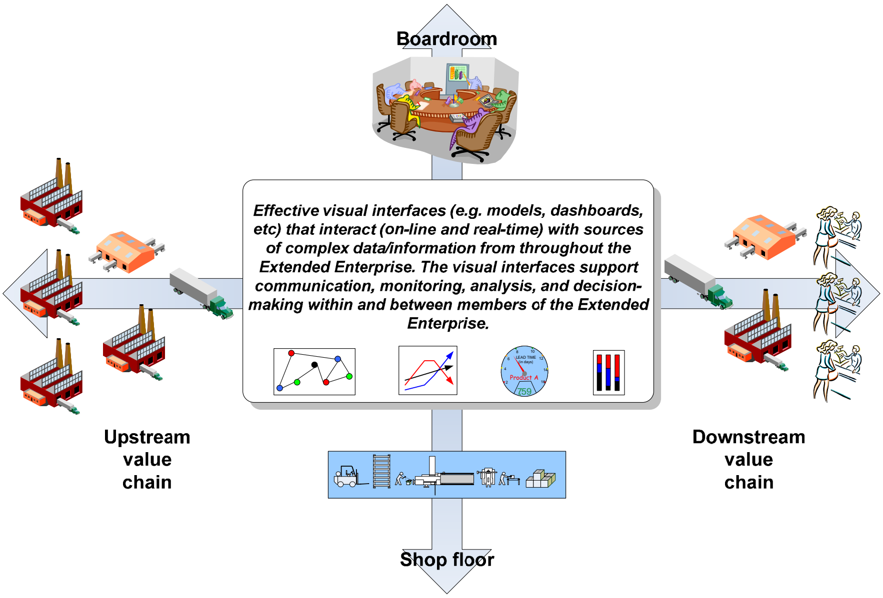


Figure 65 Extended Enterprise information visibility and visualization

The intention is to have a seamless, accurate and timely flow of information both internal within each company (from boardroom to shop floor) in the Extended Enterprise and external between the individual companies (upstream and downstream in the value chain) in the Extended Enterprise. This information is then visual available and/or customized presented for individuals or group of individuals at all levels within each company of the Extended Enterprise. In this manner do not only the companies in the Extended Enterprise have access to all relevant information regarding manufacturing and logistics processes, but they also posses a powerful visual tool supporting planning and control of operations in the Extended Enterprise.

This visual tool will secure a proactive, responsive and effective planning and control of manufacturing and logistics processes in the Extended Enterprise through:

- ***Improved and action-oriented communication*** between the members of Extended Enterprise. The communication will be supported by the use of models and other graphical interfaces enabling an easy and rapid understanding. This communication between members of the Extended Enterprise will typical be virtual; globally dispersed teams communicating through ICT tools, where the models and other graphical interfaces plays a decisive role. Within the companies in the Extended Enterprise, the communication should in addition be enhanced through the use of strategic located board and screen (e.g. at the shop floor). Further, the models will function as a common language in the communication between the various actors of the Extended Enterprise.

- *Customized graphical user interface* where each user has direct access to all relevant and critical information. The customized graphical user interface will enable quick access to information, avoiding time consuming information searching efforts, help monitoring the operations in the Extended Enterprise, and alerting the responsible persons when a problem or event occurs.
- *Visual models enabling holistic thinking* in the Extended Enterprise. The information will be accessible through layered models providing the big picture of operations. In this manner it is easier to understand the relationships between the various processes in the Extended Enterprise and how one process may affect others. This will enable system thinking in the planning and control of operations, and not sub-optimization.
- *Monitoring the flow of information* along the value chain, and alerting when events, exceptions and/or problems occur or are in the progress of occurring. In this manner it is possible in most cases to take action prior actual event and minimize the potential damage. However, of equal importance is the possibility to take advantage of such events or opportunities that are emerging (e.g. detecting new demand trends), and be able to respond to these.
- *Visual analysis of the operations* in the Extended Enterprise, and the accompanying information. The visual analysis will help improve the actual operations and/or the planning and control of operations in the Extended Enterprise. A key objective will be to improve the material flow throughout the Extended Enterprise, e.g. smoothen and speeding up the flow.
- *Improved decision support* due to the availability of (accurate and timely) information and the powerful means that the models and the graphical user interfaces are providing. The access to and the visualization of information enables a rapid and concise support to planning and control decision in and between the companies in the Extended Enterprise.

All in all, information visibility and visualization in the Extended Enterprise is a new and promising concept for supporting planning and control of operations in the Extended Enterprise.

5.2.2 Information visibility and visualization system functionality

The second purpose of chapter 5.2 is to specify functionalities of an information visibility and visualization system.

An information visibility and visualization system is a system that is coincident with the definition of information visibility and visualization given in chapter 5.2.1; i.e. a system that enables information visibility and visualization in the Extended Enterprise. It is a system that:

- o Support a seamless flow of accurate and timely information across the Extended Enterprise.
- o Enable easy integration, connectivity and interoperability between various and necessary ICT systems in the Extended Enterprise.
- o Enable visualization of the shared information through the use of computer supported models and other graphical interfaces.
- o Support communication, monitoring, analysis, and decision making within and between members of the Extended Enterprise.
- o Enable automation of operations, and provide alerts prior to events and/or exceptions.

The functionalities are based on the literature study given in chapter 2-4, then particular the discussion of the information visibility and information visualization concepts made in chapter 3 and 4, the experience gained through the case studies (chapter 7 and 8), and not at least the research problems and objectives outlined in chapter 2.

Table 5.1 lists and summarizes the functionalities of information visibility and visualization systems. The functionalities are grouped into six properties:

- o *General* – includes some overall properties of an information visibility and visualization system.
- o *Mode* – includes the basic functions or area of application of the system.
- o *Focus* – includes the focus areas of the system.
- o *Use* – includes important aspects of the user-friendliness of the system.
- o *ICT* – includes some high level ICT requirements.
- o *Integration* – includes several aspects of how the systems should share information and integrate with other ICT systems.

These six properties constitute a system fulfilling the requirements of an information visibility and visualization system specified above. The six properties are further explained and detailed in table 24.

Functionality of a information visibility and visualization system		
Properties		***Comment***
General	*Low cost*	The system should be low in cost for acquisition/development, implementation and maintenance. This will enable a widespread diffusion of the system in the Extended Enterprise, including SMEs.
	Security and trust	Security and trust are key issues in information visibility. Without adequate built in security into the system, partners will not share information with each other. Further, each partner in the Extended Enterprise must be assured that the shared information will be used as intended (Davis and Spekman, 2004).
	Standards	The system should be based on well-known, rich and reliable standards, reducing the need for customized system solutions to a minimum. Further, it helps and smoothen integration and upgrades of the system.
	Low threshold	The system should have a low threshold, i.e. easy to learn how to use the system. It should not be an expert system suitable only for highly skilled and trained people, but rather a system for everybody

Functionality of a information visibility and visualization system		
Properties		***Comment***
		in the Extended Enterprise. But it is important to stress that the low threshold should not limited the functionality of the system.
	Single point of access	The system should be integrated with all relevant data/information sources throughout the Extended Enterprise, giving the user one system to relate to in order to get all necessary company and value chain information.
Mode	*Communication*	The system should facilitate and enforce the communication between the Extended Enterprise partners, as well as internally in each company. Models and other graphical interfaces will act as a common language in the Extended Enterprise, and enable a mutual and rapid understanding. Further, the system should support virtual communication between geographical dispersed Extended Enterprise partners.
	Monitoring and alerting	The system should monitor the flow of information along the value chain, and the processes associated with the information. The system should alert when events, exceptions and/or problems occur, or are in the progress of occurring, and predict future trends.
	Analysis	The system should give the user the ability of interaction and analysis of the shared and visualized information. The aim of the analysis should be to improve the material flow through the Extended Enterprise, and support planning and control of operations.
	Decision making	The system should, through access to and visualization of information, give the user a rapid and concise support to planning and control decision in and between the companies in the Extended Enterprise.
Focus	*Process based*	The core fundament of the system are processes, and than particular manufacturing and logistics processes and the management and control of these. The system is built around these processes, and the main purpose of the system is to support and improve these processes.
	Flow oriented	The system focus on flows in the Extended Enterprise, and than particular the flow of materials/products and information. One of the objectives of the system is to surpass or eliminate the information transmission lead-time from one end of the value chain to the other, see figure 4.1. The aim is to streamline the information flow in order to improve the material flow.
	Model based	The system should support six different model views (process, resource, material, information, organization, and control; see chapter 4.4.5 and 6.2.3 for more information). These six model views enable a holistic and unified presentation of the operations in the Extended Enterprise.
	Team based	The system should be team based, supporting both physical co-localized teams and virtual distributed teams. The system should provide a physical and virtual workspace, through the use of digital boards/screens, portals, cameras, instant messaging/IP telephony, etc. This will enable team based collaboration throughout the Extended enterprise.
Use	*Multimedia functionality*	The system should support multitude content forms, including text, audio, still images, animation, video, and interactivity content forms. Further, it should support non-linear medium of information – hypermedia – which offers the user interactivity to navigate in the

Functionality of a information visibility and visualization system		
Properties		***Comment***
		information.
	Visual presentation of data/information	The system should, by definition, support visual presentation of data/information. This is achieved through the use of the six model views and other graphical interfaces such as dashboards, graphs, pictures, etc.
	Multi display	The system should support multi display functionality, where the user has several (e.g. 3-9) monitors which each can be customized to his/her particular needs. See figure 4.11 and 4.12 for examples of such multi displays. However, the system should also function on a single display.
	"Play" functionality	The system should to some extend provide some "play" functionality; i.e. give the user the ability to run various scenarios ("what if") in order to find the "best" solution. The user may change an input variable, an assumption, or a parameter value, and see how this affects the solution. This may imply optimization and/or simulation.
	Multi medium	The system should support various communication medium, such as PCs, cell phones, PDAs, Hand Held Terminals etc, in order to deliver the data/information in the most appropriate manner to the user.
	Back-up (off-line) functionality	The system should always be available for the user, even in times the system is not connected to the Internet. When the system is off-line, the user is able to use the system with "old-data"; real-time data from last time the system was on-line. However, this is more like an emergency solution, and the aim is to have a 100% on-line system.
	Tracking of historical data	The system should track and store all data, and make this data available for tracing and analysis.
	Drill-down and interactivity	The system should be interactive and provide the user the ability to drill-down the information presented. It should not be merely a static presentation of data/information, but rather a structured presentation of data with the possibility to go into detail and further investigation and analysis.
	Synchronous/ Asynchronous	The system should be a combination of a synchronous and asynchronous system. Synchronous systems run in real-time and support instant team communication and collaboration, whereas asynchronous systems allow the user to access stored information (Deek et al., 2003).
ICT	*Web based*	The system is build upon a web-based ICT solution, where there are intranets within the companies and extranets between the companies in the Extended Enterprise.
	Portal solution	The system should provide personalized and customized interfaces and solutions for each members and "role" in the Extended Enterprise. This implies that each person log on to the system and access its own personal profile. The profile may be customized according to individual needs and preferences, and according to the job and function.
	On-line system	Through the web-solution (intranets and extranets) is the system globally available and accessibly for all users.
	Real-time access	Every transaction, occurrence, plan or change are immediately registered and made available in the system.
Integration	*Information sharing*	Support and enable sharing of all types of information listed in table 5.2. The sharing of this information in an automated, timely and

Functionality of a information visibility and visualization system		
Properties		*Comment*
		accurate manner, enable information visibility in the Extended Enterprise. Further, the system should address 1) what to share, 2) whom to share with, 3) how to share, and 4) when to share.
	Interoperability	The system should through the use of SOA and EAI (see chapter 5. 3) enable connectivity and interoperability between the various ICT systems in the Extended Enterprise, securing an automated and seamless flow of information along the value chain.
	Automation of data collection	The system should as fare as possible be based on automatic data collection, through the use of RFID, GPS, etc., and in less extent on manual entry.
	Adaptable	The system should be easy to adapt to new situations, e.g. inclusion of new members in the Extended Enterprise, expanding functionality, interaction with new IT systems, etc.
	Scalable	The system should be scalable, and suitable for both small and large companies, with few and many users.

Table 24 Functionality of an Extended Enterprise information visibility and visualization system

The functionalities specified in table 24 are meant on one hand as a further step in defining and explaining the information visibility and visualization concept, and on the other hand as high-level specifications and guidelines for developing, evaluating, and/or acquiring information visibility and visualization systems for the Extended Enterprise.

5.2.3 Information sharing requirements

The third purpose of chapter 5.2 is to specify information sharing requirements in the Extended Enterprise. All the functionalities specified in table 24 are worthless if not the information visibility and visualization system have access to accurate and timely information.

The information sharing requirements have to fulfil the requirements of information visibility as well as information visualization. This means that the requirements listed in this chapter are more comprehensive than the ones listened in table 14, which mainly relates to information visibility.

According to Sun and Yen (2005), sharing of information should consider four questions (see chapter 3.4.1): 1) What to share, 2) whom to share with, 3) how to share, and 4) when to share. Of these four questions, are by fare question 3 the easiest; information sharing is enabled through the information visibility and visualization system.

The remaining three questions can be illustrated and explained through the information sharing cube, see figure 66. The three questions constitute the three dimensions in the cube:

- ***Information type*** relates to *what to share*, and specifies what kind of information the members of the Extended Enterprise should share in-between them. This involves both visibility enabling information and visualization related information. The visibility enabling information is basically a more structured and compressed version of table 14. The visualization related information is additional information necessary for the various models and other graphical interfaces enabling visualization.

- *Information level* relates to *when to share*, and address the time frame of the information. This builds on the work of Seideman and Sundarajan (1998) and Derrick (2003), see chapter 3.4.1.
- ***Actors*** relates to *whom to share with*, which basically means the members of the Extended Enterprise.

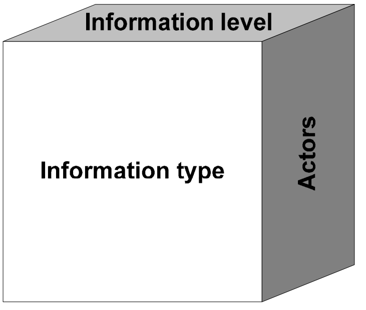


Figure 66 The information sharing cube

The information type dimension is the most comprehensive of the three dimensions in the information sharing cube. Table 25 lists the information types required to share in the Extended Enterprise. This is, as already mentioned a more structured and compressed version of table 14, with supplementary visualization related information types.

Information sharing requirements	
Information type	***Comment***
Sales and demand information	This category includes every type of information related to the demand side of the Extended Enterprise, and spans from point-of-sales (POS) data, to sales/demand forecast and information regarding promotion activities.
Order information	This is information related to actual orders, including order status. Examples of such information can be sales order, production order, purchase order, call-offs, advanced shipping notice, etc.
Planning and control information	This category is a collective term for information related to planning, forecasting, replenishment, execution, monitoring and control in the Extended Enterprise. This type of information has close links to sales and demand information and order information, as well as to inventory information, delivery information and production information. Examples of such information can be production plans/schedules, demand forecasts, material requirements, delivery schedules, shipment plans, work-in-progress etc.
Inventory information	This is information related to storage of raw-materials, components, and products throughout the value chain. This category should on one hand give information about contracts (external warehouse), locations, capacities and capabilities of the various inventories, and on the other hand provide updated information about current inventory levels.
Delivery information	Delivery type of information is information regarding the logistic process (Transport and Distribution) in the Extended Enterprise, including logistic resource oriented information. This includes information about contracts, capacities and capabilities, lead times, availability, in-transit, etc.
Production information	This type of information includes all relevant information about the production process throughout the value chain, including production resource oriented information. Examples of such information can be production location, production capacity and capabilities, lead times, availability, work-in-progress, etc.
Product information	Product information relates to the various products in the Extended Enterprise, and the products characteristic, properties and requirements. This category also involves the engineering phase, and spans the life-cycle of the products. This may be design information, drawings and documents, specifications, bill-of-material

Information sharing requirements	
Information type	***Comment***
	(BOM), start-of-production, end-of-production, etc.
Performance information	This category includes information about individual companies and Extended Enterprise performance. This may be information such as on-time delivery, plan accuracy, production quality, material flow, information/material throughput time, etc.
Event and exception information	Event and exception type of information are information about irregular occurrences in the Extended Enterprise. In most cases must the companies in the Extended enterprise take (either individual or collaborative) appropriate measures against these events and exceptions. Examples of such information can be strike, machine failure/shut-down, road construction work, bad weather, etc.
Organizational information	This type of information includes every aspect of the companies in the Extended Enterprise. The aim of sharing this information is to enable a close collaboration and trust in the Extended Enterprise, and enrich the Extended Enterprise models with useful information. This type of information spans from simple information such as telephone numbers, to more sensitive information such has processes description and strategies.
Financial information	This category includes every type of information related to value chain costs and profits, as well as contracts and other financial aspect. This information can be used to build cost models for the value chain and sharing of costs and profit between the partners in the Extended Enterprise.

Table 25 Information sharing requirements in the Extended Enterprise

A twelfth type of information that may have been included in table 25, is information about ICT systems. This type of information is however omitted, since this is indirectly covered by the information visibility and visualization system.

The information level dimension can be further detailed into three sub-groups:

- ***Strategic information*** – is information on high-level and long-term decisions, typically taken every 6, 9, 12, 18, etc months. Even though new information is seldom available in this group, it should be shared immediately as new decisions are taken. Examples of this information can be year plans, product life cycle information, strategies, etc.
- ***Tactical information*** – is information that is typically updated on a weekly or monthly basis, and shared continuous. Examples of such information can be master schedule, materials requirements, demand forecasts, new products introductions, etc.
- ***Operational (or execution) information*** – this group relates to information that is updated on a day-to-day, hour-to-hour, minute-to-minute, or second-to second basis. This group is associated with real-time information exchanging in the value chain. Examples of such information may be orders, inventory levels, actual production level, process control, etc.

The last dimension of the information sharing cube is the actors in the Extended Enterprise. In the context of this thesis are five groups of actors: ***Suppliers***, ***Transporters***, ***Manufacturers***, ***Warehouses***, and ***Customers***. In other settings there may be actors such as Retailers, Wholesalers, Consumers, etc. These actors are however not included in this thesis.

The discussion of the three information sharing dimensions over the last pages is synthesized and illustrated in figure 67, which is basically a more detailed version of the information sharing cube (figure 66).

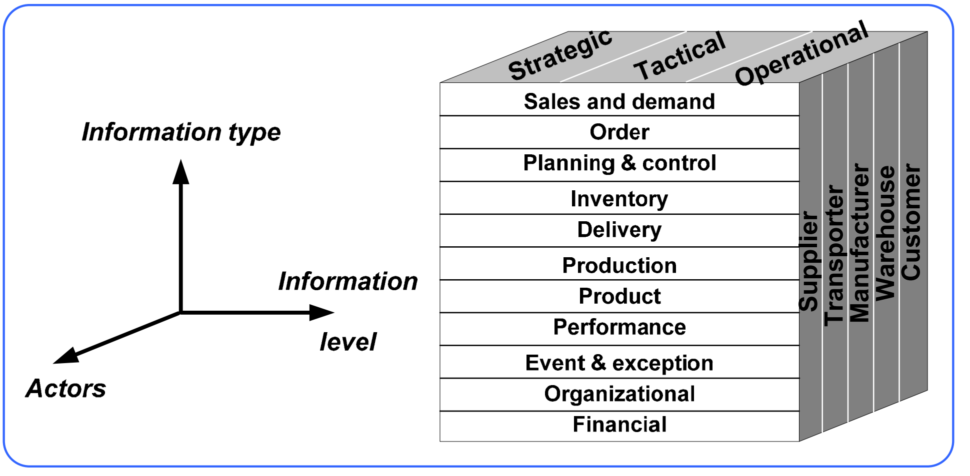


Figure 67 The detailed information sharing cube

All in all, the cube in figure 67 have 165 (11x3x5) cells which needs to be addressed when discussing information sharing in the Extended Enterprise. Some of these cells may be empty, but others may include several information units. Table 26 tries to illustrate some of this complexity, by only highlighting 15 of these cells.

Table 26 is just an example, and are by no means an all-embracing listing of all information that should be shared on an operational level between the five partners within the three information types Order, Inventory, and Production. The purpose is to illustrate that some cells may be empty, others will include one information unity, whereas others may include several. And further, to exemplify how companies should proceed when identifying what kind of information to share in the Extended Enterprise.

Information type	Actors				
	Supplier	**Transporter**	**Manufacturer**	**Warehouse**	**Customer**
Order	Purchase order Call-offs Advanced shipping notice		Purchase order Call-offs Advanced shipping notice	Pick-up orders Advanced shipping notice	Sales orders Procurement orders Call-offs Advanced shipping notice
Inventory	On-hand inventory	In-transit inventory	On-hand inventory	On-hand inventory	On-hand inventory
Production	Work in progress Actual production completed		Work in progress Actual production completed		Work in progress Actual production completed

Table 26 Sharing of operational information

The information listed below each actor should be read as the information this actor shares with the others in the Extended Enterprise.

Similar tables may be made for sharing of strategic and tactical information, and for the other information types in table 25 and figure 67.

5.3 Concluding remarks

The main purpose of chapter 5 has been to introduce the concept of information visibility and visualization. This has been done through defining and discussing the information visibility and visualization concept, and further by defining and specifying functionalities of an information visibility and visualization system, and finally specifying information sharing requirements in the Extended Enterprise.

The information visibility and visualization system and the information sharing requirements are close connected. The intention is that companies should use the information sharing requirements (e.g. the information sharing cube) to identify which kind of information to share in-between them, and the shared information is then made visual available through the information visibility and visualization system. In this manner the companies in the Extended Enterprise have access to all relevant information and posses a powerful visual tool supporting planning and control of operations in the Extended Enterprise.

The results presented in this chapter are conceptual, and can viewed as a synthesis of the literature study given in chapter 2-4, the experience gained through the case studies (chapter 7 and 8), and not at least the research problems and objectives outlined in chapter 1.

Chapter 6 will follow up the conceptual concepts and systems presented in chapter 5, and propose a concretized set of tools addressing the functionalities and requirements listed in chapter 5.

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Chapter 6

The Extended Enterprise Operations Model Toolset

6 The Extended Enterprise Operations Model Toolset

Chapter 6 will introduce and present the Extended Enterprise Operations Model Toolset. The Extended Enterprise Operations Model Toolset is an information visibility and visualization system; i.e. a system enabling information visibility in the value chain and providing powerful and rich visualization of the shared information. The objective of the EE Operations Model Toolset is to provide a powerful set of tools as decision support for planning and control of operations in the Extended Enterprise. Each tool within the toolset will be thorough debated, together with the holistic view of the toolset.

6.1 Introduction

The Extended Enterprise Operations Model Toolset (called the EE Operations Model Toolset) is a collection of individual, independent and peculiar tools. The tools and the toolset have been developed on a conceptual basis through the work of this dissertation and in some related projects at SINTEF and NTNU. Each tool can be used alone and independently, but is only when they join forces that the greatest potential can be achieved.

6.1.1 Origin and background[48]

The work of developing the Extended Enterprise Operations Model Toolset started with the MOMENT project (see Appendix B for more information). One of the work-packages in the MOMENT project (WP3) aimed at developing an ***operations model*** that enables standardized and high performance processes that are replicable and transferable, and that enables efficient planning and control in the extended manufacturing enterprises.

In the MOMENT project the fundament of the operations model was a ***process model*** for the Extended Enterprise. The idea was that the process model would enable Extended Enterprises to build up their operations based on standard processes, and allow comparison of performance levels between companies and between Extended Enterprises. Further, the operations model should be web-based and integrate information from all participants in an Extended Enterprise. Participants should get access through interfaces that are tailored to their specific needs. In the operations model, the functionality of the process model should be extended with the following additional functionalities:

- Modeling and visualization of the value chain structure and materials flow paths
- Planning and simulation functionality that supports manufacturing and logistics control
- Enable real time demand schedules to every integrated entity.

In addition, background information like product specifications, delivery agreements, resource- and transport capacities should be available.

The operations model concept was further developed and concretized in work-package 5 in the MOMENT project (The MOMENT methodology). This again, was further expanded, detailed, refined and presented in Alfnes (2005).

[48] This chapter contains quotes from the MOMENT Annex 1 “Description of Work” written by SINTEF in 2001. This document is restricted and not public available, and it is therefore not possible to reference in a traditional manner.

Later the ideas and results from the MOMENT project have been further developed through the work of this thesis and at other projects at SINTEF and NTNU (see appendix B).

6.1.2 Objective

The objective of the EE Operations Model Toolset is to provide a powerful set of tools as ***decision support for planning and control of operations in the Extended Enterprise***. The tools have been developed with a particularly focus on the manufacturing and logistics processes in the Extended Enterprise, and the aim has been to develop tools and concepts *supporting the development and operation of integrated, global and responsive value chains.*

The EE Operations Model Toolset seeks to enable ***communication***, ***monitoring***, ***analysis*** and ***decision support*** within and between the members of the Extended Enterprise, regarding manufacturing and logistics processes. The EE Operations Model Toolset will support short term operational and tactical planning and control of operations, as well as more long term strategically improvements of operations in the Extended Enterprise. This is achieved through a combination of information visibility and information visualization. The combination of information visualization and information visibility is on one hand meant to provide simple, intuitive and non-ambiguous models that structure, transform, condense, and visually display the complex structure, operations and events of the Extended Enterprise. On the other hand however, this combination provides the models with all the necessary and updated (real-time and on-line) information regarding the operation in the Extended Enterprise.

The assumption in the thesis and the rationale behind developing the EE Operations Model Toolset is that information visibility and visualization can help Extended Enterprises to overcome many of the problems they are facing, in particular: 1) enable and enforce value chain integration and collaboration, and 2) take advantage of new seducing possibilities offered by ICT. The rationale can in more detail be described as:

- Enabling value chain synchronizing and holistic thinking
- Improving, simplifying and supporting the planning and control process
- Reducing costs and risks
- Speeding up processes
- Reducing system demand variation

The logic behind the EE Operations Model Toolset is illustrated in figure 68. In figure 68 an analogy to a house is used; the fundament is the EE Operations Model Toolset, the pillars are the cornerstones in the concept (information visibility and visualization), the wall symbolizes the prerequisites, and finally the roof represents the objective and functions of the EE Operations Model Toolset.

The two cornerstones, information visibility and information visualization, in the EE Operations Model Toolset are fully presented and debated respectively in chapter 3 and 4. Value chain collaboration (e.g. the Extended Enterprise), Information and Communication Technology, and Extended Enterprise models and modeling are regarded as prerequisites for information visibility and information visualization, and ultimately the EE Operations Model Toolset. These three concepts are presented and discussed in chapter 2 and 4. The focus in this chapter will be on the fundament of the house – the Extended Enterprise Operations Model Toolset.

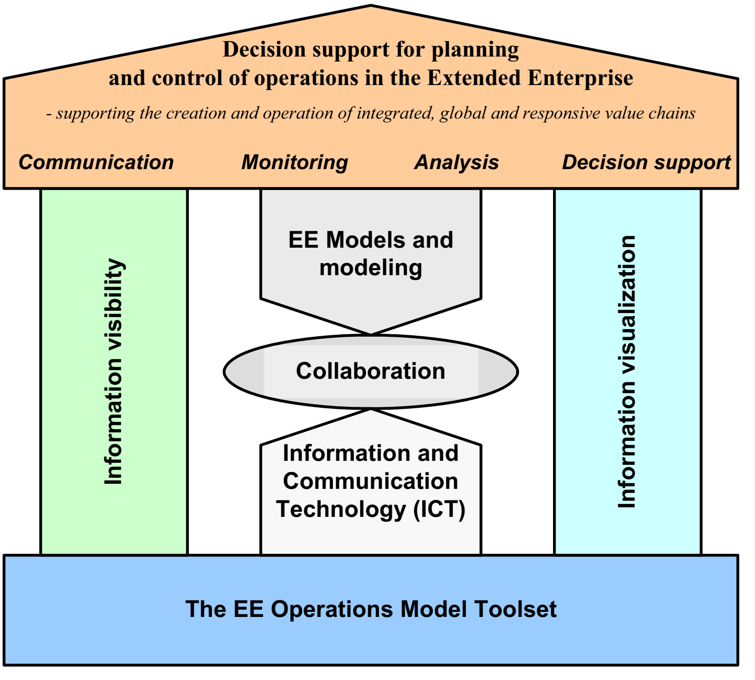


Figure 68 The Extended Enterprise Operations Model Toolset house

6.1.3 Tools and relationships

Up to now, little attention has been given to the content and functionality of the EE Operations Model Toolset and its individual tools. The remaining part of chapter 6 will be devoted to the EE Operations Model Toolset, and its tools.

The EE Operations Model Toolset constitutes six different tools:

- ***The Extended Enterprise (EE) Operations Model***
- ***The Extended Enterprise (EE) Process Model***
- ***The Extended Enterprise (EE) Modeling Tool***
- ***The Extended Enterprise (EE) Dashboard***
- ***The Extended Enterprise (EE) ICT Infrastructure***
- ***The Extended Enterprise (EE) Studio***

Figure 69 illustrates the EE Operations Model Toolset, its individual tools, and to some regards the relationship between these tools.

The main element in the EE Operations Model Toolset is the Extended Enterprise Operations Model. Like the name indicates, the toolset is focused on the EE Operations Model, and the five other tools can be seen as supporting tools for establishing, running and maintaining an EE Operations Model.

All tools contributes in some way or another to visibility and visualization in the Extended Enterprise, and ultimately to improve material and information flow through the value chain.

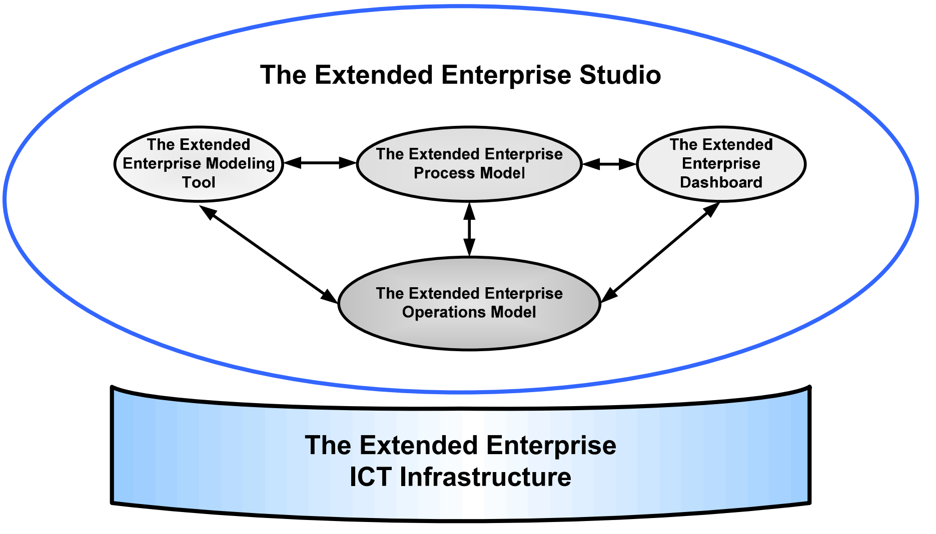


Figure 69 Overview of the EE Operations Model Toolset

The various tools play different roles in the EE Operations Model Toolset (see table 31), and all tools are in some ways both depended and related to each other. All tools can also be used separately and independently of each other for different purposes.

Even though all tools contributes and are of importance for achieving the objectives given in this dissertation, the main attention will be on the EE Operations Model and the EE Process Model. There are many reasons for this, among others:

- *Innovation* – The greatest innovation is within the EE Process Model, and partial within the EE Operations Model (in sense of further development).
- *Contribution* – The candidate is the main person responsible for developing the EE Process Model, as well as the specifications for the EE Modeling Tool, and has further contributed in developing the EE Operations Model concept. Whereas the EE Dashboard, the EE ICT infrastructure and the EE Studio have been developed among several persons at SINTEF, NTNU and external partners.
- *Scientific area* – the EE Operations and Process Model are within the scientific field of the dissertation (e.g. the candidate scientific area). The EE Modeling Tool, the EE Dashboard and the EE ICT Infrastructure are mainly ICT programming tasks, and the EE Studio is an organizational task.

In order to fulfill its objectives, the EE Operations Model is heavily dependent on the other tools in the EE Operations Model Toolset. The EE Process Model is one of six views of the EE Operations Model (see chapter 6.2.3), and may to some extent be viewed as a sub-set of the EE Operations Model. The EE Process Model is however also a tool that can be used independently of the EE Operations Model. The EE Modeling Tool may be viewed as the engine that generates web-based models. The EE Dashboard monitors the operations. The EE ICT Infrastructure is an enabler for the EE Operations Model, feeding the model with information, and enabling communication and coordination within the Extended Enterprise. The EE Studio is the environment in which the EE Operations Model is best used.

Each tool within the EE Operations Model Toolset will be presented in the remaining part of chapter 6; 6.2 – 6.7.

6.2 The Extended Enterprise Operations Model

An operations model is some sort of representation of operations in the enterprise and/or the value chain. In its simplest form it is just a picture of the processes and/or the structure of the network.

6.2.1 The traditional operations model

An operations model[49] is typically represented by model compromising four basics elements: Inputs, transformation, outputs and control. An illustration of such a model is given in figure 6.3[50] - which is identical to figure 5.

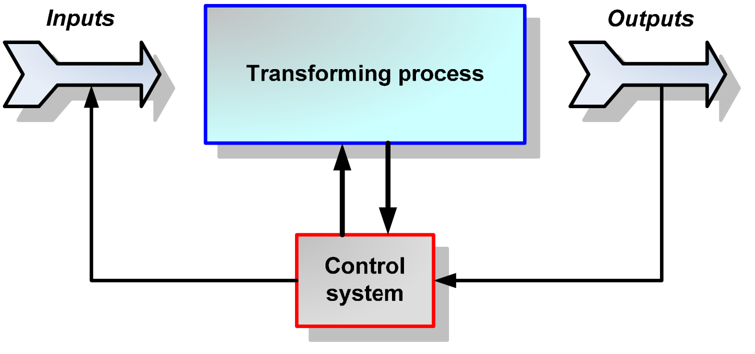


Figure 70 A typical example of an operations model

When analysing textbooks in Operations Management it is possible to conclude that only few authors use or refer to the term operations model. According to table 27 only two textbooks use the term operations model, whereas two other textbooks refer to a model of operations.

Reference to Operations Model	Operations Management textbooks
Operations model	Jacobs et al. (2009), and Waller (2003)
Model of operations	Brown et al. (2005), Brown et al. (2001)
Non referral	Russell and Taylor III (2009), Bozarth and Handfield (2008), Slack et al. (2007), Stevenson (2007), Bozarth and Handfield (2006), Greasley (2006), Hill (2005), Krajewski and Ritzman (2005), Reid and Sanders (2005), Slack and Lewis (2005), Stevenson (2005), Chase et al. (2004), Heizer and Render (2004), Gaither and Frazier (2002), Slack et al. (2001), Chase et al. (1998), Gaither and Frazier (2002), Vonderembse and White (1996), and Markland et al. (1995)

Table 27 References to Operations Model in Operations Management textbooks

Waller is the only author (in this sample) who presents an Operations Model, or more correctly an example of an Operations Model. He claims that an Operations Model is a miniature supply chain (Waller, 2003). Figure 71 is taken from his textbook and illustrates an Operations Model for nine different types of industry. On the other hand, Jacobs et al. (2009)

[49] Operational model and operating model are two related and partial congruent terms/concepts. See chapter 5.4.6 for more information.

[50] Most textbooks on Operations Management include some version of figure 6.3, but use other names, like *the transformation process model* (Slack et al., 2007), *the operations functions* (Stevenson, 2007), *operations as a transformation process* (Bozarth and Handfield, 2006), *the role of operations management* (Greasley, 2005), and *the operations process* (Hill, 2005).

just quote a consulting company[51], which lists *drive innovation in your operations and business model* as one of six essential ingredients of operational strategy.

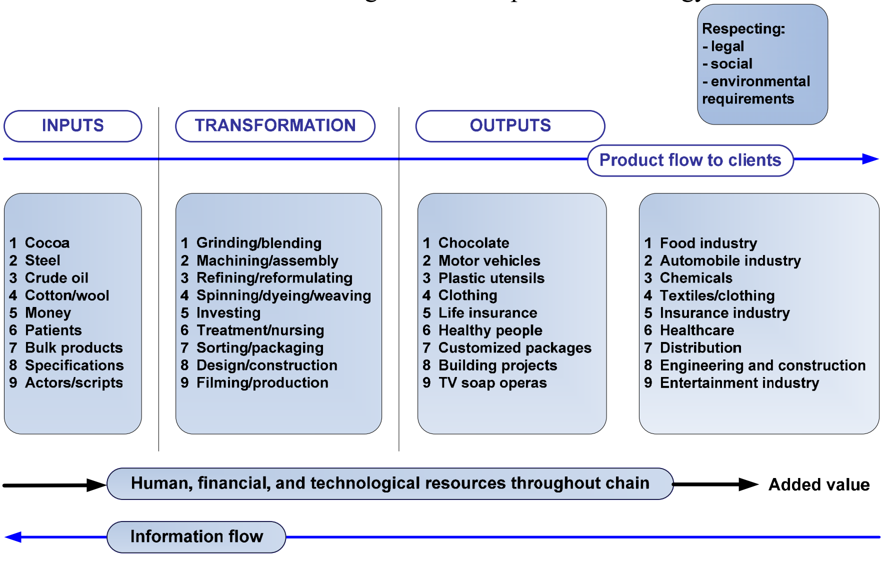


Figure 71 Example of Operations Model from Operations Management textbooks

Source: Waller (2003)

This thesis will use a more comprehensive interpretation of the term Operations Model, and the remaining part of chapter 6.2 will be devoted to this term/concept.

6.2.2 The operations model concept at SINTEF/NTNU

SINTEF/NTNU has over the last years developed a more comprehensive interpretation of the operations model concept. Alfnes et al. (2006), Alfnes (2005), Bolseth (2004), Bolseth et al. (2003), and Bolseth and Johnsen (2003) have all published about the operations model concept developed at SINTEF/NTNU. When reading these publications, it becomes clear that the operations model concept has been used in two slightly different ways (approaches) at SINTEF/NTNU:

- As a mapping data-set supporting enterprise engineering/reengineering
- As a web-based operations information portal

Regardless of approach, the main contribution in defining, conceptualizing, and formalizing the operations models concept is Alfnes (2005). In his PhD (Alfnes, op cit)[52] he argues that models that represent more details and perspectives, than figure 70, are often required to support real enterprise engineering projects (ibid). As a response he introduces what the calls the operations model-set (see figure 72).

[51] Pittiglio, Rabin, Todd, and McGrath (PRTM), www.prtm.com

[52] The work of Alfnes is influenced by earlier work at SINTEF/NTNU, such as the Control Model Methodology (see among others Quistgaard et al (1989), Strandhagen and Skarlo (1995), and Alfnes and Strandhagen (2000)), and to some extent the MOMENT project.

The operations model set can be viewed as a conceptual enterprise model[53], which aims at generating coarse description models of the enterprise operations (ibid). These models enable managers to design and analyze operations without a high level of detail, but linking them with strategy of the enterprise, and the parameters they must use to measure performance (ibid).

The operations model-set by Alfnes (op cit) is mainly developed to support enterprise engineering/reengineering, where the model-set is used for developing AS-IS model (mapping the current state of operations), and ultimately TO-BE models (new and improved operations).

However, in the MOMENT project the operations model was also used as an information portal, in addition to support enterprise engineering/reengineering. The intention was to use the operations model as a single source of information about operations (Bolseth et al., 2003), with access to on-line and structured information regarding all processes, performance and status in the Extended Enterprise (Bolseth and Johnsen, 2003). In this regard, the operations model can be viewed as a web-based ICT tool that ensures efficient and coordinated control, and real-time information and communication in the Extended Enterprise (Bolseth and Johnsen, 2003).

The two approaches to the operations model (as presented above) may seem very different and apart, but the reality is that these two approaches are coterminous and connected. Firstly, they share the same basic understanding that the operations model is some sort of representation of the operations. Secondly, both approaches share the same modeling construct, see chapter 6.2.3. Thirdly, both approaches need to map the same information in order to fill the model.

The difference between the two approaches is the range of use of the operations model. When the operations model is used to support enterprise engineering/reengineering, it is mainly used on a strategic level and the mapping (acquiring the information) is done once. When the operations model is used as a web-based information portal, it is mainly used on an operational and tactical level, with a continuous gathering of information and adjustments of the model. Thus, the operations model used as a web-based information portal, may also be used on a strategic level to support enterprise engineering/reengineering. And vice versa, the enterprise engineering/reengineering operations model may function as a basis in developing the web-based information portal.

6.2.3 Views of the EE Operations Model

When developing the operations model in the MOMENT project, it soon became clear that it was not possible to represent the operations in the Extended Enterprise through just one model/perspective. There was need for an enterprise model set, in order to obtain a coherent and comprehensive picture of Extended Enterprise operations. In the MOMENT project this

[53] Conceptual enterprise models are coarse symbolical representations that serve as the means for sense making, understanding and imagination (Alfnes, 2005). They are the manifestation and representation of a cognitive process, and represent some knowledge about the enterprise at an abstract level. Conceptual enterprise models can be viewed as any visual abstractions of the enterprise that are expressed using some modelling constructs. However, conceptual enterprise models can be distinguished from other types of enterprise models by the simple representation of knowledge (ibid).

model set included four types of conceptual models, and each type of model captured different views[54] of the Extended Enterprise. These models were:

- The process model
- The product flow (and layout) model
- The MPC systems and information flow model
- The organizations structure model

These views tried to contribute to a holistic perception of the Extended Enterprise and as a source of on-line and real-time information about operations along the value chain.

However, these four views of the Extended Enterprise were not sufficient in order to get a holistic and comprehensive picture of the Extended Enterprise. In his PhD Alfnes (2005) further developed and modified the work in the MOMENT project, and introduced an operations model-set with six different views. These six views are (ibid):

- The resource view
- The material view
- The information view
- The process view
- The organization view
- The control view

The operations model-set, with its six different views, is illustrated in figure 72.

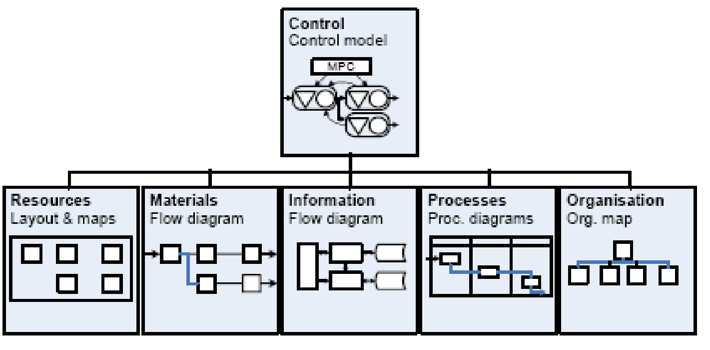


Figure 72 The operations model-set

Source: Alfnes (2005)

It is important to remember that the model-set presented in figure 72 was mainly developed to support enterprise engineering. Figure 72 propose six perspectives that should be covered in a coarse enterprise modeling effort, and shows how core concepts from several perspectives could be synthesized in an overall control model (Alfnes, op cit).

However, when applying the operations model-set as an information portal, the views may be regarded as more equal, with perhaps the process model as the core. Further, the model-set presented by Alfnes (op cit) has a limited focus on products, as the attention is on materials

[54] These views define a perspective or viewpoint from which the enterprise is considered for a given purpose, concentrating on some aspects and hiding irrelevant aspects to reduce complexity (Vernadat, 1996). It is widely recognized that these views must at least cover ***function***, ***information***, ***resource***, and ***organization***), and make possible the representation of ***material***, ***information*** and ***control*** flows of the enterprise, either separately or together (Berio and Vernadat (1999).

and material flow. Product information is of utter importance in the web-based operations model, which may be regarded as a miniature product data management (PDM) system. Thus, the material view must also incorporate product information.

6.2.4 Basic principles of the EE Operations Model

The EE Operations Model is a tool for visualization of operations in the Extended Enterprise, as well as a tool for supporting planning and control of operations in the Extended Enterprise. The basic concept of the EE Operations Model is that operations management in the Extended Enterprise can be executed and supported through a computerized operations model.

Compared to the simple version of the operations model introduced in chapter 6.2.1 (see figure 70), this is a fundamental and extensive enlargement of the concept. It is no longer just a simple illustration of inputs, transformation process, outputs, and control, but rather a powerful operations management tool.

The EE Operations Model is a visual presentation of the operations in the Extended Enterprise, and a model with several levels and dimensions; a model-set. The EE Operations Model gives an overview the Extended Enterprise, as well as access to more detailed information about all operations in the Extended Enterprise. This is enabled through the six view/perspectives of the model, and includes information about processes, resources, materials/products, information (flows and systems), organizations, and control. In more detail this means:

- ***The process view*** describes how the activities are related in terms of process stages and flows, and at a macro level, the process view describes the enterprise/Extended Enterprise functionalities (Alfnes, 2005). The process view basically gives an overview of all processes in the Extended Enterprise, and may in its simplest form be an illustration as figure in 94. The high level processes, may be further detailed into sub-processes and activities. In addition, the process model also gives access to all information related to the processes (e.g. who are responsible for process, what are the current status for process, input/output of the process, etc.).
- ***The resource view*** describes the physical attributes of resources and facilities and how they are located in space (ibid). In more detail, the resource view gives access to all sorts of information about the resources (e.g. pictures of machines, drawings, maintenance log for the machines, training manuals, capacity information, status information (temperature, pressure, amount produced), etc).
- ***The material/product view*** shows how resources are connected in space (e.g. through material flow diagram), and how tasks are linked in processes (ibid). Further, the material view also gives detailed information regarding the Extended Enterprise's products (e.g. Bill-of-Material (BOM), part description, cost/price, component and/or products drawings, etc).
- ***The information view*** describes the way in which data ise accessed, stored, processed, and transferred in the Extended Enterprise (ibid). However, the information model is not limited to just illustrate the information flow, but also gives access to all the information illustrated in the model (past and/or current information; e.g. sales orders, plans, invoices, shipping notice, etc). Further, the information view also focuses on ICT systems and the ICT architecture in the Extended Enterprise.
- ***The organization view*** describes the responsibilities and authorities of employees and organizational entities at different decisions level (ibid). In addition, the organization model gives more in-depth information about organizational issues (e.g. pictures of

the employees, phone and email addresses, access to on-line communication, competence and skills of employees, etc).

- ***The control view*** describes the Extended Enterprise in terms of decision centres and their connected control method (ibid). Further, the control model makes it possible to actively participate and support the planning and control of operations in the Extended Enterprise. This may involve activities like coordination and synchronization of plans throughout the Extended Enterprise, monitoring of operations (production, inventory, transport, etc), event and exception management, etc.

The EE Operations Model is developed to visualize, plan and control information- and material flow in the Extended Enterprise. The EE Operations Model is computerized and web-based, it ensures efficient and coordinated planning and control, it enables real-time information flow and communication, and function as an on-line repository for the Extended Enterprise.

The basic principles of the Operations Model are very simple:

- To have access to all relevant information regarding operations in the Extended Enterprise at a single source. This source may of course be accessible from a wide range of people at various locations with odd and specific needs regarding information and application for connecting to the source. In addition the information needs to be updated, accurate, timely, real-time, and on-line available. This is basically a ***visibility system***.
- To visualize this information in such a manner that it is intuitive and proactive as decision support in the planning and control of operations in the Extended Enterprise. The visualization processes does not only include the basic (but unfortunately not as simple) process of generating visual representation of the information (basically information regarding the operations), but almost equally important: Grouping and filtering of the information; building logic into the visualization. This is basically a ***visualization system***.

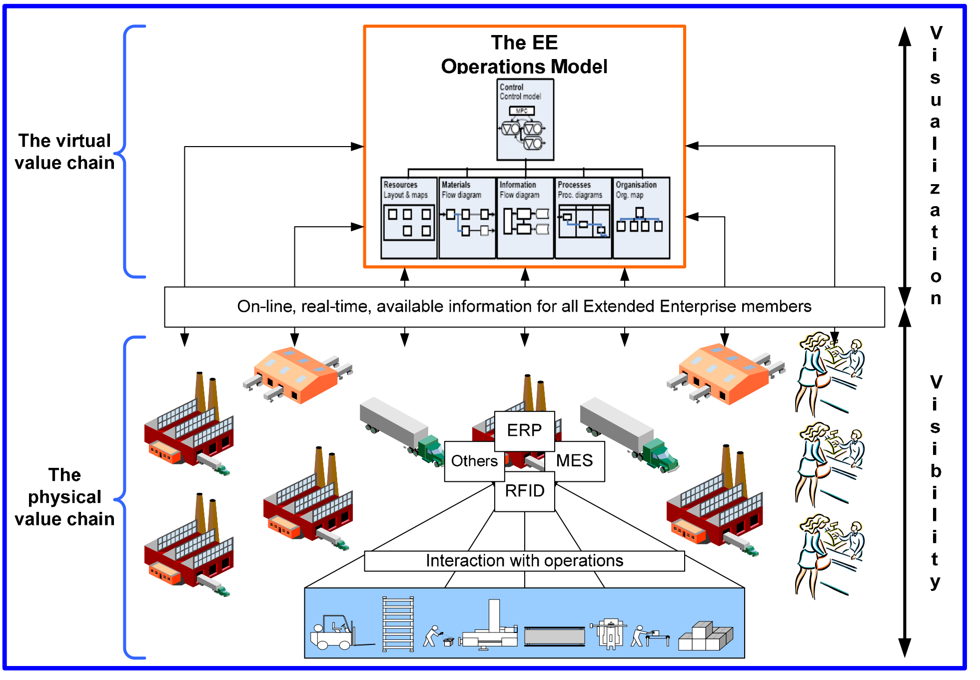


Figure 73 Principles of the EE Operations Model

Modified from (Johnsen, 2003)

Figure 73 gives an overview of the basic principles of the EE Operations Model. The figure illustrates the visibility and visualization aspects; how the different members of the Extended Enterprise are integrated and able to share information regarding the operations and finally how this information is visualized through the EE Operations Model (illustrated with the model-set). And not at least, how the EE Operations Model is used to manage the virtual values chain, in such a manner that it supports, improves and enhances the physical value chain (see chapter 5.1.1).

In figure 73 the EE Operations Model is illustrated as a unification of six different models. All these six models need to be developed in order to have truly EE Operations Model. However, in the context of this thesis only the EE Process Model is developed.

6.3 The Extended Enterprise Process Model

The Extended Enterprise (EE) Process Model has been developed at SINTEF over the past decade, and was one of the deliverables in the MOMENT project (Deliverable 3.2). The work of developing the EE Process Model was done under the responsibility of the PhD candidate. The EE Process Model has been further developed and tested in the work of this dissertation.

6.3.1 The objective and purpose of the EE Process Model

The objective of the EE Process Model is to enable Extended Enterprises to build up their operation based on standard (state-of-the-art) processes. The EE Process Model allows mapping of all actors, processes and activities in the Extended Enterprise, and thereby have a complete and corresponding description of the Extended Enterprise. When the EE Process Model is continuously fed with real-time information from the Extended Enterprise, the EE

Process Model can be compared to live television broadcasting, where the user/viewer can monitor and control the ongoing processes in the Extended Enterprise. Further, the EE Process Model may also be used to measure and evaluate the Extended Enterprise performance.

In more detail, the purposes for developing the model can be split into four categories. First, it seeks to be an efficient tool for ***mapping processes in engineering and re-engineering projects***, both in enterprises and along the value chain in the Extended Enterprise. Secondly, the model will provide ***visualization of material and information flow*** as decisions support for planning and control of operations in the Extended Enterprise. Thirdly, it will be a ***common language*** for the Extended Enterprise. And finally, provide enterprises with a set of ***pre-defined state-of-the-art processes***.

Thus, the contribution of the EE Process Model can be seen along three axes:

1. ***Scientific development of the EE*** – by describing and standardizing processes within the Extended Enterprise
2. ***Mapping and modeling purpose*** – be a powerful tool in any kind of situation where mapping and modeling are necessary
3. ***Necessary input to the Extended Enterprise Operations Model*** – provide visualization of operations in the EE Operations Model

In the MOMENT project, the EE Process Model was developed according to requirements in the automotive industry, and is not yet generic and able to support all kind of operations. The focus of the EE Process Model is processes associated with the material and information flow through the Extended Enterprise, and some supporting activities. The EE Process Model has been tested and validated in several automotive supplier cases, and to some degree in other industries (e.g. furniture, food and pharmaceutical).

6.3.2 Requirements for the EE Process Model

The overall requirement for the EE Process Model is to be able to model/visualize all manufacturing and logistics processes in the Extended Enterprise, and the processes supporting these processes. Further, the model should be easy and simple to use; i.e. the model should be plain, intuitive and have a low threshold. Table 28 presents the requirements for the EE Process Model.

Requirements	In detail
Give the overall structure of the Extended Enterprise	Identify all actors in the Extended Enterprise
	Geographical location of actors
	Links between the actors
Illustrate material and information flow in the Extended Enterprise	Both internally within a actor as well as external in the Extended Enterprise
	Including reverse logistics
Information about all actors in the Extended Enterprise	Identify the actor attributes
	Visualize top level (relevant) information of each actor (e.g. contact persons, products, contracts, web page, address etc)
Information about all processes and activities in the Extended Enterprise	Input and output of all processes and activities
	Performance indicators for all processes

	and activities
	Cost drivers for all processes and activities
	Resource information for all processes and activities
Easy use	Plain
	Intuitive
	Low threshold

Table 28 The Extended Enterprise Process Model requirements

In chapter 4 some of enterprise and value chain models are presented, discussed and reviewed. Throughout the last two decades several efforts and initiatives have been carried out within the development of enterprise models and modeling. Some of these efforts and initiatives resulted in well-known enterprise modeling frameworks (architectures, languages and methodologies) such as CIMOSA, PERA, and GIM (see Vernadat (1996), Bernus and Nemes (1996), Rolstadås and Andersen (2000) and Chalmenta et al. (2001) among others). Most of these modeling frameworks are developed for Computer Integrated Manufacturing (CIM) enterprises in supporting their enterprise integration efforts (Delen and Benjamin, 2003). Other efforts and initiatives have approached a more narrow and specific aim and application. Examples of such efforts are process modeling for ERP implementation and BPR projects (see among others Hammer and Champy (1993), van der Aalst et al. (2000) and Becker et al. (2003)), the SCOR model (www.supply-chain.org) for supply chain modeling and performance measurement, and Value Stream Mapping (VSM) (Rother and Shook, 1999) for eliminating waste and creating continuous flow within enterprises and Extended Enterprises.

Due to several reasons, neither of the models presented in chapter 4 were regarded as suitable to fulfill the purposes listed above and the requirements specified in table 28. In short the arguments can be repeated as the following (accordingly to the reasoning in chapter 4.4.9):

- ***Existing solutions are developed for another purpose than the one in mind***
  - Few, if any, are developed in the context of the Extended Enterprise
  - The majority of modeling approaches and models presented in table 18 and 19 and chapter 4.4.9 are developed to support software development and product development projects, and not business processes
  - Few, if any, have an operational and control of operations focus
  - The models that could have been applicable, are not developed in necessary detail; they are still on a conceptual level
- ***Existing solutions can not provide desired flexibility***
  - Few of the models can provide necessary visualization support; a intuitive and plain visualization of operations
  - Few of the models can support all categories
  - The majority of models are to time consuming to use
- ***Reluctance in companies to use new tools and techniques***
  - Need a model with low threshold
  - Some of the models/modeling tools have high cost

The SCOR Model is the model which comes closest to fulfilling the purpose and requirements of the EE Process Model. But still, it was not found applicable. An additional comment is that some tools may in many regards be suitable, e.g. ARIS, but are unfortunately quite costly and not freely (or at low cost) available. The low cost requirement has been considered as an absolute prerequisite for the model.

Shortly it can be concluded that the aim of developing the EE Process Model is to develop something in between the SCOR Model and the Value Stream Mapping approach. Basically an EE Process Model which gives access to predefined hierarchically and structurally processes, and at the same time provide a tool for mapping all kind of operations associated with manufacturing and logistics activities in the value chain.

6.3.3 Overview of the EE Process Model

The EE Process Model is developed for, and gives particularly focus on, operations in the Extended Enterprise. The model is developed accordingly to the requirements in table 28, and the purposes highlighted in 6.3.1.

The EE Process Model has four levels of details:

- *Level 0 - Actors (with attributes) and group of actors*
- *Level 1 - Processes (Operate, Manage and Support)*
- *Level 2 - Sub-Processes*
- *Level 3 - Activities*

Figure 74 illustrates the four levels of detail in the EE Process Model. The example given in figure 74 shows how the *operate process* at a *Manufacturer* constitute of several *sub-processes* and *activities*.

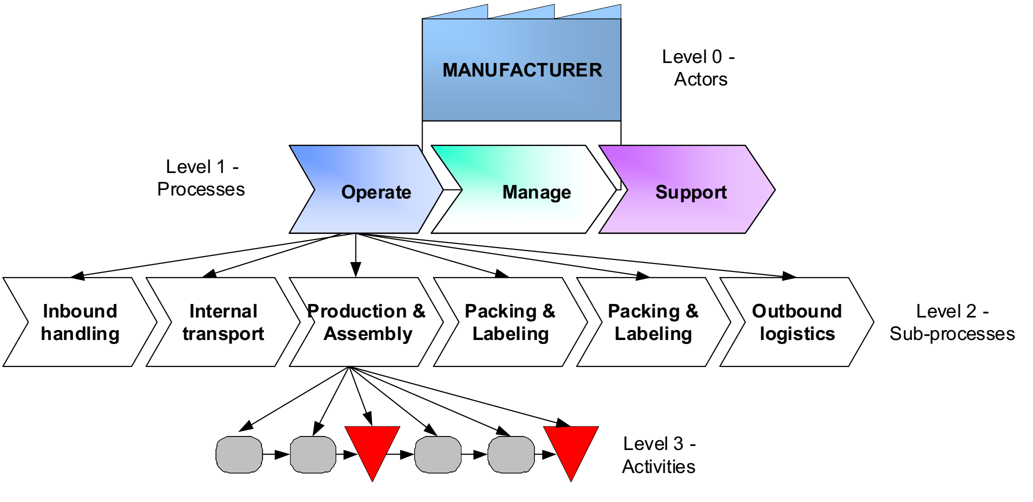


Figure 74 The EE Process Model levels

An alternative view of the EE Process Model is given in figure 75[55]. In this figure three actors are illustrated, together with processes, and sub-processes of the *operate* and *manage processes*.

[55] This view of the model is inspired by the Supply Chain Management Model presented by Lambert et al. (1998)

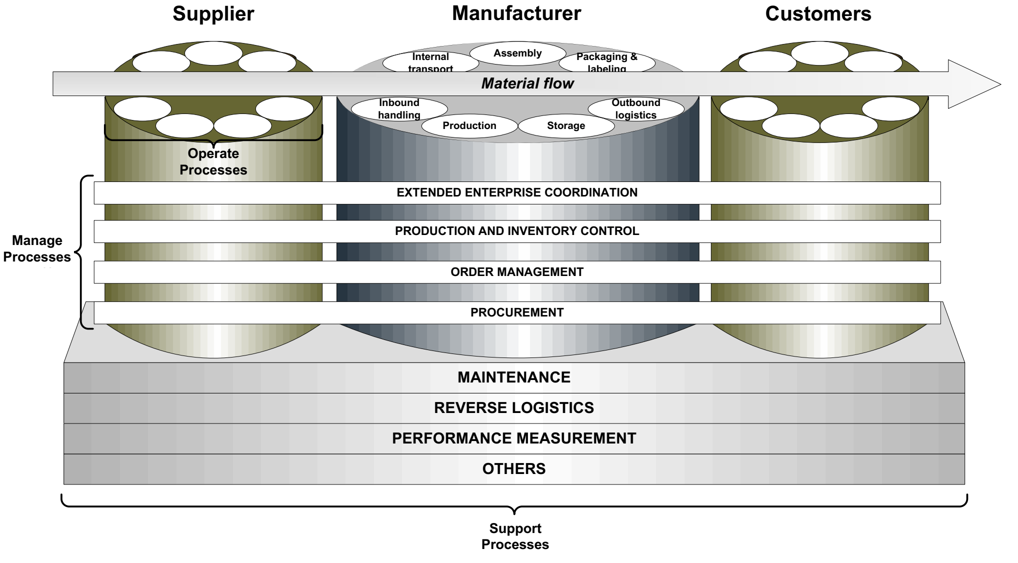


Figure 75 Overview of the EE Process Model

Inspired by Lambert et al (1998)

The next sections will give a brief introduction to the EE Process Model and the four levels of detail. For a more detailed and complete description of the different levels the readers are encouraged to read Appendix A or to thorough study the MOMENT Process Model Browser.

6.3.4 Actors

In this thesis, as well as in the MOMENT project, the Extended Enterprise's value chain consits of five different types of actors (see also figure 76):

- *Suppliers*
- *Transporters*
- *Warehouse (distribution centers)*
- *Manufacturer (focal company)*
- *Customers*

The suppliers, manufacturers, and customers are the three main actors in the EE Process Model and also the main focus within the EE Process Model. This is due to the fact that these three actors are engaged with the manufacturing part of the Extended Enterprise, and therefore are in line with the domain and scope of this thesis. A more detailed description of each actor is given in Appendix A.

Figure 76 illustrates the Extended Enterprise. While there can be several suppliers, transporters, warehouses and customers in the value chain, there is always one focal company from which the value chain is viewed.

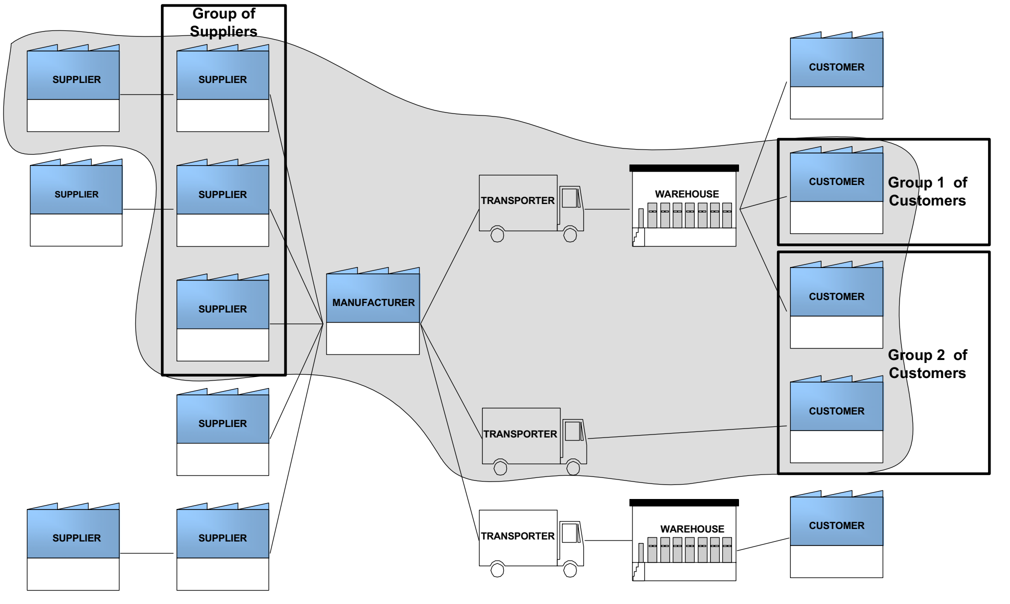


Figure 76 Group of actors in the EE Process Model

By grouping of actors, adequate actors (within the same type of actor) can be grouped and when required, treated as one entity. The reasoning for this is several:

- It can be appropriate to group similar actors, e.g. suppliers of raw material and suppliers of components
- It can be desirable to compare at set of actors with others, e.g. compare performance level etc
- It can be necessary to group actors in order to achieve simplification of the Extended Enterprise, e.g. in cases where there are a large numbers of actors involved

A manufacturing company can have several manufacturing plants, which are either in sequence (along the value chain) or parallel (at the same stage in the value chain). As a basic role it is recommended that each manufacturing plant (of the focal company) is the foundation of its own Extended Enterprise, as long as there are no material flow links to other manufacturing plants within the same company. In the case where two or more manufacturing plants within the same company are in a sequence in the value chain, these can be aggregated into a manufacturer group. In the other case, where the manufacturing plants are in parallel, these should only be included if they share capacity and any material flow between them. In all other cases separated process models for each manufacturing plant need to be developed.

In the EE Process Model each actor has attributes assigned to it. The actor attributes are high-level information that gives the reader/user practical, general and informative information about the actor. The attributes are assigned to the actor independently of the processes. The attributes should give the reader/user value information about the actor, without going into detail with the processes. Each actor can be described using several predefined set of attributes. S*uppliers*, *Manufacturers* and *Customers* can for example be either *engineer-to-order*, *make-make-to order*, *assembly-to-order* or *make-to-stock*. *Transporters* can be *Vessel*, *Truck*, *Air*, *Train*, etc and *Warehouses* have attributes such as *normal*-, *clean-* or *cold-*environment.

All attributes are defined and described in the Appendix A: the EE Process Model - Actors.

6.3.5 Processes

In the EE Process Model the five actors perform *manage processes*, *operate processes* and *support processes*. The o*perate processes* are defined as those concerning the physical material flow in the value chain. Each actor will therefore always contain one or more out of the operate processes. The m*anage processes* are defined as those concerning the management activities undertaken to support the operate processes. The s*upport processes* are those processes not directly associated with the operation, but with indirectly influence on the operation.

Figure 77 illustrate how each actor can be split into operate, manage or support processes.

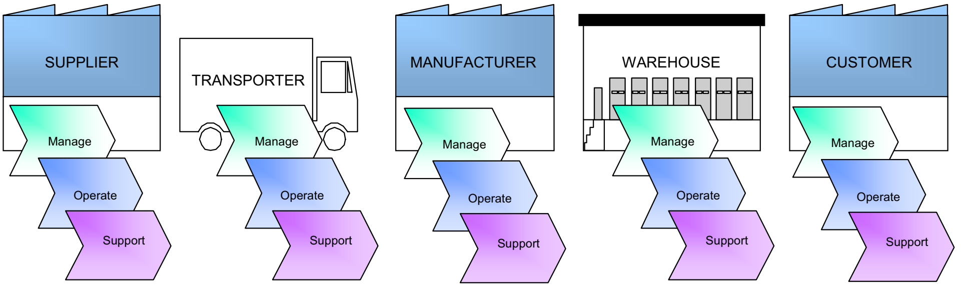


Figure 77 The actors perform operate, manage and support processes

A more detailed presentation of the operate, manage and support process are given in Appendix A.

6.3.6 Sub-processes

Each (operate, manage and support) process can be broken down into slightly more detail, but still generic sub-processes. The sub-process provides a more accurate view of what is "going on" in the company. The suppliers, focal company and the customers are all considered to be manufacturing companies and therefore these actors perform similar sub-processes.

Figure 78 illustrates in principle how operate, manage and support processes can be broken down into sub-processes for the Manufacturer.

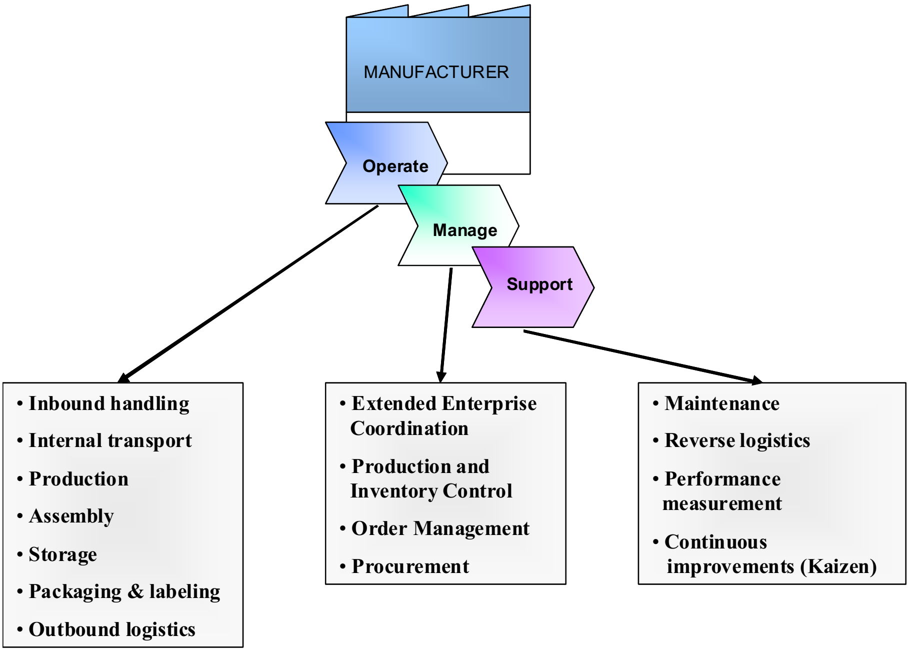


Figure 78 Processes broken down into sub-processes

Appendix A gives an in-depth description of all sub-processes.

6.3.7 Activities

Activities are the lowest and most detailed level in the EE Process Model. Activities are attached to organizations (the actors) that operate, manage and support them. Activities more than organizations are the building blocks of the Extended Enterprise. The activities can be outsourced, shifted between organizations, consolidated for the system as a whole or combined into new forms of enterprises (Schary and Skjøtt-Larsen, 2001). Figure 74 gives an illustration of all four levels of the EE Process Model and how actors, processes and sub-processes are built up on the basis of activities.

Whereas the processes, and mostly the sub-processes, are generic for all kind of manufacturing companies, the activities are more particular and specific. Every manufacturing company are conducting operate, manage and support processes. Similar it is possible to model nearly all manufacturing companies by the sub-processes. All manufacturing companies receive material/components, transform these (production, assembly and/or packaging) and send them further on. However, activities are more depended on the industrial sector (e.g. food & drink, furniture, automobile etc), type of manufacturing (process, discrete and project) and kind of manufacturing (batch, mass, job production etc). This implies that there exists a considerable amount of activities, which have to be identified, defined and described. The activities described in this thesis are within the flow oriented mass production in the automotive industry.

Appendix A describes all activities in the EE Process Model.

6.2.8 The EE Process Model Browser

Due to the complexity of the EE Process Model, a software tool has been developed in order to improve the comprehensibility and user-friendliness. The software tool is a web-browser (a set of hyperlinked web pages), which let the user play, explore and learn the EE Process Model in a perspicuous way.

The application of the EE Process Model Browser is mainly for training and demonstration of the concept and content of the EE Process Model. It is suitable for students, researchers, academics and practitioners from industry. A draft version of the EE Process Model Browser is available on CD, and may be acquired by e-mailing the candidate[56]

Figure 79 illustrates the entrance page of the EE Process Model Browser (taken from the draft version of the EE Process Model Browser).

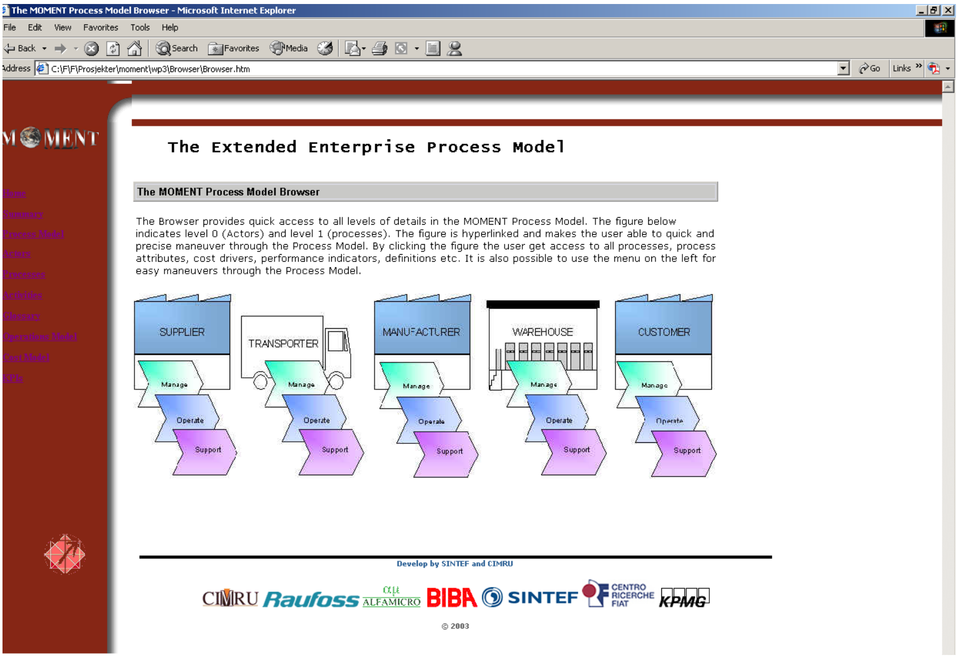


Figure 79 The EE Process Model Browser

The Browser provides quick access to all levels of details in the EE Process Model. In figure 79 level 0 (Actors) and level 1 (processes) are illustrated. All figures are hyperlinked and make it able for the user to quick and precise manoeuvre through the EE Process Model. By clicking any figure the user gets access to all processes, process attributes, cost drivers, performance indicators, definitions etc. It is also possible to use the menu on the left for easy manoeuvres through the EE Process Model.

6.4 The Extended Enterprise Modeling Tool

The Extended Enterprise (EE) Modeling Tool is a tool for mapping and modeling operations in the Extended Enterprise; i.e. a tool for generating computerized models. The tool has to be

[56] Sindre.Bolseth@ntnu.no

seen in close connection with the EE Operations Model and its six models (views). Since the EE Process Model is the only one out of these six models that has been developed and presented in this thesis, this model will be used as an example.

It is important to see the distinction between the models and the modeling tool. The EE Process Model is a way of describing the Extended Enterprise and breaking it into a set of pre-defined actors, processes, sub-processes and activities. The EE Process Model is generic and independent of individual (Extended) Enterprises. When a company whishes to create a process model of its Extended Enterprise, it can either use pen and paper or a software (in this case the EE Modeling Tool) to generate a process model (a figure) on the basis of the pre-defined actors, processes, sub-processes and activities. The EE Modeling Tool is consequently a method for generating individual models (e.g. process models). In additional to generate models, the EE Process Tool also provides a standard notation of how the models should be presented (e.g. actors, process, sub-processes, activities, links between them, information flow etc).

In this sense the EE Operations/Process Model can be compared to the SCOR model, whereas the EE Modeling Tool is more equivalent to software programs like ARIS, which uses standard modeling notation such as UML or BPMN to generate models.

6.4.1 Purpose and requirements for EE Modeling Tool

The purpose of developing the EE Modeling Tool is two folded (once again the EE Process Model will be used as an example). Firstly, the EE Modeling Tool seeks to provide a standard notation for describing/presenting the issue on-hand; in this case, processes and the relations between processes in the Extended Enterprise. This basically means to develop a template for how to visualize actors, processes, sub-processes, activities, and the relationships between these. This has to be done accordingly to the specifications made in table 28.

Secondly, the EE Modeling Tool has to support generations of individual models. During mapping the EE Modeling Tool has to be able to visualize the operations by using the standard notation developed and the pre-defined processes in the EE Process Model. The EE Modeling Tool has to be capable to both provide *top-down* and *bottom-up* approach. In a top-down approach the user starts at a high level (the actors) and drills down into more details (down to activities), whereas in the bottom-up approach the user starts at the most detailed level (activities) and builds up the operations on the basis of this.

Figure 80 gives an example and/or suggestion of notation of how to represent the operations in the Extended Enterprise. It is important to underline that this is just a proposal and not a final version. The work with developing the notation is dependent on gaining more experience from different types of industry and not at least, feedback from users using the tool and the process models.

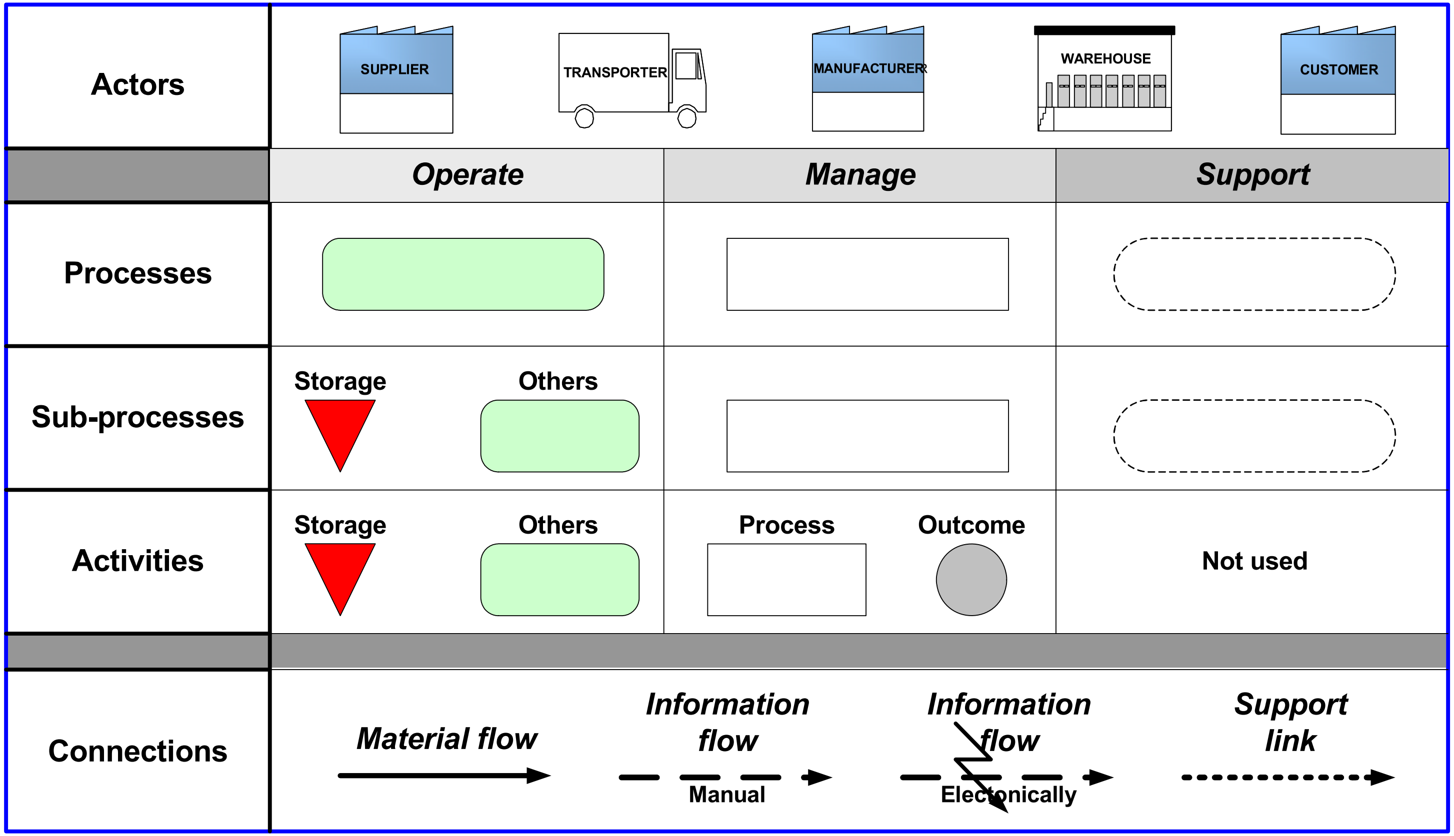


Figure 80 Standard notation for elements in the EE Process Model

The EE Modeling tool has to support three different kinds of mapping situations:

1. ***Drag and drop mapping*** – quite rapidly be able to represent the operations in the Extended Enterprise by using pre-defined symbols and inserting these in to the model and connecting them trough various types of links. Figure 81 gives an illustration of the idea of drag and drop mapping.
2. ***Manual typing of data*** – by typing all kind of data about actors, processes, sub-processes and activities etc into a database, the tool (software) should be able to represent this data visually as a process model. Figure 82 gives an example of a manual mapping data collection.
3. ***Automated mapping based on ERP/Legacy data*** – by importing data by a pre-defined spreadsheet with defined headings (coulombs/rows) the tool should be able to create a high level representation of the Extended Enterprise including information such as customers, transporters, warehouses, suppliers etc.

It is important to underline that these three approaches are not mutually exclusive. A normal mapping situation will acquire a mixture of the approaches, and it is therefore important that the approaches can be added to each other.

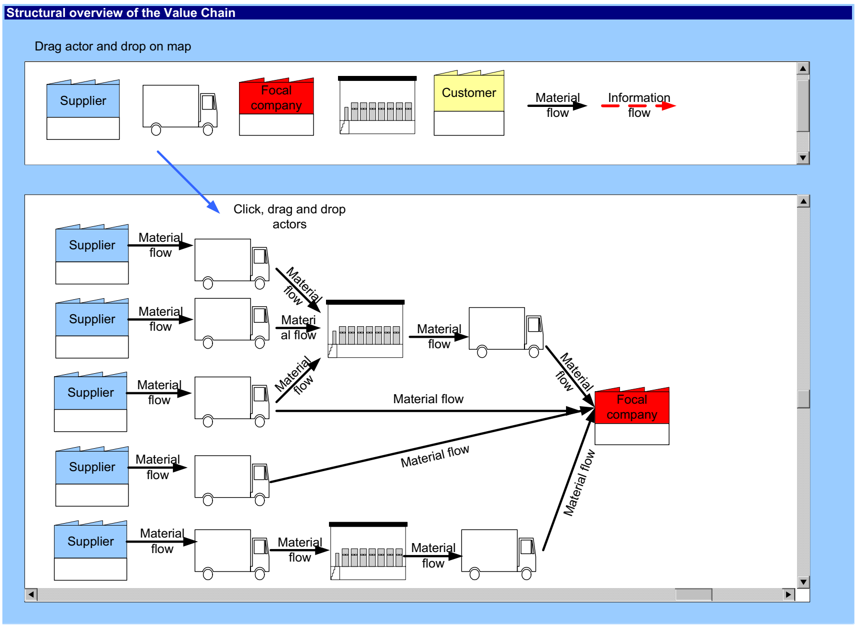


Figure 81 Drag and drop mapping functionality

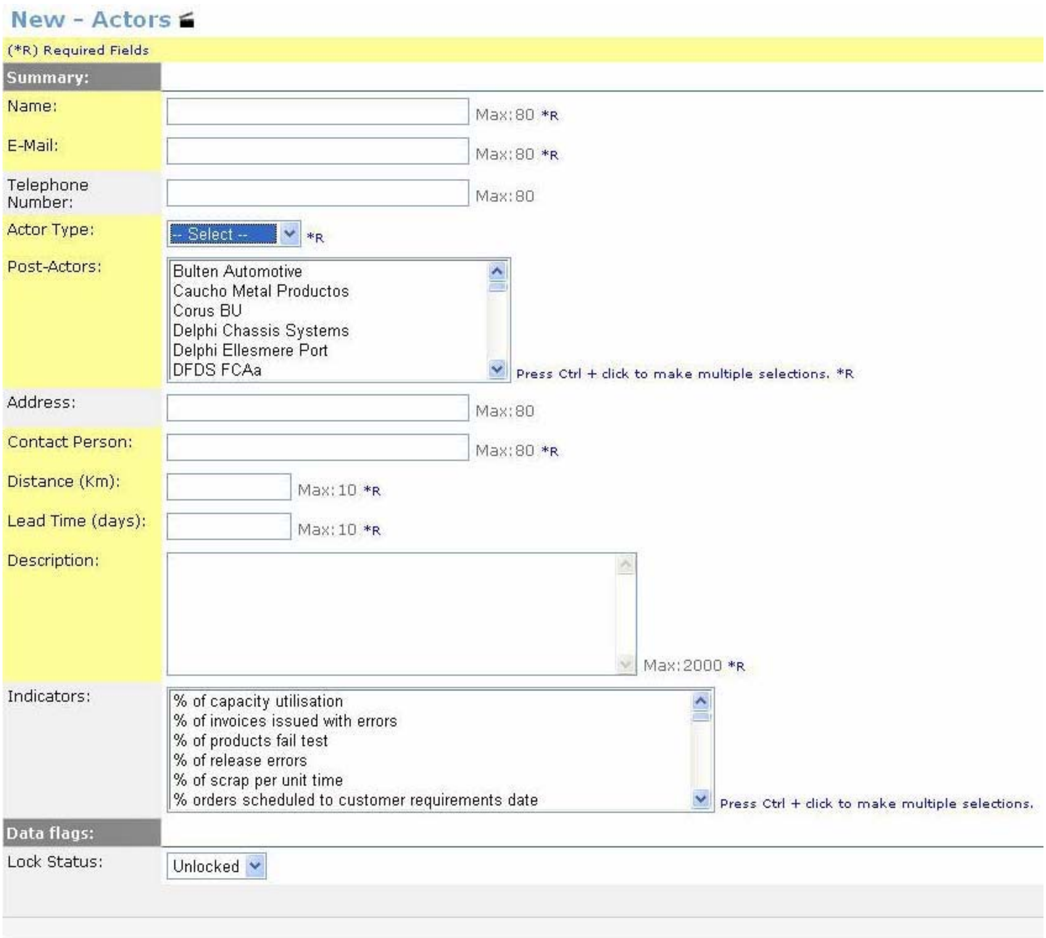


Figure 82 Mapping by manual typing of data into a database

6.4.2 Mapping with the EE Modeling Tool

The aim of mapping with the EE Modeling Tool is to enable computerized structured and visual information about operations for a wide range of purposes. Hence, the EE Modeling Tools aims to generate various particular models of operations (resource, material, information, process, organization, control) in the Extended Enterprise.

The mapping done with the EE Modeling Tool can be split into three different levels (the EE Process Model will be used as an example):

- Level 1 – Extended Enterprise structure and graphical presentation
- Level 2 – Process and sub-process modeling
- Level 3 – Activities modeling

It is important to underline the fact that these levels are not chronological, but can be applied to a top-down or a bottom-up approach. All three levels must support the three mapping situations outlined in the previous chapter (6.4.1)

Another important aspect is that the time involved with mapping and colleting information at all levels should be kept at a minimum. This implies that as much as possible of the information/data should be gathered from electronically sources (e.g. ERP systems etc).

The remaining part of this chapter will be used to describe some important considerations at each level.

The aim of *level 1* in the mapping of processes is to make a graphic representation of the structure of the Extended Enterprise (i.e. the actors involved in the Extended Enterprise) and provide the model with information about these actors. Andersen et al. (2008) calls this kind of mapping the value chain map. The EE Modeling Tool should be able to generate visualization of the geographical location of the actors as well as simpler schematic overview of the value chain with connected material flow. A fictitious example of this is illustrated in figure 83, whereas figure 76 and figure 18, are examples of Extended Enterprise structure models.

In addition, various information regarding the actors need to be collected and associated with the respective actor. Information at the actor level includes (an example of interface for actor information is given in figure 84):

- Name of actor, address, contact person etc.
- All attributes
- Distance (in km)
- Product information (costs, package, batch etc)
- Demand information (if known)
- Lead time from order to delivery
- Type of communication used (EDI, e-mail, phone, web, etc.)
- Payment terms
- General comments
- etc

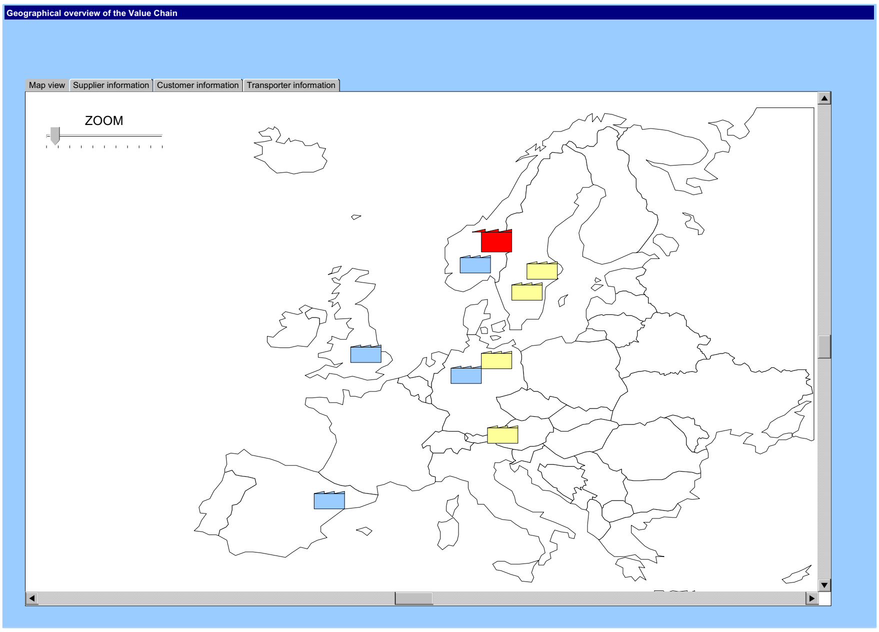
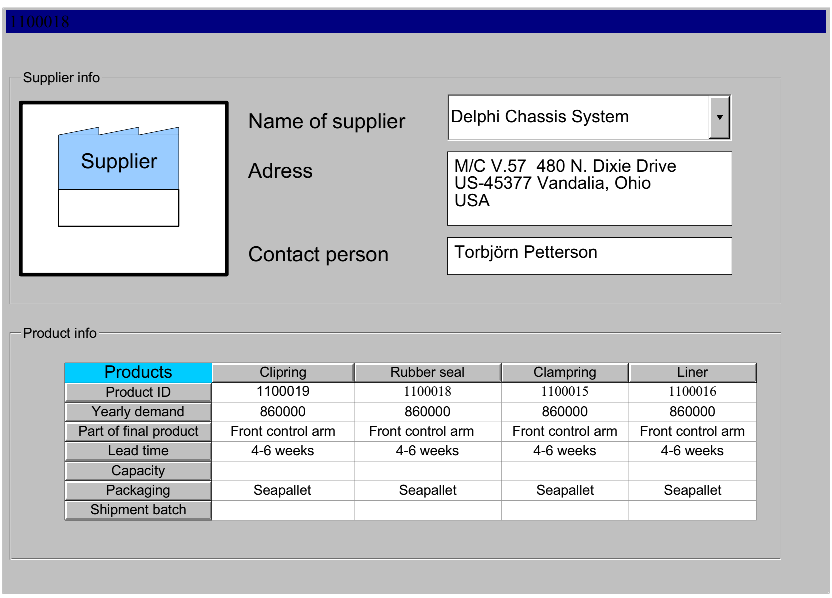


Figure 83 Geographical localisation of the actors in the Extended Enterprise



Products	Clipring	Rubber seal	Clampring	Liner
Product ID	1100019	1100018	1100015	1100016
Yearly demand	860000	860000	860000	860000
Part of final product	Front control arm	Front control arm	Front control arm	Front control arm
Lead time	4-6 weeks	4-6 weeks	4-6 weeks	4-6 weeks
Capacity				
Packaging	Seapallet	Seapallet	Seapallet	Seapallet
Shipment batch				

Figure 84 An example of an interface for actor information

Level 2 is the mapping of processes and sub-processes in the Extended Enterprise, and is not as straightforward as level 1. Andersen et al. (op cit) calls this kind of mapping high-level process models.

One may ask if we really need to map at this level: Is it sufficient with just a high level model of the actors (level 1) and a detailed model of the activities (level 3)? There are however several arguments that support a mapping at level 2. Many actors are sceptical to share information and will probably be reluctant to share detailed activity data, but may be willing to share some aggregated key-information about the sub-processes. Similarly, it can be desirable to compare or benchmark sub-processes from one actor with similar sub-processes within other actors. Further, companies can use information regarding sub-processes from a manufacturing plant in order to get data for analysis for establishing new similar manufacturing plant (e.g. an almost identical manufacturing plant established at a different location). A final reason is that it is desirable to have a third level of visualization, in between the high level and detail level.

When the sub-processes are mapped and modeled, it should be possible to add information and attributes to these processes (see figure 85). Examples of information would be:

- Definition of the process
- Input (materials, information)
- Output (materials, information)
- Linkages to other processes (Preceding processes and following processes)
- General comments

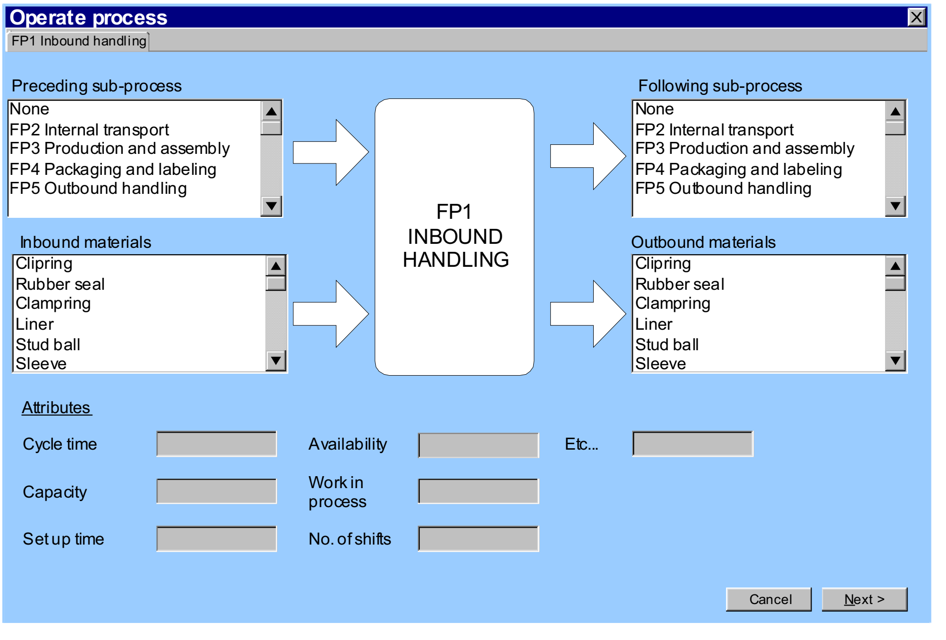


Figure 85 Sub-Process Modeling

Level 3 deals with the most detailed level in the EE Process Model; the activities. An activity represents the "atomic" level of the process flow; it presents the actual work being done and is the lowest level of detail in the model. You can use an activity to sum up several low-level tasks performed by a single resource. In this level the activities of the sub-processes are mapped, and assigned with information and attributes. Figure 86 illustrates how a set of activities constitute a sub-process.

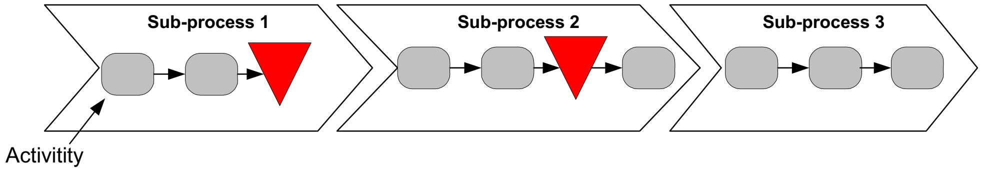


Figure 86 Sub-Processes with corresponding activities

As with the actors and sub-processes, the activities need to be associated with information. It is at the activity level that it is possible to get real time data from the shop floor, and thus enabling real-time information visibility in the Extended Enterprise (see figure 73). The following information is regarded as useful input for the mapping of activities:

- Input
- Output
- Connected activities and sub-processes
- Resource consumption (materials, energy, people, equipment, procedures)
- Capacity
- Cycle time
- Work-in-progress
- Etc.

When these and other data are continuously fed (on a real-time basis) into the models constituting the EE Operations Model, the EE Operations Model can be regarded as an information visibility system.

6.5 The Extended Enterprise Dashboard

The dashboard concept was introduced and discussed on a generic level in chapter 4.6.4. A dashboard is a rich computer interface with charts, reports, visual indicators, and alert mechanisms that are consolidated into a dynamic and relevant information platform (Malik, 2005). The dashboard concept is crucial in operational measurement, monitoring, and management, and can be used to define and measure the pulse of operations globally (Tyndall et al., 1998).

According to Eckerson (2006), see chapter 4.6.4, there are three types of dashboards: 1) Operational dashboards, 2) tactical dashboards, and 3) strategic dashboards. In this thesis the focus will be on operational and tactical dashboards, and less on strategic dashboards.

This chapter will introduce the Extended Enterprise (EE) Dashboard as one of six tools in the EE Operations Model Toolset.

6.5.1 The objective and purpose of the EE Dashboard

The objective of the EE Dashboard is to measure, monitor, analyze and mange the operations in the Extended Enterprise through visual displays, indicators, reports and alarms. This is achieved through an interactive and visual web-portal solution. The EE Dashboard has access to real-time information regarding operations, and this information is matched up to operational, tactical and strategic objectives for the Extended Enterprise through the use of (key) performance indicators.

The EE Dashboard is closely linked to the EE Operations Model. The interdependency between the two tools can shortly be described as: The EE Operations Model visualizes the operations in the Extended Enterprise, whereas the EE Dashboard visualizes the performance of the operations. An overwhelming amount of information is available through the EE Operations Model (an information visibility system), and this information is constantly supervised and filtered by the EE Dashboard. Further, key information, together with events, exceptions and deviations are visual illustared. In this regard the EE Dashboard can be viewed as a layer on top of the EE Operations Model, or a magnifying glass highlighting and analysing the operations (or more precisely the performance of the operations) in more detail, see figure 87.

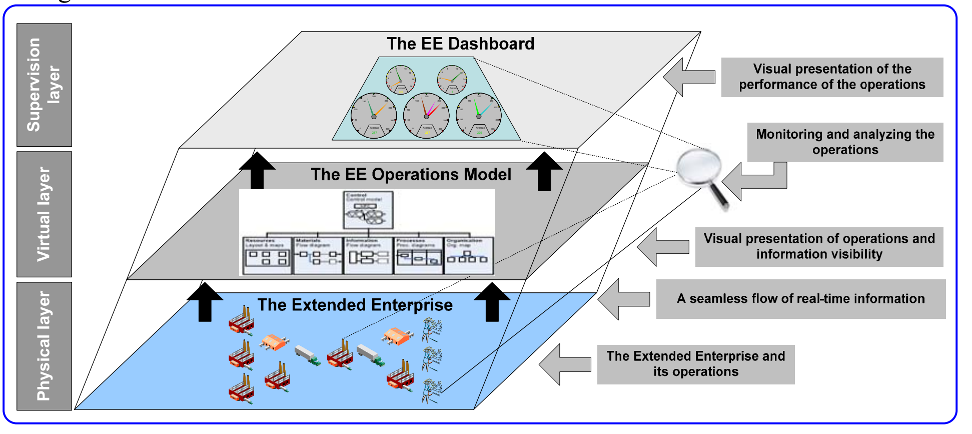


Figure 87 The EE Dashboard as a magnifying glass

Figure 87 illustrates three layers; the physical layer (the Extended Enterprise), the virtual layer (the EE Operations Model) and the supervision layer (the EE Dashboard) and the interdependency between these three layers. The Extended Enterprise encompasses a wide set of distributed data sources, which are continuously feeding the EE Operations Model, and thus the EE Dashboard, with real-time information. The EE Dashboard uses this information in order to measure, monitor, analyze and mange the operations in the Extended Enterprise through visual displays, indicators, reports and alarms.

In line with the objective stated earlier and with Eckerson (2006) (see chapter 4.6.4) the purposes of the EE Dashboard can be descried as:

- ***Measure*** – the EE Dashboard is linked to a continuous flow of real-time information (through the EE IT Platform and the EE Operations Model) from data sources along the value chain, such as ERP-systems, MES, RFID sensors, POS, etc. This information is assigned to (key) performance indicators.
- ***Monitor*** – the EE Dashboard monitors critical business processes and activities by using metrics of business performance that trigger alerts when potential problems arise (ibid). When the EE Dashboard is used to monitor real-time information, and in combination with the EE Operations Model, there is a close resemblance with the "operational monitoring and control in the process industry" concept (see chapter 6.4.6) and "control centres/towers" concept (see chapter 4.6.3).
- ***Analyze*** - the EE Dashboard analyzes the root cause of problems by exploring relevant and timely information from multiple perspectives and at various levels of detail (ibid).
- ***Manage*** – the EE Dashboard manages people and processes to improve decisions, optimize performance, and steer the organization in the right direction (ibid).

Measure, monitor and analyze are mainly covered by operational and tactical dashboards, whereas strategic dashboards are more concerned with the management. The EE Dashboard can be viewed as combination of an operational and tactical dashboard. This is due to the thesis focus on planning and control of operations in the Extended Enterprise.

The four purposes highlighted above are fulfilled through three views or layers of information (ibid) in the EE Dashboard (Eckerson, op cit):

- ***Summarized graphical view*** – provides a summarized view, usually graphical, of the status of KPIs and exception conditions. When performance exceeds thresholds applied to each metric/indicator, the dashboard interface alerts users. The summarized graphical view can be regarded as the default view of the EE Dashboard view; this is the main page of the web-portal solution.
- ***Multidimensional view*** - provides the data behind the graphical metrics and alerts. The multidimensional analysis tools let the users "slice and dice", "Drill down and up", "pivot", apply complex calculations to the data, perform "what-if" analyses, and switch between tables and charts.
- ***Detailed reporting view*** – lets users view detailed reports and transaction records (invoices, shipments, trades, etc). Users often need such data to understand the root cause of a problem.

Each successive layer provides additional details, views, and perspectives that enable users to understand a problem better and identify the steps they need to take to address it (ibid). This layered approach gives users self-service access to information and conforms to the natural sequence in which users want to handle that information (ibid): 1) monitor, 2) analyze, and 3) examine. That is, most business users first want to monitor key metrics for exceptions; then explore and analyze the information that sheds light on those exceptions; and finally, examine detailed reports and data before taking action (ibid).

6.5.2 Measures and indicators

Too many companies use measurement system that contain overly complicated metrics, too many metrics, or uses metrics for which reasonable data cannot be collected quickly (Tyndall et al., 1998). According to White (1996), there are two basic questions that must be answered in any measurement situation:

- What will be measured?
- How will it be measured?

This chapter will address the first question; what will be measured. The second question includes issues such as data source and location at which the measurement is taken. Briefly, one may answer this by stating that the EE Dashboard will use tangible data from the EE Operations Model.

This thesis will use a hierarchical structure to describe the performance measures[57] with performance measures as the fundament, followed by a selection of performance indicators (either a measure or a combination of measures) and a few (5-20) key performance indicators (KPIs) on top (see also chapter 2.5.4):

- ***Performance measure*** - can be defined as a metric used to quantify the efficiency and/or effectiveness of an action (Neely et al, 1995). Or, a description of something

[57] Other types of categories exist: Parmenter (2007) divides between three types of performance measures: 1) Key result indicators, 2) performance indicators, and 3) key performance indicators. Andersen (1999) and Bredrup (1995) divide between: 1) Result measures, 2) Diagnostic measures, and 3) Competence measures. Kaplan and Norton (1996) divide, among others, between: 1) Diagnostic measures, and 2) strategic measures. In addition do table 7.3 lists some key characteristics and types of categories of KPIs.

that can be directly measured (e.g. number of reworks per day) (Browne et al., 1997). In the EE Dashboard performance measures are all those data that are collected from various sources along the value chain, and can typically involve thousands of such measures.

- ***Performance indicator*** – can be defined as something that is calculated from performance measures (e.g. percentage reworks per day per direct employee) (ibid). In the EE Dashboard there can be hundreds of performance indicators, and these are accessed through the drill-down functionality.
- ***Key performance indicator*** – are a set of measures focusing on those aspects of organizational performance that are the most critical for the current and future success of the organization (Parmenter, 2007). The KPIs are the indicators that are highlighted and visualized on the EE Dashboard, at the summarized graphical view. The number of KPIs should be limited, typically 5-20[58].

Performance measurement and management have been on the research agenda since the late-1980s (Johnson and Kaplan, 1987; Lynch and Cross, 1991; Eccles, 1991; Kaplan and Norton, 1992; EFQM, 1999; Thorpe, 2004). Since then, there has been a proliferation of theories, models and tools (Franco and Bourne, 2003) to support companies to better measure their performance and hence manage through measures. Thus, today there exists several performance measurement frameworks and systems, which among other guide the user on how to select the right KPIs (Kaplan and Norton, 1996; Bradley, 1996; Medori and Steeple, 2000; Folan and Browne, 2005, Parmenter, 2007).

It is out of scope of this thesis to go into detail of these frameworks and systems. For more information regarding the topics it is refered to the references list above. However, there are two important aspects of performance measures and indicators that are worth highlighting: 1) Several authors address flaws with the existing frameworks and systems, and 2) there exists some key characteristics of KPIs. These three aspects will shortly be presented/debated in the subsequent paragraphs.

Firstly, various authors (e.g. Busi and Bititci, 2006; Chan et al., 2006; Busi, 2005; Nuthall, 2003; Bititci et al., 2002; Bourne et al., 2002) list weaknesses and flaws with exiting performance measurement and management systems. Some examples of the critiques are:

- Today most performance measurement systems are historical and static. That is, they are not dynamic and sensitive to changes in the internal and external environment of the firm (Bititci et al, 2002; Bititci and Carrie, 1998).
- Few performance measurement systems have an integrated IT structure. This results in cumbersome and time-consuming data collection, sorting, maintenance and reporting (Bititci et al, 2002; Bititci and Carrie, 1998).
- There has been a lack of a balanced approach to performance measurement (Gunasekaran et al., 2001). This is, companies need to understand the balance between financial and non-financial measures.
- There has been a lack of a clear distinction between metrics at strategic, tactical, and operational levels (Gunasekaran et al., 2001).

The EE Dashboard, as a performance measurement system, addresses these four flaws: 1) it is a dynamic system, with high degree of customization and adaptability, 2) it is a web-based portal solution, with an integrated IT structure (the EE ICT Platform), 3) it uses a balanced

[58] Kaplan and Norton (1996) recommend no more than 20 KPIs, Hope and Fraser (2003) suggest fewer than 10 KPIs, and Parmenter (op cit) recommends 10 KPIs.

approach to performance measures (and KPIs), and finally 4) it focuses on both operational and tactical, and partially on strategic, measures.

Secondly, to design an appropriate set of performance measures to use at a company and/or in a value chain is not an easy task and several aspects must be taken into consideration (Tangen, 2004). According to Nuthall (2003) "good" performance measures have several distinguishing characteristics:

- They are directly related to objectives and strategies
- They must be understandable but not underdetermining
- They must be meaningful
- They vary between locations and customer segments
- They change over time, and
- They provide fast feedback

Other important aspects, or characteristics, of KPIs are summarized and listed in table 29.

Category	Detailed	Description
Balanced (Kaplan and Norton, 1996)	*Financial*	Financial performance measures indicate whether a company's strategy, implementation, and execution contribute to bottom-line improvement.
	Customer	The customer perspective typically includes several core or generic measures of the successful outcomes from a well-formulated and –implemented strategy (e.g. customer satisfaction, customer retention, etc).
	Internal business process	The internal-business process measures focus on the internal processes that will have the greatest impact on customer satisfaction and achieving an organization's financial objectives.
	Learning and growth	This perspective measures the infrastructure that the organization must build to create long-term growth and improvement.
Elements of a KPI (Malik, 2005)	*Data sources*	Identifies the high-level information regarding where to retrieve the information for a given KPI.
	Granularity	Granularity establishes the various levels of calculations required for each of the KPIs, where each KPI could have different grains across three basic dimensions: 1) time, 2) geography, and 3) product.
	Calculation	Calculation would indicate any mathematical operation required to arrive at a given KPI.
	Variance	Variance establishes the comparison benchmark for each KPI, and has two requirements: 1) the basis for change, 2) change calculation.
Types of Metrics (Eckerson, 2006)	*Leading*	Leading indicators measure activities that have a significant effect on future performance.
	Lagging	Lagging indicators measure the output of past activity.
	Diagnostic	Diagnostic measures signal the health of various operational initiatives or processes.

Table 29 Important aspects for key performance indicators (KPI)

The success and applicability of the EE Dashboard dependens on choosing the right KPIs, where the KPIs can be regarded as the "brain" or "logic" of the EE Dashboard. It may be appropriated to use an analogy to the dashboard in cars: If the well-known and vital indicators (e.g. speed, fuel level, engine temperature, etc) were exchanged with more insignificance and trite indicators (e.g. ignition rate, flushing fluid indicator, outdoor temperature, etc), the benefits and usefulness of the car dashboard would be dramatically reduced.

Identifying the right KPIs is particular important in value chain collaborations like the Extended Enterprise. According to Stallkamp (2005) gives a common, channel-wide dashboard of performance measures, the collaborators, for the first time, the possibility to view how their own performance affects the overall system's performance.

Another success factor for the EE Dashboard is the design of the dashboard. Most dashboards fail to communicate efficiently and effectively, not because of inadequate technology (at least not primarily), but because of poorly designed implementations (Few, 2006). It is however, out of scope of the thesis to go into detail of design of dashboards. Nevertheless, some design issues will be presented and discussed in the following chapter.

6.5.3 Requirements and functionality for the EE Dashboard

In the MOMENT project some early requirements for the KPIs and the dashboard solutions in the project were identified. These requirements are summarize in table 30.

Requirements	Description
Measures and indicators	The indicators will be used: 1. To monitor performance. 2. To evaluate and analyze performance. 3. To monitor the status of the flows and processes in the value chain. The flows are flow of information and flow of goods. 4. As decision support for controlling the flow of goods and information in the value chain (supply chain control) 5. In improvement projects in order to pinpoint problems and focus areas and efforts.
	Indicators should show the values for the past, the present and the expected future.
Data sources	The collection of all indicators should be automated to highest possible level, and be based on information collected from various ICT systems along the value chain, e.g. ERP-system.
Aggregation	There should be several aggregation levels and methods.
	The same type of indicators should be measured at multiple locations in the value chain, in order to achieve comparison and so that an aggregation of them gives a complete value chain picture.
Visualization	The indicators should be displayed and visualized for easy conception. Functionality for comparison should make the user able to: • Compare to days value with previous values • Compare to days value with required/expected/planned value • Compare to days value with expected future values • Etc

Table 30 Early dashboard requirements

The requirement listed in table 6.4 served as an early inspiration for the dashboard concept. Later several authors, like Eckerson (2006), Few (2006), and Malik (2005), have made considerable contributions to the dashboard concept, and they have all listed key features and requirements of dashboards in their publications. Simultaneously, the dashboard concept has been addressed in several national and international projects at SINTEF over the last 5 years.

Based on the above the following requirements, or guidelines, for the EE Dashboard functionality were developed:

- ***Web-based solution*** – the dashboard should be a web-based portal solution, enabling accessibility everywhere through the Internet and various mediums/channels like computers, cell phones, PDAs, etc.
- ***Visual information*** – the dashboard should visually present the measured information in order to gain new knowledge, amplify cognition, and rapid and action-oriented

understanding. This yields for the continuous monitoring of operations, as well as the analytic capabilities of the dashboard.

- *Single screen* – all relevant information should be instantaneously viewable (Eckerson, 2006).
- *Synergetic* – the dashboard must be ergonomically and visually effective for a user to synergize information about different aspects within a single screen view (Malik, 2005).
- *Keep it selective* – display only critical metrics (i.e. KPIs) that users need to achieve their objectives (Eckerson, op cit).
- *Keep score* – The metrics should visually express *performance state* (e.g. superior, good, bad), *performance direction* (e.g. trending up, down, or steady), and/or *performance progress* (e.g. gap between performance and targets) (ibid).
- *Keep is sparse* – do not clutter the screen with unnecessary or overly fancy graphics (ibid).
- *Make it structured* – create easy-to-use prompts and predefined drill paths that structure how users navigate the information (ibid).
- *Abbreviated form* – the main purpose of the dashboard graphics is to display performance in context so users can quickly ascertain what is going on (ibid). There are three aspects to context (ibid): 1) the *performance state*, which indicates whether performance is good or bad according to predefined thresholds; 2) the *performance trend*, which indicates whether performance has improved, declined, or held steady during the prior period; and 3) the *performance variance*, which shows how performance compares with the target for that period.

o ***Powerful measures and indicators*** – the dashboard is (as described in chapter 6.5.2) totally dependent on selecting the right indicators supporting the strategy and objectives of the companies and the Extended Enterprise.

- *Accurate* – information being presented must be entirely accurate in order to gain full user confidence in the dashboard (Malik, op cit)
- *Balanced* – there needs to be a balance between financial and non-financial measures.
- *Lead* – the dashboard should focus on lead indicators, and not on lag indicators.
- *Quantitative and non-quantitative data* – most information that typically finds its way onto a dashboard is quantitative, some types of non-quantitative data, such as simple lists, are fairly common as well (Few, 2006).
- *Enrichment through comparison* – the measures can be displayed by themselves, but it is usually helpful to compare them to one or more related measures to provide context and thereby enrich their meaning (ibid).
- *Value chain based* – the indicators should strive to give a true and complete picture of the value chain performance.
- *Aggregation* - there should be several aggregation levels and methods.

o ***Monitor KPIs*** – the dashboard must display critical KPIs required for effective decision making for the domain to which a dashboard caters (Malik, op cit).

o ***Analytic*** – the dashboard should make it effortless for a user to visually navigate through different drill-down paths, compare, contrast, and make analytical inferences (ibid).

- *Compare to plan* – use targets and goals so workers can gauge their progress and improve accuracy (Eckerson, op cit).
- *Advanced analytics* – it should allow users to perform guided analysis such as what-if analysis (Malik, op cit).

  - *Off-line functionality* – allow users to disconnect from the network and take the dashboard system and data with them for further analysis (Eckerson, op cit).
- ***Reporting*** – the dashboard should provide a built-in reporting feature (Malik, op cit).
  - *Sorting and filtering* – users should be able to sort a report by the different data fields contained in the report (ibid).
  - *OLAP features* – the dashboard should have common online analytical processing (OLAP) features, because users may want different summaries, computations, and popular statistics for a given report (ibid).
  - *Snapshot capture* – the dashboard must allow a user to save the reported data at a given instant for future reference (ibid).
- ***Alerts and response*** – the dashboard must respond to predefined thresholds by creating user alerts in addition to the visual presentation on the dashboard (e.g. sound alarms, e-mails, pagers, blinkers) to draw immediate user attention to critical matters (ibid).
  - *Highlight exceptions* – use colors or symbols only to express out-of-control conditions or performance states (Eckerson, op cit).
- ***Timely information*** – the dashboard must display the most current information possible for effective decision making and response (ibid).
  - *Real time information* – the dashboard should be based on and continuously fed on real-time information; capturing and processing data at the time of occurrence.
  - *"Right" time information* - the dashboard should provide the right information in the right format to the right people at the right time, in order to take the appropriate action.
- ***Interactive*** – make sure users can switch views and contexts, access reports, and drill from high to low levels of details using simple point-and-click techniques (ibid).
- ***Trackability*** – the dashboard should provide seamless and dynamic access to transaction data stored in a data warehouse or an operational system (ibid).
  - *Track historic data* – the dashboard should allow users to review the historical trend for a given KPI (Malik, op cit).
- ***Customized and personalized*** – the web-based portal solution provides personalized and customized interfaces.
  - *Customize* – dynamically generate screens that are generically geared to every individual's role and responsibilities (Eckerson, op cit)
  - *Personalize* – allow users to personalize the customized screens by selecting the objects they want to view from a predefined list (ibid).
- ***Collaborative*** – collaboration extends the dashboard's role from a passive information interface to an active enterprise/value chain management console (Malik, op cit).
  - *Discussion forum* – the dashboard must provide a discussion forum, enabling a thread of communication among several users (ibid).
  - *Publish it broadly* – provide open access to the results throughout the company/value chain, among peers so they can compare their performance (Eckerson, op cit).
  - *Exchange it widely* – exchange performance information with other groups that have other dashboard systems to improve coordination and cross-pollination of ideas (ibid).
  - *Attach commentary* – allow users to attach comments to dashboard views and respond to those comments (ibid).

Simple prototypes of dashboards where developed in the two cases in this thesis, see chapter 7 and 8, and in the MOMENT projects and other projects listed in Appendix B. However, none of these prototypes were close to fulfilling the requirements specified above, with the exception of the GPM-SME project, where the candidate played an insignificant role. Further, the candidate does not posses the necessary ICT skills to fully develop the EE Dashboard solution. Hence, the EE Dashboard tool is on a conceptual level, and is only exemplified through a fictitious illustration, see figure 88.

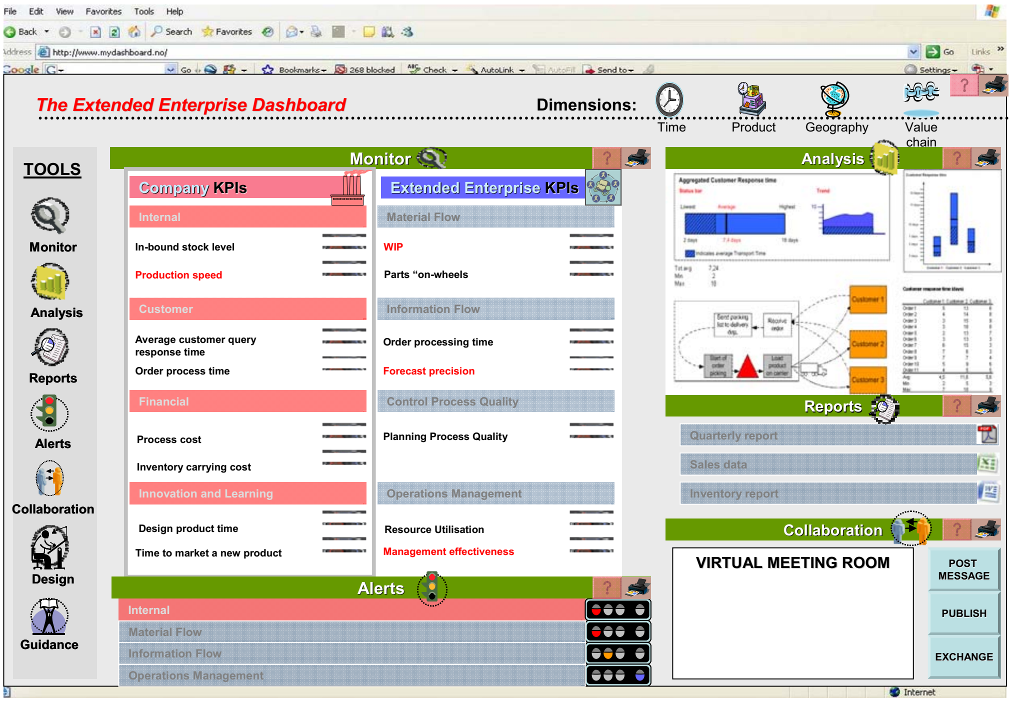


Figure 88 The EE Dashboard

Based on the GPM-SME Dashboard[59]

Figure 88 illustrates an example of a dashboard developed accordingly to the requirements listed above. In this solution the users can monitor a set of KPIs, do in-dept analysis of critical KPIs and other issues/circumstance, generate various reports, collaborate with value chain partners, and receive early warnings through alerts. All this based on real-time information from the Extended Enterprise, and in a visual and interactive manner.

However, it is important to point out that figure 88 is heavily influenced by the dashboard solution developed by the GPM-SME project, and is just slightly modified in this thesis to fit the requirements listed above.

[59] The GPM-SME (Global Performance Management for SMEs) was a 6th FP EU-project, which aimed at development of instruments (methodology, architecture and toolset) to transform Global Performance Management into a common and affordable practice for SMEs. SINTEF was one of nine partners. The project developed a computer (portal) based dashboard solution. There are however no public available publication to quote.

6.6 The Extended Enterprise ICT Infrastructure

In figure 69 the Extended Enterprise (EE) ICT Infrastructure was introduced as the bedrock or fundament for the EE Operations Model Toolset, thus supporting the 5 other tools in the toolset. If we use an analogy with TV; the EE Operations Model, the EE Process Model and the EE Dashboard without the EE ICT Infrastructure is like a TV without any signals - completely useless. According to Boyson et al. (2004), successfully embracing an ICT infrastructure that extends an organization's value chain reach externally, up and down the global product/service pipeline, represents a potential gold mine for companies.

An ICT infrastructure[60] consists of the physical facilities, services, and management that support all shared computing resources in an organization (Turban et al., 2006). There are five major components of the infrastructure: 1) computer hardware, 2) software, 3) networks and communications facilities (including the Internet and intranets), 4) databases, and 5) information management personnel (ibid). Each organization, in this case the Extended Enterprise, must carefully design and manage its ICT infrastructure so that is has the set of technology services it needs for the work it wants to accomplish with ICT systems (Laudon and Laudon, 2007).

This sub-chapter will introduce and present the EE ICT Infrastructure, however on a minor scale than the pervious tool presentations. The reason for this is threefold: 1) the scope of the EE ICT Infrastructure is extensive, and justifies a PhD in itself. 2) Even though the EE ICT Infrastructure has a decisive role, it is still regarded as more of a support tool in the EE Operations Model Toolset, where the main focus is on the EE Operations Model, the EE Process Model, and the EE Dashboard. 3) And not at least, the candidate does not posses the necessary ICT skills to fully go into detail on this issue.

6.6.1 Objective and purpose of the EE ICT Infrastructure

The objective of the EE ICT Infrastructure is to overcome the (technological) barriers of information sharing in the value chain, and thus enabling information visibility in the Extended Enterprise. As indicated in chapter 2.6, 3.1, and 3.2, the exchange of information between companies is not as easy as it should be. Many different systems and standards are used, the number of peer-to-peer relations with other companies in the network is usually too large to manage, most systems are not open for easy exchange of information with other systems, and most companies are very reluctant to share information with other companies in the first place (Boyson et al., 2003). Further the integration of the various ICT systems is time consuming, very costly, dependent of specialists, and static (in the sense that every time a system is modified or a new system is included, the integration has to be redone) (Ray and Jones, 2006).

Thus, the EE ICT Infrastructure should be able to facilitate a seamless flow of timely and accurate information, from various data sources all over the globe, along the value chain. This should be done at reasonable costs and time consumption, and through a dynamic system, where it is easy to add/remove data sources.

Further, the EE ICT Infrastructure should also make it possible to digest, to understand, and to act on this growing abundance of information by using sophisticated analysis, modeling, and decision support capabilities (Boyson et al., 2003).

[60] ICT infrastructure is derived from the ICT architecture – a high-level map or plan of the information assets in an organization including the physical design of the building that holds the hardware (Turban et al., 2006)

In more detail, the purpose of the EE ICT Infrastructure can be described as:

- ***Value chain (information) integration*** – enabling integration of internal, as well as external, ICT systems in the Extended Enterprise. The EE ICT Infrastructure should enable the transfer and use of real time information across multiple technologies/systems by creating commonality in the way that business systems share information and processes across enterprise boundaries; also known as interoperability (Brunnermeier and Martin, 2002; Lau and Lee, 2000). Where the ultimately goal is to have self-integrating systems (Ray, 2002). Value chain (information) integration is prerequisite in achieving information visibility in the Extended Enterprise, and renders the EE Operations Model Toolset into an information visibility system.
- ***Computerization of tools*** – support the computerization of the EE Operations Model, the EE Process Model, the EE Modeling Tool and the EE Dashboard. These four tools need to be developed into software applications, providing the users with computerized visual decision support for planning and control of the value chain operations.
- ***Communication platform*** – providing the Extended Enterprise with an ICT "platform" for communication, and thus enhancing value chain collaboration between the partners in the Extended Enterprise. The EE ICT Infrastructure should support instant, multitude content forms (text, audio, images, video, animation, etc) and multi medium (PCs, cell phones, PDAs, etc) communication along the value chain.

A high level, coarse, outline of the EE ICT Infrastructure is illustrated in figure 89. Due to practicalities warehouses and transporters are not illustrated in the value chain of figure 89. Data sources such as GPS, RFID, WMS, TMS, etc are also omitted from the figure in order to simplify the figure for easier understanding. However, these data sources are of utter importance in achieving information visibility in the Extended Enterprise.

It can be useful to compare figure 89 with figure 73: Figure 73 illustrates the principles (or to some degree the architecture) of the EE Operations Model (and the toolset), whereas figure 89 focuses on the underlying ICT infrastructure supporting the principles illustrated in figure 73.

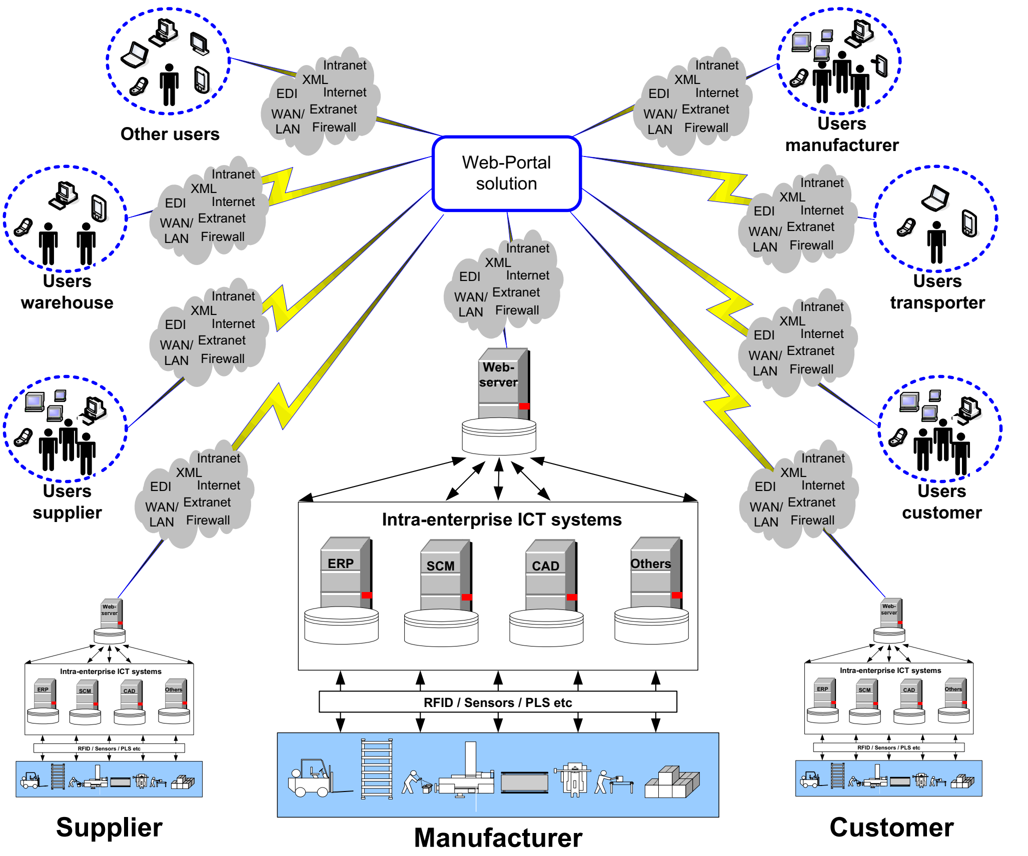


Figure 89 The EE ICT Infrastructure

A key element in the EE ICT Infrastructure illustrated in figure 89 is the web-portal solution. The portal provides an organization with a single, unified database, linked across all functional systems, both within the organization and between the organization and its major supply chain partners (Boyson et al., 2003).

6.6.2 The web portal solution

(Enterprise Information) Portals are applications that enable companies to unlock internally and externally stored information, and provide users a single gateway to personalized information needed to make informed business decisions (Finkelstein and Aiken, 2000). Portals are web-based[61] and accessed through a web-browser. Through the portal, users can have structured and personalized access to information across large, multiple, and disparate enterprise ICT systems, as well as the Internet (Turban et al., 2006). Further, the portal technology provides the unifying structure allowing a single, shared database to coordinate all the transactions within the Extended Enterprise in real-time (Boyson et al., 2003). The use of portals to integrate enterprises in the value chain has many advantages (Linthicum, 2004). The primary one is that there is no need to integrate back-end systems directly between companies and within enterprises, which eliminates the associated cost or risk (ibid).

[61] Web-based refers to those applications or services that are resident on a server that is accessible using a web-browser and is therefore accessible from anywhere in the world via the web (Turban et al., 2006).

What makes the portal so valuable as a business tool is the fact that it serves a dual function (Boyson et al., 2004): 1) it provides a focal point for each individual in the value chain to access critical information, and 2) the portal also offers an effective mechanism with which users can input important data. This implies that users can not only read information via the portal, but also respond to the data and take action accordingly.

According to Polgar et al. (2006) there are five necessary elements of portal applications:

- A portal combines several legacy back-end systems and applications at the request time into one page;
- It provides single sign-on facility;
- The content is highly dynamic and can be filtered, personalized, and secured;
- A portal is designed to service thousands of concurrent sessions in an implementation, and;
- Portals are enterprise applications that can run on load-balanced Web and application server clusters.

All the listed elements above address in one way or another EE ICT Infrastructure. The three first bullets also applies for the EE Operations Model, the EE Process Model, and the EE Dashboard.

Similar Boyson et al. (op cit) list three layers (of levels) of value chain portal solution (see also chapter 3.5.2 for more information):

- ***The presentation layer*** – has easy-to-use screen, which allow fast access to both data and business logic located within the underlying *application layer*. This is basically the information visualization aspect of the EE Operations Model Toolset. It provides an easy, interactive and visual presentation of information (through the EE Operations Model, the EE Process Model, and the EE Dashboard) to gain new knowledge, amplify cognition, and rapid and action-oriented understanding. In this regard, the EE Operations Model, the EE Process Model, the EE Modeling Tool, and the EE Dashboard can be regarded as the applications and web-pages available through the portal solution. In figure 73 the *presentation layer* is represented in the upper part of the figure.
- ***The integration layer*** – links disparate systems together in real-time and enable communication within the Extended Enterprise. This is one part of the information visibility aspect of the EE Operations Model Toolset, securing a seamless flow of accurate and timely information along the value chain. This information is then visually presented through the *presentation layer*. In figure 73 the *integration layer* is represented in the middle of the figure; on-line, real-time, available information for all Extended Enterprise members.
- ***The applications layer*** – is the central repository for value chain data and business logic for automating business processes and transactions. This is the second part of the information visibility aspects, and represents the various data sources distributed all along the value chain. The *application layer* is the lower part of figure 73, here represented with ERP, MES, RFID systems etc.

6.7 The Extended Enterprise Studio

The Extended Enterprise (EE) Studio is the last of the six tools in the EE Operations Model Toolset. In figure 69 the EE Studio was introduced as the environment where the EE Operations Model (including the EE Process Model) and the EE Dashboard are best used. The EE Studio can be viewed as the human interaction with EE Operations Model Toolset; it is about how humans, i.e. the employees in the Extended Enterprise, uses or approaches the various tools in the toolset.

The EE Studio is a collaborative, physical and/or virtual, environment where teams of Extended Enterprise representatives' mutually and simultaneously plan and control the value chain operations through visual support tools. To some extent the EE Studio may be compared to groupware products, which support groups of people who share a common task or goal and who collaborate on its accomplishment (Turban et al., 2006). However, the EE Studio is also something more than just a groupware product, is it also about the physical/virtual co-localization of teams, and the interaction between the team members.

This sub-chapter will introduce and present the EE Studio. As with the EE ICT Infrastructure, the EE Studio will be presented and discussed on a minor scale than the first four tools. This of much of the same reason listed in chapter 6.6.

6.7.1 Objective and purpose of the EE Studio

In the Extended Enterprise there is a need for value chain orchestration and choreography of globally distributed processes, resources and actors (Chopra and Meindl, 2007, Christopher, 2005; Boyson et al., 2004, Harrington et al., 2003). This implies that there needs to be some sort of common agreed, holistic, and thorough coordination of the activities in the Extended Enterprise. This coordination may be performed by one company in the Extended Enterprise, often the most powerful member (centralized control), or as a mutual effort by all members (decentralized control). The EE Studio is an enabler for such value chain orchestration and choreography.

The objective of the EE Studio is to provide a physical and/or virtual team-based collaborative environment for planning and control of value chain operations, and thus enable value chain coordination. The EE Studio relies on the information visibility and visualization provided by the EE Operations Model (including the EE Process Model) and the EE Dashboard.

It may be adequate to compare the EE studio with the concepts of control centre/towers presented in chapter 4.6.3. As airplanes need to be controlled and guided from the control centre, globally distributed Extended Enterprise operations need a holistic coordination throughout the value chain.

In more detail the purpose of the EE Studio can be described as:

- ***Value chain planning and control*** – enabling a holistic and responsive planning and control of value chain operations, through collaborative use of the EE Operations Model and the EE Dashboard.
- ***Collaborative environment*** – providing the Extended Enterprise with a physical and/or virtual collaborative environment, and thus overcoming the barriers of distance and time.
- ***Team synergies*** – exploiting the synergies of team-based collaboration and bridging some of the traditional divides between disciplines, professional groups and companies.

6.7.2 The EE Studio environment

The EE Studio environment is physical and/or virtual rooms designed and equipped to support planning and control of value chain operations. A key equipment in the EE Studio is the EE Operations Model (including the EE Process Model) and the EE Dashboard, providing information visibility and visualization.

The main intention behind the EE Studio environment is to physically/virtually gather an adequate set of people and have all these focusing on exactly the same thing and hereby understand the issue in the same way (Jonsson and Lindau, 2002). In doing so, the EE Studio environment contribute to (see also chapter 3.5.3) (ibid):

- ***Working in the "right way"*** – benefits of the synergies of team-based collaboration.
- ***Working with the "right issues"*** – due to accurate and timely information, the ability of the team is enhanced dramatically.
- ***Working in an "alert mode"*** – posses the right competence when problems and alerts occur.

There are three possible types of such EE Studio environments: 1) one single person and his computer, interacting with the EE Operations Model and the EE Dashboard; 2) a physical co-localized team working in an open office space where the EE Operations Model and the EE Dashboard are projected on large screens, in addition to on individual computer screens; and 3) a virtual and distributed team linked together, as in figure 6.22, communicating and jointly working together through the EE Operations Model Toolset. In addition, it is possible with a combination of 2) and 3). The three scenarios are illustrated in figure 90.

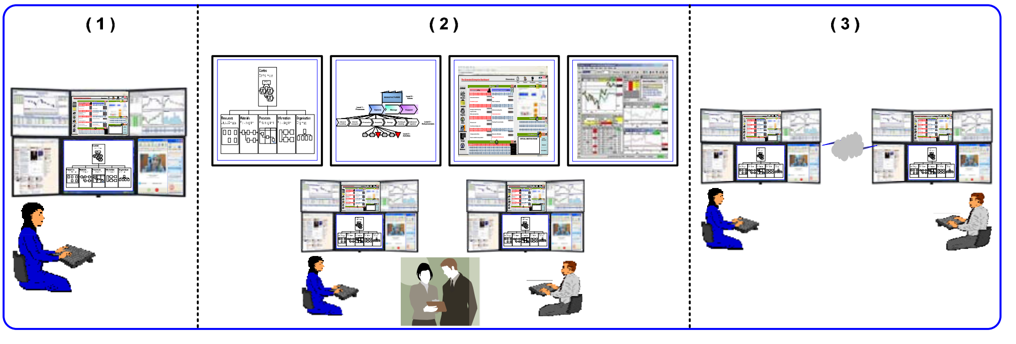


Figure 90 The EE Studio

Scenario 2) and 3) are the preferable solutions, where teams physically or virtually collaborate in planning and control of value chain operations.

The EE Studio environment should also be scaleable to support mobile devices.

6.8 Summary – bringing the pieces together

Chapter 6 has introduced the EE Operations Model Toolset, and its individual tools. The Extended Enterprise Operations Model Toolset is an information visibility and visualization system; i.e. a system enabling information visibility in the value chain and providing powerful and rich visualization of the shared information. The objective of the EE Operations Model Toolset is to provide a powerful set of tools as decision support for planning and control of operations in the Extended Enterprise. Some key aspects of the EE Operations Model Toolset are:

- It focuses on manufacturing and logistics processes
- It seeks to enable communication, monitoring, analysis and decision support within and between the members of the Extended Enterprise
- It supports short term operational and tactical planning and control of operations, as well as more long term strategically improvements of operations in the Extended Enterprise
- It provides simple, intuitive and non-ambiguous models that structure, transform, condense, and visually display the complex structure, operations and events of the Extended Enterprise,
- It provides the models with all the necessary and updated (real-time and on-line) information regarding the operation in the Extended Enterprise.

Figure 91 outlines the basic principle of the EE Operations Model Toolset, how the various tools are related, and how they all work together to fulfil the objectives of the toolset.

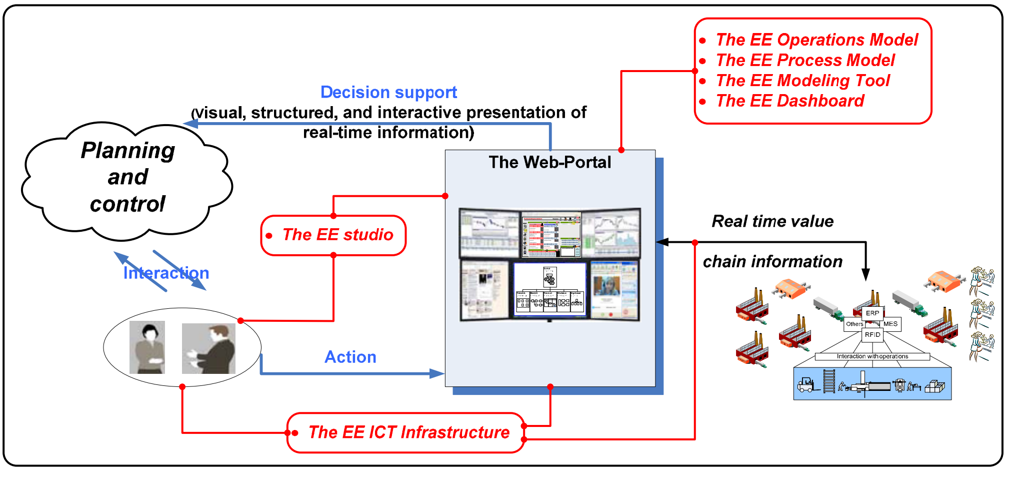


Figure 91 The EE Operations Model Toolset

Table 31 gives a summarized presentation of the Extended Enterprise Operations Model, and highlight key issues such as innovation, the degree of formalization, and the candidate contribution.

The Extended Enterprise Operations Model Toolset						
Description	**The EE Operations Model**	**The EE Process Model**	**The EE Modeling Tool**	**The EE Dashboard**	**The EE ICT Infrastructure**	**The EE Studio**
Objective	• Enable visual, on-line and real-time access to all relevant information in the EE	• Enable EEs to build up their operations based on standard (state-of-the-art) processes	• Enable modeling of operations • Generate computerized models	• Enable visual presentation of operations performance in the EE	• Overcome the (technological) barriers for information sharing in the EE	• Provide a physical and/or virtual team-based collaborative environment
Purpose	• Visualize, plan and control information and material flow in the EE • Have access to all relevant (online and in real-time) information • Decision support for planning and control	• Pre-defined state-of-the-art processes • Common language for the EE • Visualization for processes • Support engineering and re-engineering	• Standard notation for modeling • Generation of models	• Measure, monitor, analyze and manage operations in the EE	• Value chain (information) integration • Computerization of tools • An ICT platform to the Extended Enterprise	• Value chain planning and control • Collaborative environment • Team synergies
Result	• The EE Operations Model concepts	• The EE Process Model • The EE Process Model Browser	• The EE Modeling Tool concept • EE Modeling Tool requirements	• The EE Dashboard concept • EE Dashbaord requirements/ guidelines	• The EE ICT Infrastructure concept • Web-portal solution concept	• The EE Studio concept
Innovation	• High, and new solution • Very few, if any, solution available	• Medium, but new approach • A few adjacent model exists	• Low, but with new requirements • Many commercial products exist	• Medium, but new approach • Few solutions exist for the EE	• Low, with high focus in literature/ practice • Few systems operational	• High, and new solution • Some system exist within other area of application
Links to other tools	All	All	EE Operations Model EE Process Model	All, except EE Modeling tool	All	All
Formalization degree	Partial	"Fully"	Partial	Partial	Minor	Minor
Candidate's contribution	High	High	Medium	Medium	Low	Low

Table 31 The Extended Enterprise Operations Model Toolset

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PART IV

Empirical study

The main objective of Part IV is to ***present the empirical part of this dissertation****. The results of the research has already been presented in Part III, and Part IV aims* ***to substantiate how*** *these* ***results*** *partial* ***can be derived from the two case studies*** *carried out in this dissertation. These two case studies are from the automotive industry, and involve two companies;* ***Raufoss Chassis Technology*** *and* ***Hydro Automotive Structure.*** *Part IV will present these two case companies, and not so much on the various projects carried out in these companies. For more information regarding these projects, see chapter 1.2.2, table 1, figure 9 and figure 10, as well as Appendix B.*

Chapter *7 will introduce and present the main case in this dissertation, the* ***development of an Operations Model at Raufoss Chassis Technology****. The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.*

Chapter 8 *will introduce and present the minor, test, case in this dissertation, the* ***testing of the Operations Model at Hydro Automotive Structure****. The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.*

Part IV

Chapter 7

Development of an Operations Model at RCT

Chapter 8

Testing the Operations Model at HAST

Chapter 7

Development of an Operations Model at RCT

7 Development of an Operations Model at Raufoss Chassis Technology (RCT)

Chapter 7 will introduce and present the main case in this dissertation, the development of an Operations Model at Raufoss Chassis Technology (RCT). The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.

7.1 Introduction to the case

In the period 1998-2004 there were several concurrent NTNU/SINTEF projects at RCT with focus on manufacturing and logistics; with particular high focus and intensity in 2001-2003. Some of these projects had coinciding objectives and their intervention with RCT can be described as (for more generic information about the projects, see chapter 1.2.2 and Appendix B):

- ***MOMENT*** – RCT was used as a case in developing the conceptual framework for the Mobile Extended Manufacturing Enterprise (including EE KPIs, EE Process and Operations Model, ICT decision support for EE establishment, and the EE engineering methodology).
- ***SMARTLOG*** – sought to develop a set of models of the value chain for improved control of material and information flow, with RCT as one of the main partners in the projects.
- ***P2005 – PLOG*** – studied the development of distributed production networks at RCT.
- ***POND*** – aimed at developing innovate logistics solutions and lean manufacturing at RCT.
- ***PhD project*** – was performed in close collaboration with the projects listed above, and focused on RCT as an Extended Enterprise, and the use of ICT to support manufacturing and logistics in the value chain.

The candidate participated more or less in all these projects, and the experience gained from these projects at RCT are presented as ***the RCT case*** in this chapter. The RCT case is the pillar in developing the Extended Enterprise Operations Model Toolset, see chapter 6.

7.2 RCT and the Extended Enterprise

RCT is a (1st and 2nd tier) supplier to the automotive industry, with production facilities in Raufoss (Norway) and Montreal (Canada). This case description will focus on the Raufoss plant.

7.2.1 History

RCT has proud and long industrial traditions, which can be traced back to the establishment of Raufoss Amunisjonsfabrikker (ammunition producer) in 1986. The spin-offs of Raufoss Amunisjonsfabrikker constitute today one of Norway's largest industrial parks, with almost 40 companies and 3000 employees.

RCT has since 1981 developed and produced aluminum chassis components to the European OEM car industry. The customers have traditionally been prestige carmakers such as BMW, Daimler Chrysler, Audi, Porsche, Saab and Volvo.

Neuman Aluminum (from Austria) acquired RCT 1st July 2004, and RCT operates today with the name Raufoss Technology (RT) AS. This take-over was conducted after the case presented in this chapter was finished, and has no implications for the results. The name RCT will be used throughout this chapter of historical reasons, and the case description is based on mapping done between 2001 and 2003, prior the Neuman Aluminum acquisition.

7.2.2 The GM Epsilon contracts

The development and co-operation with General Motors (GM), i.e. SAAB, in 1998-1999 for a new GM platform resulted in new innovative aluminum solutions. The processes are hot forging of rods (front arm) and mechanical stretch bending of profiles (rear arm).

In 1999 RCT was nominated as sole supplier of complete aluminum control arms for the new GM European Epsilon platform (Opel/Vauxhall Vectra and SAAB 9-3), to be introduced in the spring 2002. Due to this contact with GM, RCT decided to build a new plant at Raufoss to serve the European plants of GM. Total investments were 25 mill US$, and expected revenue was 35 mill US$ per year. Start-of-Production (SOP) was January 2002, with expected production to be 500.000 cars per year. The GM cars (Vauxhall, OPEL, and SAAB) are assembled in England, Germany and Sweden.

In 2000 RCT was once again nominated as sole supplier for GM, this time for the North America Epsilon platform (Chevrolet Malibu, Pontiac, Grand Am and Saturn LS) to be introduced in 2003. The products are similar to the GM European Epsilon platform. A duplication plant (of the Raufoss plant) was built near Montreal in Canada to serve US clients. Total investments were 42 mill US$, and expected revenue was 48 mill US$ per year. Start-of-Production (SOP) was September 2003, with expected production to be 650.000 per year in full volume. The GM cars are assembled at different locations in USA. The components produced by RCT are further sub-assembled by Yorouzu and AETNA, before delivered to GM plants.

The remaining part of this chapter will solely focus on the RCT Raufoss plant.

7.2.3 Product characteristics

RCT has been developing and manufacturing chassis components for the automotive industry. RCT has more than 25 years experience in this market segment. RCT are mainly producing two components (see figure 92): ***Front wheel suspension*** and ***rear wheel suspension***

The parts are identical for all possible variants within the Epsilon platform, although the labelling and packaging requirements differ from car-plant to car-plant. The Raufoss plants is designed to a meet the capacity requirements for a single source supplier to GM. The manufacturing is organised in two fully automated manufacturing lines where all handling of the parts is automated through robots and conveyors.

The front arm is distinguished in left and right, while the rear is identical left and right. For the front arm the same subcomponents are used, but the machining process creates different shapes of the left and right arm. The components are shown in Figure 93.

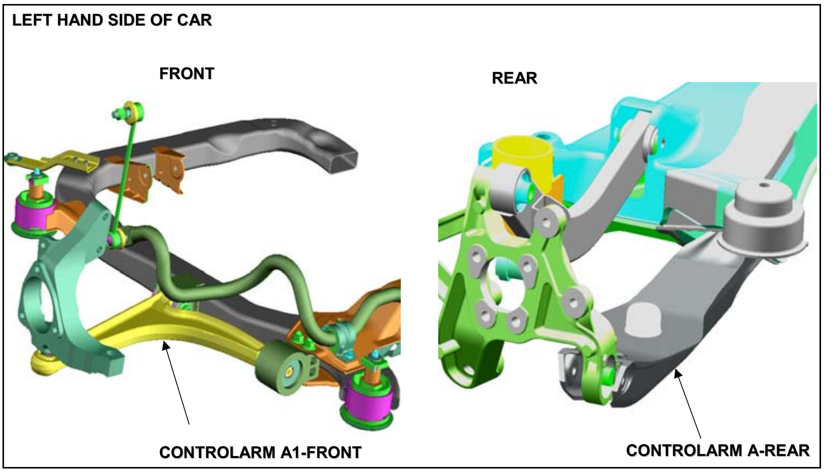

Figure 92 RCT products on GM cars

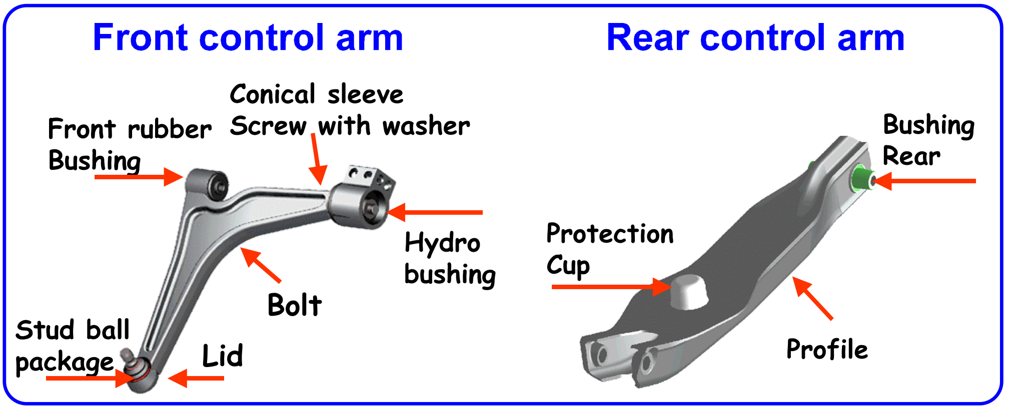

Figure 93 Front and rear control arms

7.2.4 The value chain – the RCT Extended Enterprise

From an overall point of view RCTs (European) value chain is extremely simple:

- They have only one customer (GM)
- They produce two products (front and rear control arm)
- The production is fully automated in two dedicated lines
- They have only 11 suppliers, located mainly in Europe
- There are no RCT owned warehouses
- Outbound transport are coordinated by the customer
- Inbound transport is mostly coordinated by RCT (by a transport company).

However, by going into detail of the upstream and downstream value chain, a more complex value chain or Extended Enterprise emerges. Figure 94 gives an overview of the RCT Extended Enterprise.

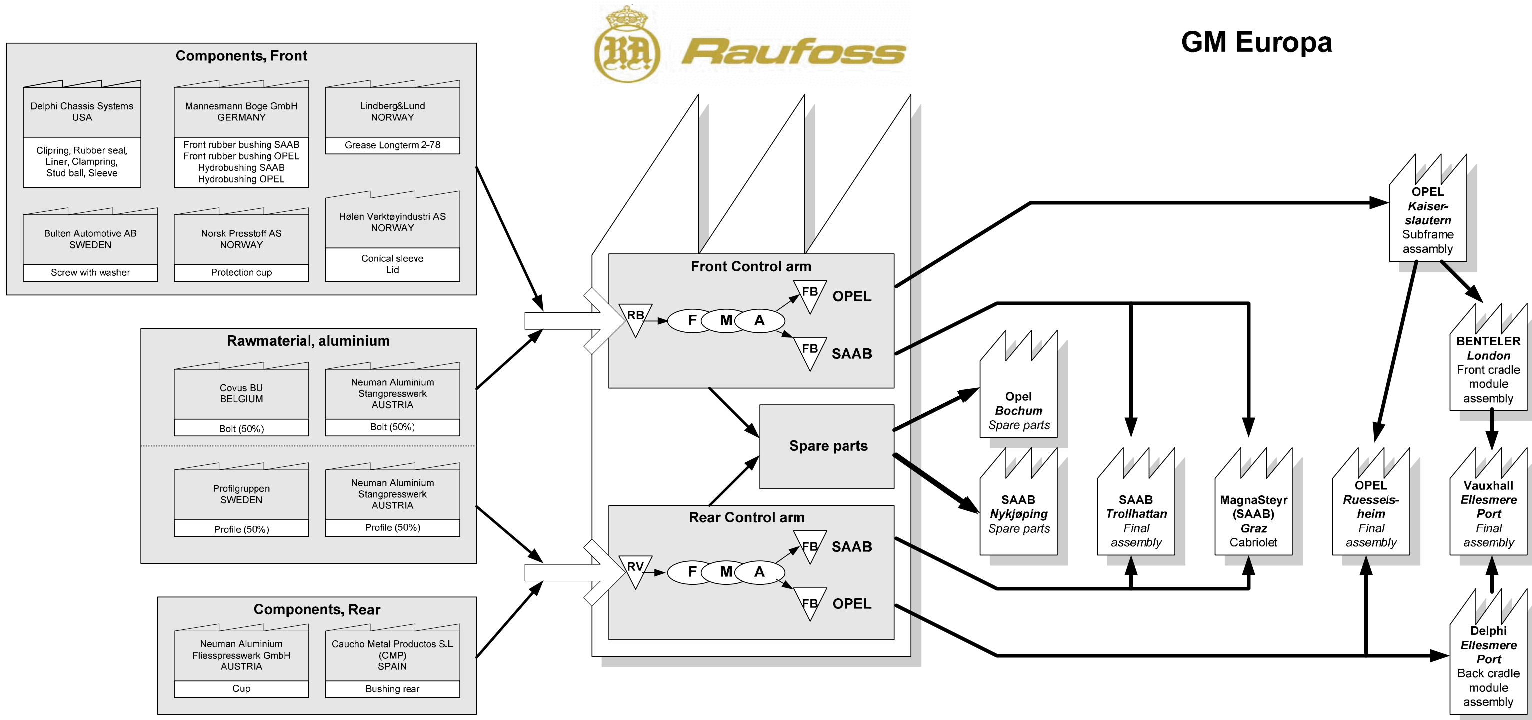

Figure 94 The RCT Extended Enterprise

The downstream part of figure 94 (the right-hand side) indicates that RCT is supplying three GM brands (OPEL, SAAB, and Vauxhall) at 7 different geographically locations. The products are labelled with car brand in the production process, one component is assembled according to car brand, and the products are also packed and labelled with the final destination. And, the frequency of delivery between RCT and the different customers differs from daily to weekly.

The upstream part of figure 94 (the left-hand side) is a little more complex than down-stream; RCT source 17 (19) different raw material and/or components from 11 different suppliers. The raw materials (aluminium bolt and profile) are both sourced from two companies, each with 50 % of the volume. This is done deliberately in order to ensure the supply of raw material. The two sets of suppliers (two supplying bolt and two supplying profile) are supposed to supply exactly the same product done after specifications made by RCT. Further, RCT are using 15 different components, in additions to raw materials, in the productions of the front and rear control arms. Two components are assembled into the rear arm, whereas the rest are included in the front arm. All components are single sourced. The lead time for inbound deliveries spans from one day (the suppliers located in Norway) to 4-6 weeks (Delphi, located in USA).

7.2.5 The manufacturing system

The manufacturing system at RCT is designed for a yearly production volume of 860 000. The manufacturing is divided into two separated and dedicated production lines; one production line for the front arm and one line for the rear arm. The production is highly efficient, and has a cycle time on 10 sec (front line) and 7,8 sec (rear line). The wheel suspensions are produced in aluminum, which requires time consuming steps like heating and deburring. The throughput time is therefore 8 hours (front line) and 5,5 hours (rear line).

The production lines are fully automated with a conveyor system transporting parts between the main processes. The front and rear arm lines have two separate conveyors systems. Robots upload and download of parts to/from these conveyor systems. The conveyor systems not only serve as transportation devices – they also serve as intermediate downstream buffers.

The front arm line is continuously fed with bolts from the aluminum billet cutter. These bolts are then passing through a number of forging related processes including heating, pressing, forging, cooling and deburring. The forged parts are then entered into an ageing process where they are heated while being carried by the conveyor system on their way to the machining segment of the line. Here a series of machining operations are carried in lines of CNC machining tools. The last main segment of the front arm line is the final assembly centre. In this segment, left hand side and right hand side arms are separated into two parallel and dedicated assembly lines. At the packaging point the downloading robot differentiates on left hand side and right hand side by a sensor reading an ID chip on the pallet on which the arms are attached. Very simplified this production line can be divided into 6 processes:

1. Cutting (of aluminum rods)
2. Forging (of arm from heathen bolts)
3. Ageing (of arm)
4. Machining (of arm)
5. Assembly (15 components are assembled together with the arm)
6. Packaging and labeling

The input to the rear arm line are extruded, closed aluminum profiles which are heated and cooled followed by a number of forming processes like press bending, grading and stamping. Before the final assembly and packaging, the arms are entered into an ageing process. The rear line is not as complex as the front line. It consists of 4 processes:

1. Heating, stretch bending, machining and assembly (one out of two components are assembled)
2. Ageing
3. Final assembly
4. Packaging and labeling

7.2.6 Supply chain management and control

RCT has organized all value chain processes in a Supply Chain Management (SCM) function, with a dedicated group of people that have a complete and shared responsibility for all value chain processes related to information and flow of goods. This centre co-ordinates all transactions regarding the RCT node in the value chain. The SCM is established based on the concept of *single-point-of-contact,* and facilitates the value chain orientation of the organization rather than a functional orientation. RCT has established some overall control principles for the complete flow of goods:

- Masterplan of resources and delivery volumes based on customers year plan
- Daily delivery to customers based on call-offs
- Delivery executed from finished goods stock
- Smoothened production plans, fixed and stable for 4 weeks horizon
- Material and components purchase making use of year-orders, forecasts, and call-off based on production plans and components stock levels
- All plans updated weekly (Monday)

The SCM is responsible for the yearly planning process and four daily processes:

- Order acceptance (receive Call-off)
- Delivery scheduling and execution
- Productions and inventory control
- Procurement

Figure 95 illustrates the yearly planning process and how this is linked to the daily (and weekly) processes.

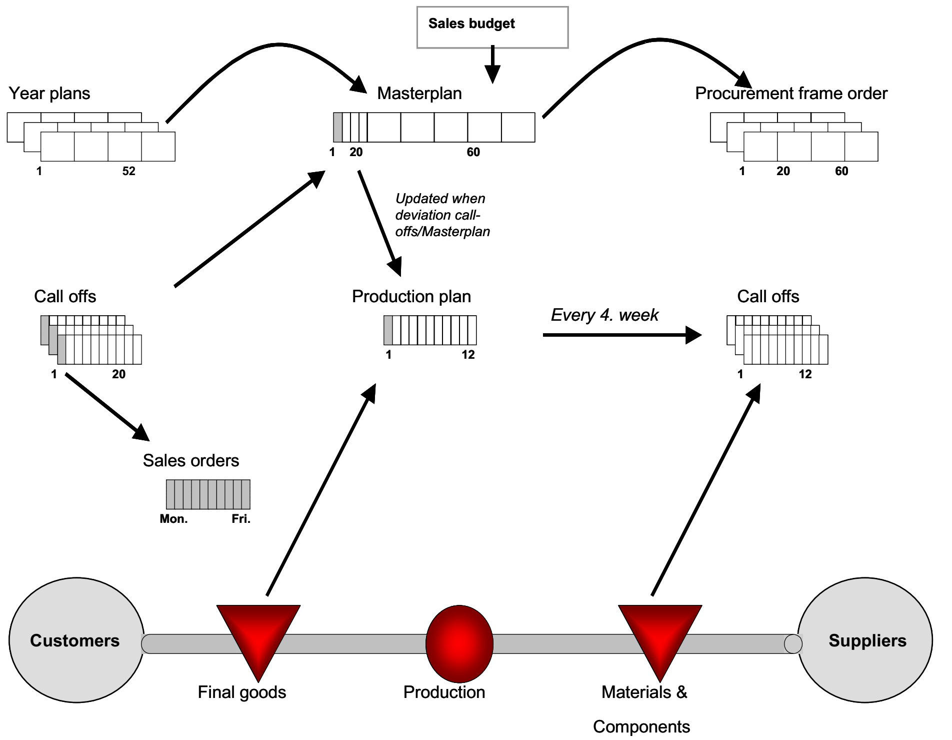

Figure 95 Planning system at RCT

The plans can be visualized in different configurations for managers, purchasing, production, and order handling. However, the major principle is that each plan is updated in only one place.

7.2.7 Information and Communication Technology systems

RCT has at set of ICT systems to serve different needs, as illustrated in figure 96. Some key features of the manufacturing and logistics related ICT systems are:

- ***Oracle 11i*** – RCT started the implementation of the Oracle 11i ERP system in November 2001, and the implementation was not finished until mid 2003. The implementation went through various difficulties (particularly associated with the EDI solution towards GM) and the solution was changed several times. The manufacturing part of the Oracle 11i solution was very simple, based on the repetitive (flow) manufacturing module, with two registration points (inbound goods (components/raw materials) and finished goods), and a backflushing pull of components.
- ***WinCC*** – is software for process visualization and a platform for ICT and business integration. RCT uses 600 points of measurement, where data is collected from the automated equipment every second and visualized on the web for process control. WinCC visualize all processes and use the data from the automated machines to enable process control and detect coming trends at an early stage.
- ***GMSupplyPower*** - is an initiative by GM to empower suppliers to conduct business online. At the SupplyPower.com site each function in a firm is divided into Powers, e.g. Material Power, Finance Power etc, where all the desired information regarding

this function can be found. There is also a mandatory daily view function called *My bulletins*.

- ***EDI*** – the EDI solution towards GM is based on the EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport) standard. The EDI solution used for forecasts, call-offs, and advanced shipping notification.
- ***DocuShare*** - enables document management, collaboration, review and approval, and Web publishing to support information sharing at all points of the enterprise by every knowledge worker.
- ***Intranet*** - communicate and interact with many of the IT systems at RCT (see figure 96). On one hand the Intranet is an electronic version of the *quality handbook*, describing organization, processes, etc. The manufacturing and logistics part of the intranet is also an *Operations Model*.

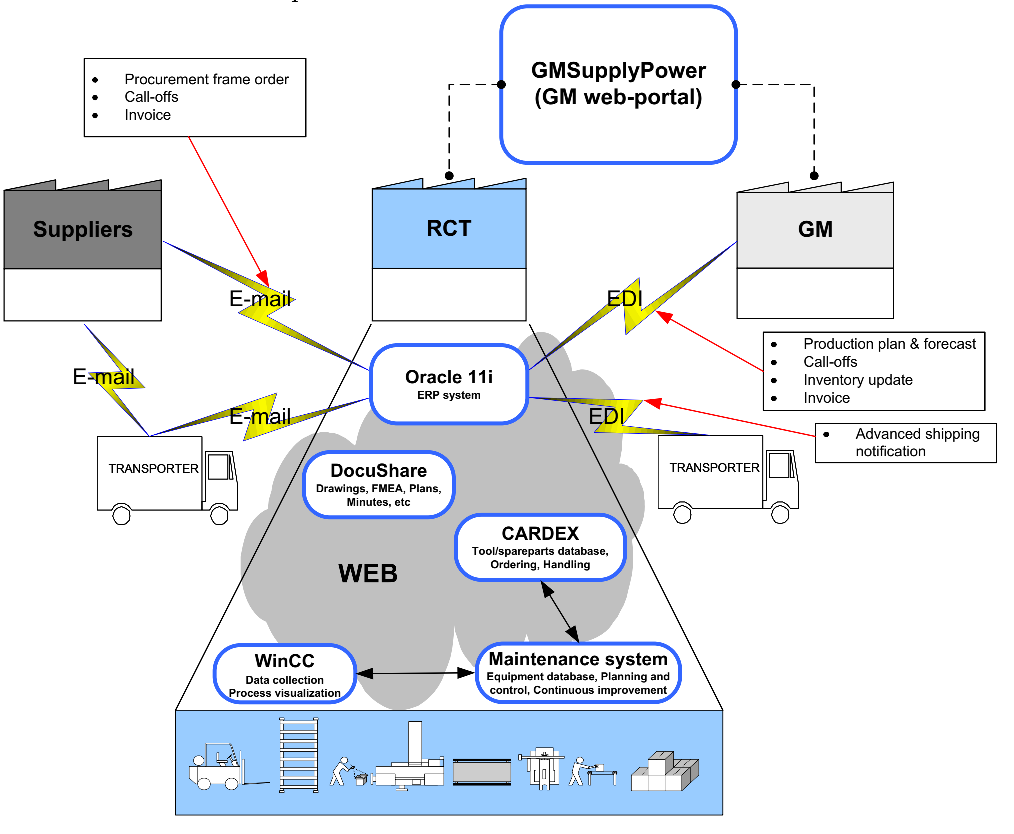

Figure 96 ICT systems at RCT

7.2.8 Performance measurement

RCT actively uses performance measurement in the management and control of the Extended Enterprise; upstream and downstream in the value chain as well as internally at the Raufoss plant.

GM has a mandatory performance measurement system that it applies to all its suppliers, and then consequently RCT. RCT uses this compulsory system to measure its downstream performance. In this system, GM uses five generic criteria to evaluate their suppliers:

1. Schedule adherence
2. Material handling quality
3. Reliability, responsibility, early warnings and communications
4. Flexibility
5. EDI

Within each of these generic criterias there are several KPIs (see table 32), which are collected twice a year, or if necessary at any time. Based on the score on the lowest rating of the single criterion, an overall supplier rating is calculated (see figure 97). Depending on the score, the suppliers are divided into five categories: 1) Outstanding, 2) Good, 3) Approved, 4) Not approved, and 5) Unacceptable.

Rating 3 (Approved) is the lowest acceptable to be approved in the GM evaluation. A lower rating will result in a supplier training process and/or new business on hold with GM.

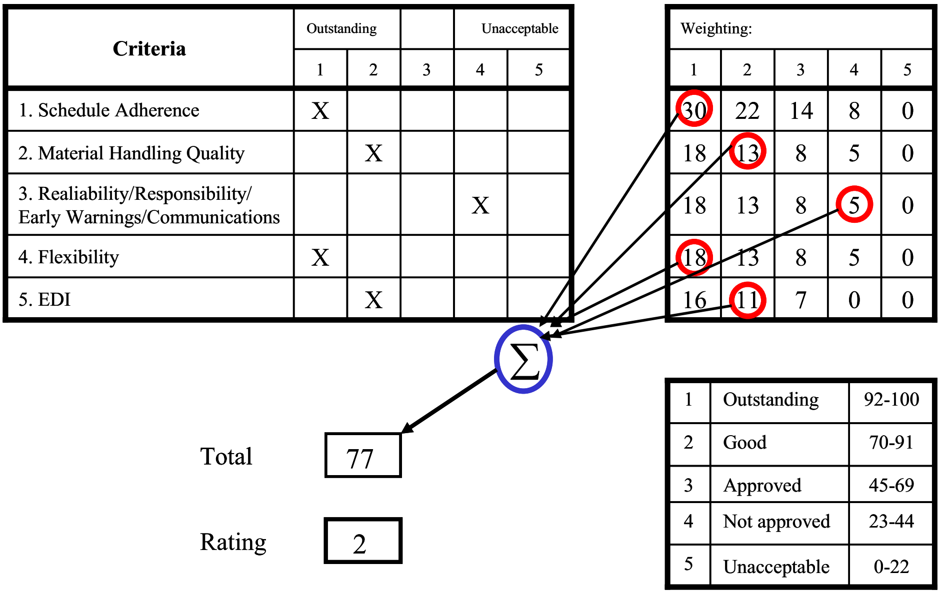

Figure 97 Calculation of rating

Generic criterion	Contents
Schedule adherence	The supplier confirms to: • Shipping schedule • Stock status system • MAIS-pick-up procedure (Material Information System) • Container and quantity instruction • Specific labels • Correct deceleration
Early warnings	The suppliers gives: • Early warning to the plant, when unable to despatch • Advice (in time) that he provides material shortfall (MAIS-pus) • Advice on non-availability of packing
Reliability	The supplier: • Responds promptly to faxes, questionnaires, letters, and phone calls • Gives reliable information respectively keeps his promises

	• Communicates in English (at least) • Mentions a night time contract • Has suitable deputy during holidays • Keeps us informed about his organisation changes • Informs about plant downtime, strike, etc. • Advises that material is not available for pick-up (MAIS) • Does not provide surplus material for pick-up (MAIS) • Supplier signs and stamps the pick-up-sheets
Flexibility	The supplier: • Reacts promptly to changes in requirements such as increases, decreases, stock discrepancies etc.

EDI (trading partner communication)	The supplier:
	• Meets all EDI-requirements of GM Europe in respect of:
	  o Delivery forecast
	  o MAIS
	  o (if required) stock-status-system and advanced shipping notification)
	  o Label
	  o Material Globalisation Optimisation

Table 32 KPI measured by GM towards suppliers

The performance measures used internally are less comprehensive. Table 33 depicts the current KPIs used at the Raufoss plant for logistics processes

KPI	Definition
Stock level inbound buffer and production	Level of incoming goods stock and goods being processed in production
Quality of plan	Deviation from planned, from week to week
Number of corrections pr. week	Number of corrections per week
SPOC use of resources	Relative resources usage in relation to the previous month, adjusted on delivery volume

Table 33 Current KPIs used at Plant Raufoss for logistics processes

Some of these could be aggregated to a higher level, and thus be used as input for the corporate level.

RCT uses only two indicators to evaluate and monitor their supplier:
- Quality (PPM)
- Delivery precision

7.3 Challenges

The nomination for the GM Epsilon platform contracts implied great potential for RCT, as well as demanding challenges for RCT[62].

7.3.1 The new RCT strategy and the strategic challenges

The Epsilon contracts were the starting point for a new RCT strategy: *Light weight chassis technology* became the new core business. This involves new innovative aluminum processes and products where RCT will serve their customers globally and expand customer- and product platform in Europe and North America.

[62] One may argue, retrospective, that RCT was not able to meet these challenges, and this resulted in the financial problems in 2003/2004, and ultimately the Neuman Aluminum takeover in 2004.

RCT has furthermore focused its strategy to being a w*orld class supplier of Light Weight wheel suspension components for the Automotive Industry***.**

This focused strategy is based on the fact that RCT today has world class competence and experience in processes of forming aluminum by hot forging of rods and mechanical stretch bending of profiles into high quality and cost effective automotive components.

This strategic focus has several consequences.

- The market is strongly limited (automotive and only a small selection of components)
- The components are crucial regarding safety and lifetime of the cars.
- RCT will normally achieve Single Source Life Time contracts for car models.
- RCT must in the bidding phase compete against alternatives in other materials (like steel) that normally are cheaper in material cost and well proven bye decades of use.
- RCT must adapt to the contract concept of the Automotive Industry; that of yearly price reduction within the contract.

This again leads to the following:

- RCT must fulfill extreme requirements regarding product quality of own produced parts as well as purchased sub-components.
- RCT must fulfill extreme requirements regarding delivery performance.
- The location of RCT plants is strongly influenced by the OEMs location of assembly plants.
- RCT must from Start of Production (SOP) until End of Model Lifetime be able to operate its plants extremely cost effective.
- RCT must thoroughly understand the automotive business, and have strong competence of the functional requirements for components that are supplied.

These statements can be summarized into to the two following consequences regarding the logistics and value chain challenges of RCT:

- RCT must be able to ***operate all plants*** with ***extreme quality***, ***precision*** and ***low cost*** of the ***entire value chain*** related to each plant
- RCT must be able to make all strategic decisions regarding creating new business (from identification of new market opportunities until SOP) with as thorough insight in all logistics and supply chain issues as possible

The ability to be at the front of the development of ***logistics and value chain*** solutions is therefore vital to RCT`s competitive edge.

7.3.2 Customer requirements and internal challenges

As something between a 1st and 2nd tier supplier to automotive industry, RCT is facing extreme demands from the customer. Zero defects and 100% precision of delivery are obligatory. Continuous improvement is a must since prices are decreased by contract every year. The combination of these demands, the high volumes of identical parts, and the fully automated manufacturing, makes RCT very vulnerable to any kind of disturbances. From the operations perspective of the company the overall competitiveness is dependent on the ability to manufacture and deliver with:

- Zero defects
- Full precision of delivery
- Fast responses to changes required from the OEM
- Correct and speedy information flow

Further, to be able to operate the business and achieve business goals this certainly leads RCT to the general requirement of being able to ***minimize total costs***.

From a logistics point of view the main challenges resulting from customers and internal requirements are:

- No defects or deviations are allowed in the logistics process (quantity, delivery time windows, labeling, etc)
- The extreme speed of production and delivery, combined with limited space and equipment for storage allows no stop of flow to make corrections
- Variations in information (process and quality) between plants of GM
- Format and technical means (fax, e-mail and EDI)
- Frequency (weekly, biweekly, daily as well as extraordinary)
- Time horizon (20 weeks, ten weeks, fortnightly)
- Accuracy (varies more than 100% on weekly basis)

Value chain integration, with a transparent information flow (both internally and externally in the value chain), was indicated as a key parameter in overcoming the challenges and requirements.

7.4 Project results and solutions

Due to the challenges outlined above it became important for RCT to establish close relationships with Norwegian (e.g. SINTEF and NTNU) and International research institutions. The intention was to overcome the challenges and to become a sustainable, competitive and profitable Norwegian automotive industry supplier.

Earlier in the collaboration between RCT and SINTEF/NTNU, some key principles were identified as crucial for the development and operations of the RCT value chain. These principles were supposed to be normative and give guidance to remaining work.

Process (value chain) integration, information transparency, and a lean organization were understood as vital to achieve a competitive value chain. A set of basic principles was decided to rule the game of development and operations of the value chain. These principles, based on the well known principles and RCT challenges are:

- ***Time focus*** - The need to be precise and speedy in all processes, physical as well as administrative
- ***Lean manufacturing*** - Focus on value adding processes only.
- ***One-way flow and tasks done once*** - Focus on streamlining the flow of goods and information, and be sure that all tasks are done at once, and only once.
- ***Real-time information*** - All decisions and actions must be taken based on real-time information access
- ***Transparent value chain*** - Information sharing throughout the value chain. Information from customers, RCT, as well as suppliers should be transparent through the whole value chain
- ***Integrated processes*** - Seek to integrated processes, both within the company as well as with partners. Integration of processes by ICT
- ***Visual and simple*** - Keep everything as simple as possible, and visualize whatever can be visualized

These principles were followed in the various projects described in chapter 7.1, and can be viewed in line with principles outlined in this thesis.

The remaining part of chapter 7.4 will describe some of the solutions and tools that were developed by RCT and the projects. The emphasis will be on those tools and solutions that were in line with the PhD project at RCT, and decisive in the development of the EE Operations Model Toolset (presented in chapter 6).

7.4.1 The RCT Process Model

This is basically the generic EE Process Model presented in chapter 6.3, applied on RCT to develop a particular process model for RCT. As already mentioned, the EE Process Model was developed in the MOMENT project, where RCT played a key role. The EE Process Model was developed according to the requirements in the automotive industry, and RCT and its Extended Enterprise was used as the first case.

The range of use and the power of EE Process Model are best utilized as a big poster on the wall, on the computer screen and/or as a computerized visualization done by a projector. In a hierarchical structured document the flexibility, depth, richness, complexity and dynamic nature of the model are lost. Hence, only a detailed version of the RCT manage and operate processes, sub-processes and activities, in a value chain context, are illustrated in figure 98. Likewise, figure 94 can be regarded as a high-level version of the same process model, only focusing on the actor level of the process model.

The main intention behind developing the RCT Process Model was to document the feasibility of generating particular process models from the generic EE Process Model. This was confirmed by the case.

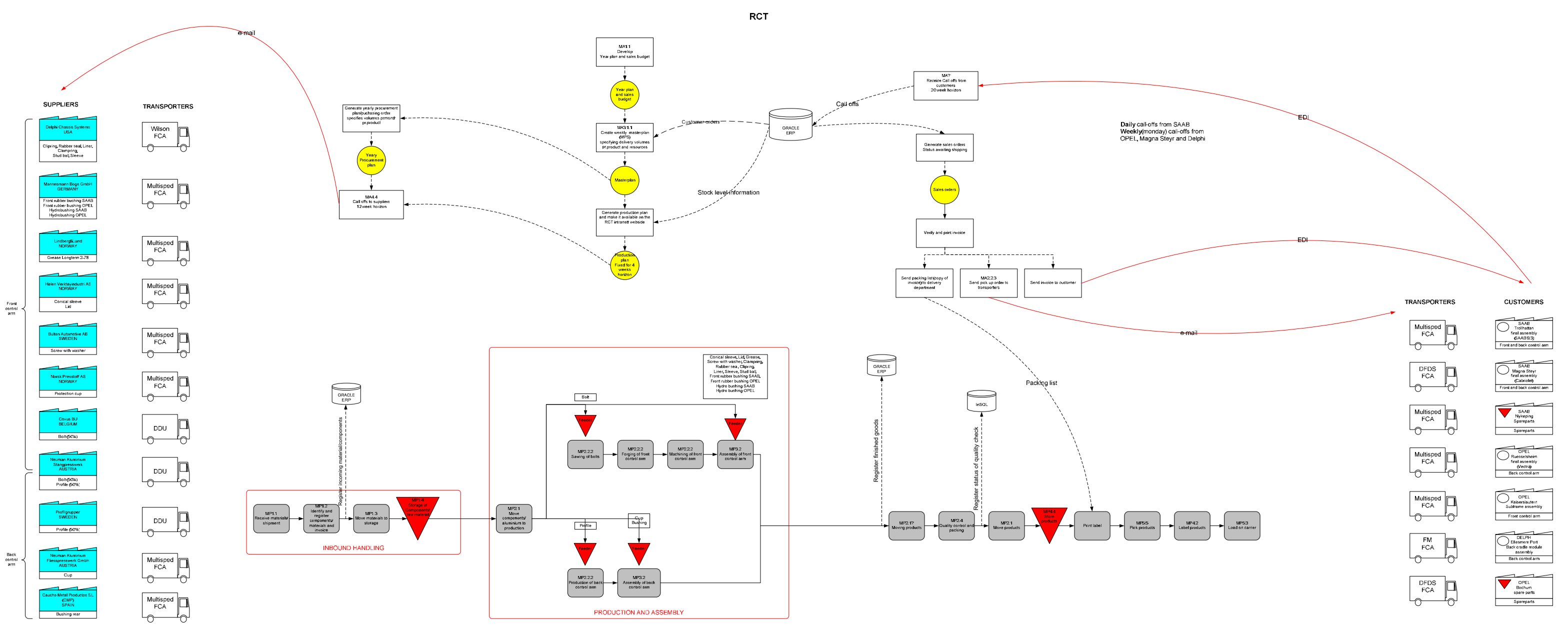

Figure 98 The RCT process model

7.4.2 The RCT Operations Model

In order to achieve a transparent value chain, and to keep everything simple and visual, RCT developed an intranet solution, which communicates and interacts with many of the ICT systems at RCT (see figure 96). Integrated processes and access to real-time information are also important principles in this Intranet solution. On one hand the Intranet is an electronic version of the quality handbook, describing organization, processes, etc. On the other hand, the Intranet is an Operations Model, focusing on the manufacturing and logistics processes.

The Operations Model concept was presented in chapter 6.2, and can in short be described as some sort of representation of the operations in the enterprise and/or the value chain. The rationale for establishing an Operations Model at RCT was:

- To have a common description with all relevant information about the operation of RCTs value chain.
- To be able to use the RCT Operations Model as a tool for future development of the value chain as well as developing the operations itself.
- To be able to use the RCT Operations Model as a learning tool for new employees.
- To secure that all description and information is stored once and only once, and is globally real-time available to all personnel involved.
- To create one single information pool whose flat structure with cross-linking and hypertext features is preferred to the more traditional hierarchical- and partition-based one. This makes the user's information quest process more time- and cost-efficient.
- To enable multi-media technical support, helpful in a wide range of situations (e.g. machinery brake-down or machinery upgrading design, etc.).

As part of the MOMENT project, SINTEF developed a conceptual operations model for RCT, see figure 99a. This model was based on the process model presented in the previous sub-chapter. In this model the intention was that every element of figure 99a could be further detailed into either *description* (generic visual information regarding the processes) or *monitoring* (visual live version of operations/processes and performance).

RCT modified the conceptual operations model developed by SINTEF and the final implement version is illustrated in figure 99b. Further, the divide between description and monitoring is removed in this model, and the operations model is very close linked to the dashboard solution, see chapter 7.4.4 and figures 101-103.

Figure 99b is in Norwegian, but the logic and content is more or less identical to the version presented in figure 99a.

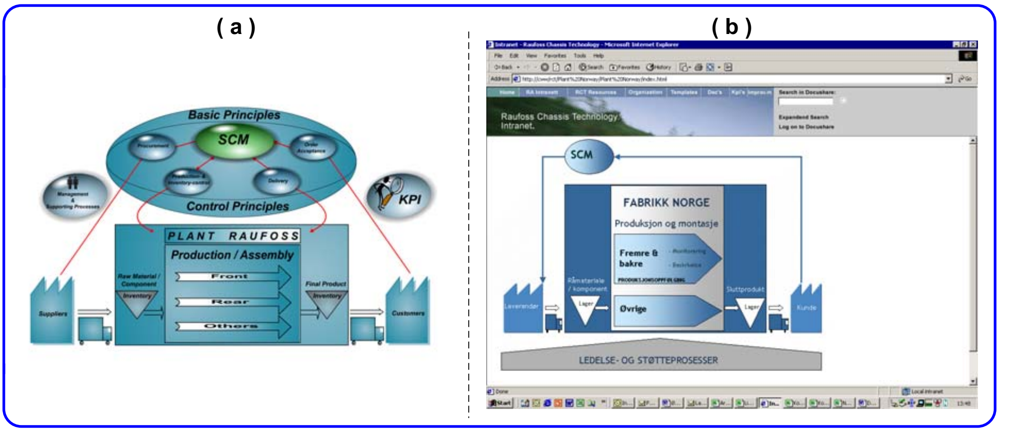

Figure 99 Operations Models at RCT

7.4.3 The RCT KPI dream concept

Another important result of the RCT and SINTEF/NTNU collaboration was the development of the *RCT KPI dream concept*. The performance measures presented in chapter 7.2.8, was not sufficient; the existing measures was indicators for the past, and were often measured with a time delay. RCT needed a set of KPIs that would give management, and employees, a visual, accurate, real-time, automatic generated, responsive and holistic view on the value chain performance.

In table 29, see chapter 6.5.2, the ideas and requirement for such a KPI set are outlined. Based on these ideas and requirements a set of five groups of KPIs were developed:

- ***Material flow indicators*** - basically, these indicators (there are two of them) indicate volume and speed of the material flow in the value chain. Updated information regarding these indicators makes it possible to foresee future stock-outs before they occur.
- ***Information flow indicators*** - these indicators are associated with the information sharing process between companies in a value chain. They indicate factors like information throughput time, forecast precision, call-off precision and demand variation.
- ***Value chain control processes quality indicators*** - These indicators indicate how well the individual companies in a value chain utilize the shared information in the value chain and are able to map this information up with its own processes.
- ***Value chain control resource consumption indicators*** - These indicators deals with the resource consumption of the value chain control process. A clear indication on improvement/decline in resource consumption is given by comparing the actual value (scaled on the actual delivery value) of resources used in SCM with the value from the previous month. Furthermore, the impact of SCM on total turnover is important in order to analyse the effectiveness of the SCM.
- ***General indicators (standard, traditional indicators)*** - In addition to the indicators listed above, RCT also include more traditional indicators. These KPIs measured along the classic measurement dimensions (time, quality, flexibility and cost) are used to monitor inbound-, internal- and outbound- logistics.

Within each group, individual KPIs were identified. The RCT KPIs dream concept was developed as a “to-be” solution regarding performance measurement at RCT. Some of the

KPIs were implemented and other not. Still, the ideas and the development of the RCT KPIs dream concept was important input in the development of the RCT Dashboard.

7.4.4 The RCT Dashboard

As an integrated part of the operations model, RCT developed a dashboard solution. The dashboard solution focuses on visualization of material flow and manufacturing process status for manufacturing operators. The aim of this solution was to ensure fast response to changes, support the team-based organization and motivate the work force. Further, maintenance, tool changes etc. are easier to synchronize to the manufacturing rate.

The idea was that each operator will have a special designed "control panel" where all the vital information is visual at any time. If necessary, the operator may detail this data, by accessing the Intranet (the Operations Model/Dashboad). Further, the operator has a graphical picture of the manufacturing line with status signals: *Green* means that everything is running correctly, *yellow* is a warning that some parameters is out of control, and *red* is alarm that something has gone wrong or some parameters are outside tolerance limits. A Yellow warning light will not stop the line, but a red alarm will.

This is similar to the Toyota ANDON principle (see among other, Monden (1998)). The most important process parameters and production data is displayed as well. Figure 100 shows a conceptual sketch of such a dashboard, and served as basis in the development of the Dashboard solution at RCT.

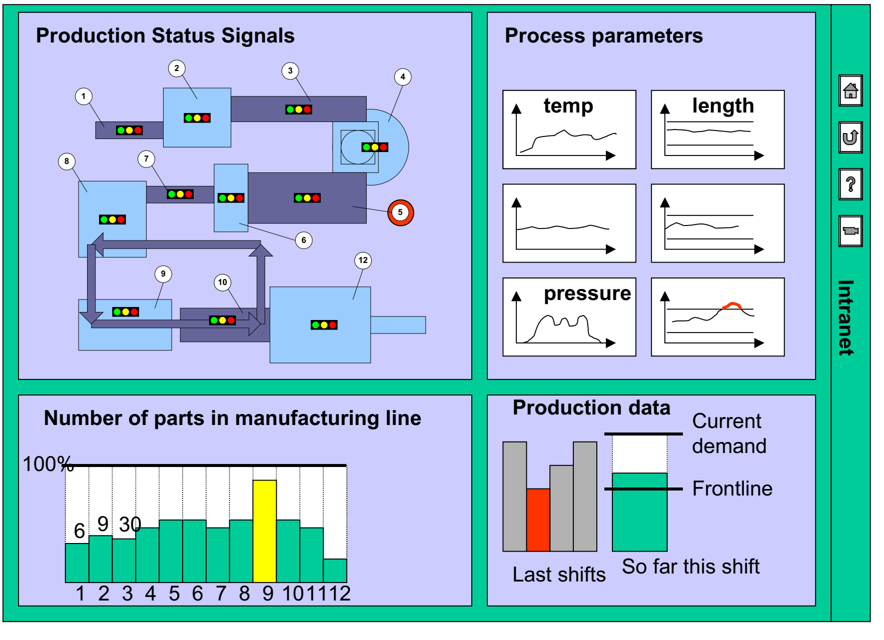

Figure 100 Conceptual sketch for the RCT Dashboard solution

Source: Martinsen et al. (2002)

Based on the sketch in figure 100 and the underlying ideas, a Dashboard solution was developed as an integrated part of the Intranet; i.e. the RCT Operations Model. By detailing the Operations Model and access the sub-processes and activities, the user also got access to performance data regarding these sub-processes and activities. Figure 101, 102 and 103 are taken from RCTs Intranet and illustrates how RCT have adopted these ideas. A detailed visual description of the rear control arm production line is given in figure 101. The production, assembly, internal transport and storage sub-processes and activities are illustrated, with the correct layout, and with status information (performance data) and alerts built-in.

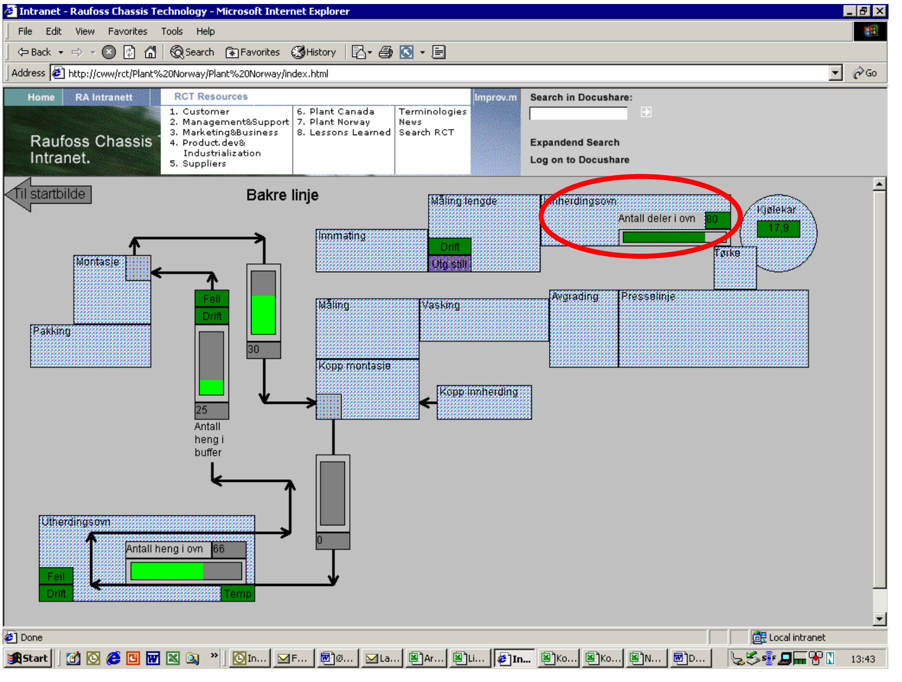

Figure 101 The rear control arm production line[63]

A further detailing of the heating oven (marked with a red oval in figure 101) is given in figure 102. This screenshot illustrated the key performance data for this activity, and gives the user the ability to supervise and monitor this activity.

An overview of the production plans (week 21) for the front control arm production line, with accumulated data as well as other key characteristics, are illustrated in figure 103.

In addition, there were some ideas to develop a more traditional Dashboard solution, with graphical display of a few KPIs. This is illustrated in figure 104. This figure is a conceptual sketch, and the solution was never implemented. In figure 104 the buffer factor indicates the changes in the buffer-sizes over the last 4 weeks period. A similar factor, not shown in figure 104, displays to which degree that the stock size is "harmonizing" with the needs in the production. The volume factor indicates the volume of goods delivered for the last period compared to the previous period. Another factor, also not shown in figure 104, displays the actual delivered volume compared to the forecasted volume four weeks earlier. The first plan quality indicator shows number of changes done in the production plan the last four weeks. The second factor shows the difference between the highest and lowest planned volumes for the current week that has occurred in the plans over the last twenty weeks.

[63] Figure 101 is a screen-shot from WinCC (a MES/SCADA system) at RCT

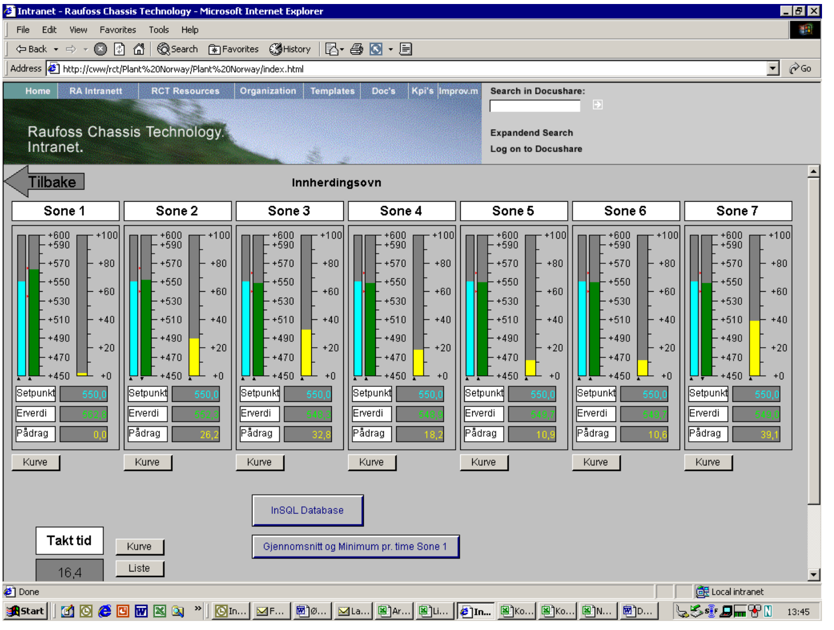

Figure 102 The heating oven activity[64]

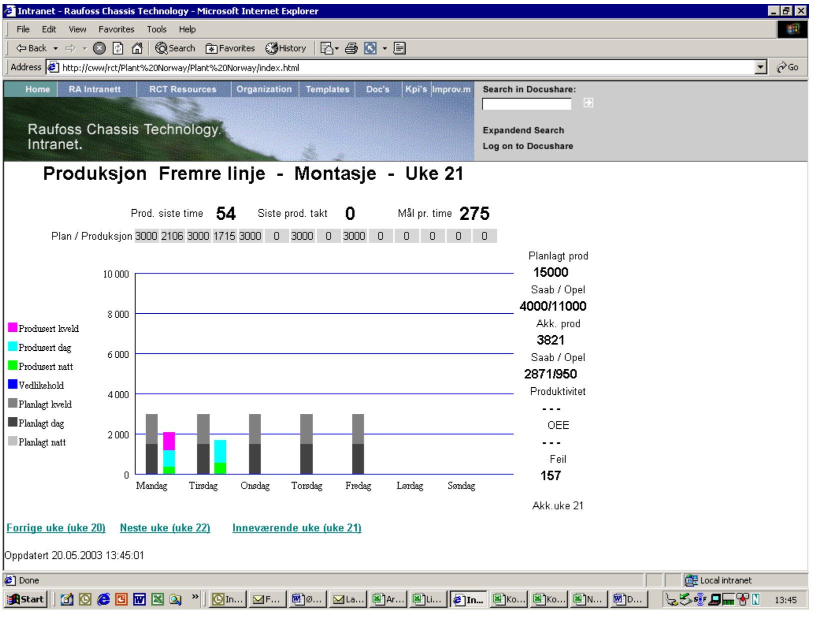

Figure 103 Production data and plans for front control arm[65]

[64] Figure 102 is a screen-shot from WinCC (a MES/SCADA system) at RCT
[65] The screen-shot in figure 103 was developed at RCT, by RCT, RTIM and ErgoRunit

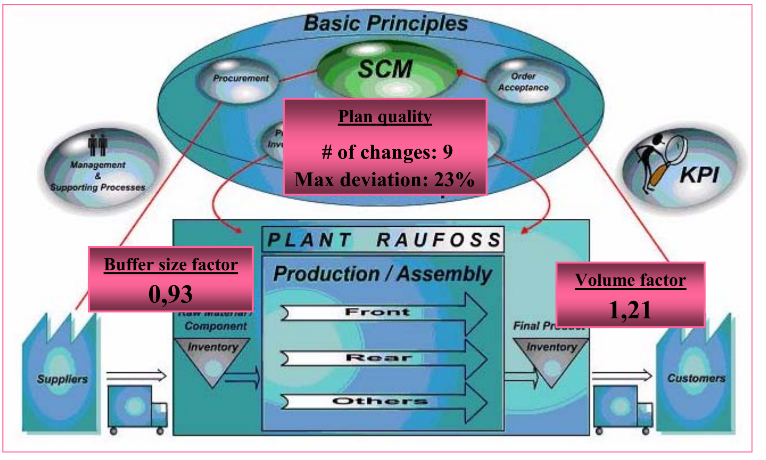

Figure 104 A conceptual sketch of the value chain Dashboard

7.5 Reflections

The collaboration between RCT and SINTEF/NTNU were quite extensive in the years between 1998-2004. Since the Neuman Aluminum acquisition, the collaboration has been limited or even non-existing. The candidate's involvement at RCT ended in 2003. Thus, the last five years are not included in this case description, and the current situation of the results and solutions presented in this chapter is uncertain.

The fruitful collaboration (1998-2004) generated many ideas, concepts, solutions, and tools. Some of these resulted in specific implemented tools and solutions at RCT. Others remained as ideas or tools on a conceptual level. However, common for all these ideas, concepts, tools and solutions are that they have been further processed and developed in this dissertation.

The Dashboard solution developed at RCT is fare apart from the EE Dashboard presented in chapter 6.5. The logic of the RCT Dashboard is incorporated into the EE Operations Model, as process and activity visualization and monitoring. The EE Dashboard focuses more on graphical visualization of KPIs (including alerts, reports, and analysis), and has much more resemblance with traditional dashboard solutions (e.g. speedometer, traffic lights symbols, etc) than the RCT Dashboard.

The collaboration was team-based, some times lead by SINTEF/NTNU and other times lead by RCT. This makes it difficult to quantify *who made what* and delegate the necessary respect and credit among the participating organizations and people. However, the candidate can claim to be the main responsible of the RCT Process Model, and one of the main contributors to the conceptual version of the RCT Operations Model (whereas the final version of the Intranet (i.e. the Operations Model and the Dashboard) was developed by RCT, RTIM and ErgoRunit based on the conceptual version).

7.6 References

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Monden, Y., 1998, Toyota Production System: An integrated approach to Just-In-Time, Engineering and Management Press, Norcross, Georgia

Chapter 8

Testing the Operations Model at HAST

8 Testing the Operations Model at HAST

Chapter 8 will introduce and present the minor, test, case in this dissertation, the testing of the Operations Model at Hydro Automotive Structure. The chapter seeks to give a short introduction to the context of the case, a thorough presentation of the case company, to highlight some important challenges and key results from the research, and finally make some reflections.

8.1 Introduction

In 2004 HAST agreed to test the MOMENT methodology, or more correctly some of the tools included in the MOMENT methodology. Work-package 6 in the MOMENT project required that the developed methodology should be tested and implemented in a second automotive case, where RCT was the first case. Hence a joint project between HAST and SINTEF were established in August 2004 (hereafter referred to as the HAST project), co-funded by the MOMENT project and the P2005-PLOG project, and with the candidate as project manager.

The aim of this project was two-folded: On one hand to test the MOMENT methodology, with a few selected tools, and on the other hand to seek to improve HAST production and logistics solutions. A key element was to use the EE Process Model to visualize the material and information flow through HAST's value chain.

The mapping and findings done in this project is presented in this dissertation as the ***HAST case*** in this chapter. The HAST case is a minor case compared to the RCT case, and the sole purpose (in regard of this dissertation) was to test (and validate) the various tools in the EE Operations Model Toolset, with a particular focus on the EE Process Model.

8.2 HAST and the Extended Enterprise

HAST is the global leader in ***crash management*** systems in aluminum and develops and manufactures bumper beams for almost all major OEMs.

HAST´s manufacturing plants, dedicated to crash management, are located in Raufoss (Norway), Louviers (France), Skultuna (Sweden) and Holland (MI, USA). The competence centre for crash management is also located in Raufoss. The case description will focus on the plants in Raufoss (in the same industrial park as RCT), and these will hereafter be referred to as HARA.

In 2002, HAST delivered over 6.6 million bumper beams as single parts or as part of a crash management system to their customers worldwide, the majority of them to Western Europe. Their customers are prestige carmakers such as BMW, Daimler Chrysler, Audi, Porsche, SAAB, Opel, Volvo, Renault and Nissan.

8.2.1 History

In 1996 Norsk Hydro ASA (hereafter referred to as Hydro) acquired Raufoss Automotive from Raufoss ASA. Raufoss ASA is the same company which owned RCT until 1st July 2004.

Hydro is a Fortune Global 500 supplier of aluminum and aluminum products. Based in Norway, the company employs 23,000 people in 40 countries and has activities on all continents. The roots of Hydro can be tracked back to 2nd December 1905, when Hydro was established as a fertilizer manufacturer.

Today HAST is organized as a part of the Aluminum Products, Automotive, division.

8.2.2 Product characteristics

HAST produce bumper beams and accompanying components, i.e. crash management, in aluminum for almost all major OEMs. Figure 105 illustrates two such cash management system.

Figure 105 Crash management products

Source: Hydro (2008)

The upper part of figure 105 is a crash management system (basically a bumper beam and crash box assembled together), whereas the lower part of figure 105 illustrates just a bumper beam. These two products and their properties and functionalities can be described as (Hydro, 2008):

- Crash boxes are easily replaceable low-cost units that prevent damage to the car body/chassis structure in medium-speed impacts, hence reducing repair and insurance costs
- The main functions of bumpers are to reduce the damage to exterior components in low-speed impacts, to keep the front structure together in high-speed impacts and to provide stiffness to ensure comfort (NVH), ride and handling under operating conditions
- In a severe frontal impact, optimum crash performance presumes that the beam and boxes provide the function of transferring the impact load into and between the longitudinal and thence into the rest of the structures, such as A-and B pillars, sill and roof structure

A more thorough and systematic illustration of the manufacturing of bumper beam and crash boxes are given in figure 106. Figure 106 may be viewed as a value chain perspective of the products, illustrating the various stages in the manufacturing process.

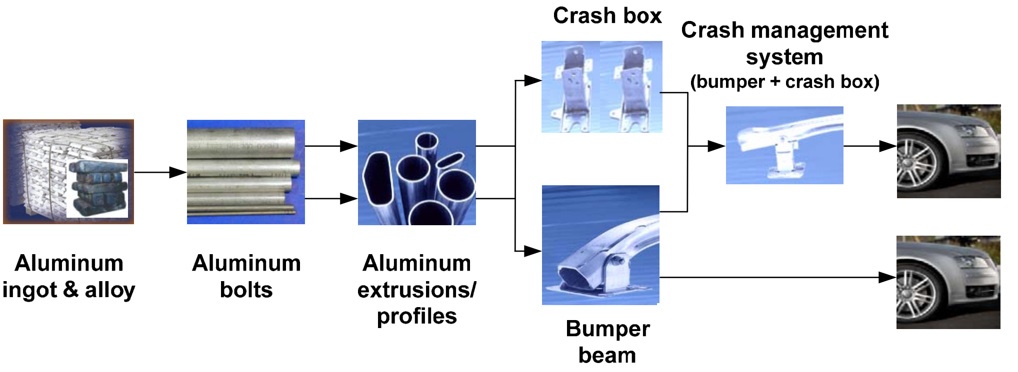

Figure 106 Product value chain[66]

8.2.3 The value chain – the HAST Extended Enterprise

Hydro controls the whole value chain from billet casting over extrusion to forming, machining and assembly (Hydro, 2008). Figure 107 illustrates a very simple value chain, where the range of Hydro, HAST and HARA are indicated. Figure 107 is very similar to figure 106, with the difference that figure 106 focuses on the components and products, whereas figure 107 focuses on the manufacturing processes and companies.

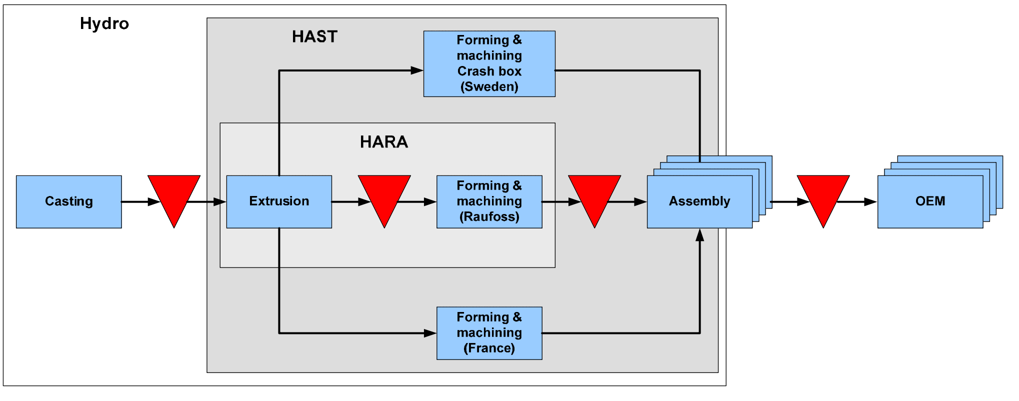

Figure 107 Hydro, HAST and HARA in the value chain

The span of Hydro and HAST is partial to include the assembly process, indicating that HAST does assembly (own assembly plants) for some OEMs, whereas for other OEMs they supply directly to the OEMs without assembly, to 1st tier OEMs suppliers, or to 3rd party suppliers.

As with RCT, the value chain is more complex than it appears at first sight. Figure 108 illustrates a more complex and true version of the crash management value chain. The focus for the HAST case is the two HARA plants, called HARA-N and HARA-S. N and S indicated the geographically location of the factories, where HARA-N is north and HARA-S is south. HARA-N is the extrusion factory, whereas HARA-S is the forming and machining factory, i.e. the bumper factory.

[66] Figure 8.2 is modified from a figure made by Torbjørn Netland (SINTEF) in the Crash project (see chapter 8.5). However the figure is not published and it is therefore not possible to reference in a traditional manner.

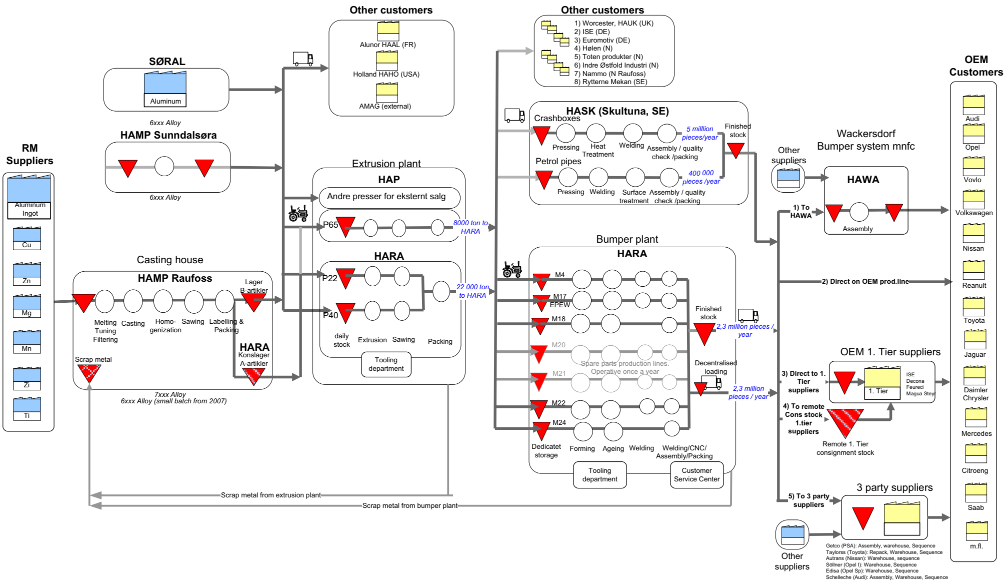

Figure 108 The HAST Extended Enterprise[67]

The HAST case is further narrowed down to look at the products produced at press M 24 in the bumper factory (HARA-S) and how these products flow throughout the value chain. HARA provide crash management to 29 different car manufactures, where M24 supply 8 products to four different car manufacturers. This is illustrated in figure 109.

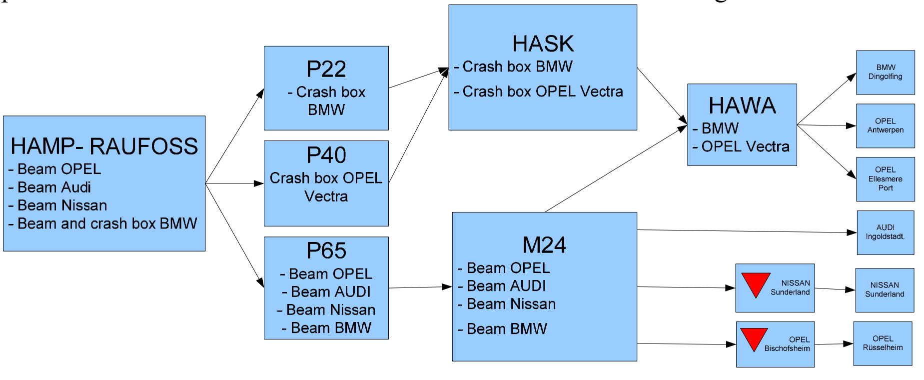

Figure 109 The M24 value chain

8.2.4 The manufacturing system

The degree of automation is high both at HARA-N and HARA-S, with machinery of very high standards. The products are produced at dedicated lines with customized tools, both at HARA – N and HARA – S.

HARA-N, the extrusion factory, has three extrusion lines producing aluminum profiles. The three line names are respectively P22, P40 and P65. All the three lines have basically the same types of machineries and functionalities. The distinctions between the three lines are the

[67] Figure 8.4 is modified from a figure made by Torbjørn Netland (SINTEF) in the Crash project (see chapter 8.5). However the figure is not published and it is therefore not possible to reference in a traditional manner.

power and thereby the ability to handle different products (e.g. different dimension of profiles). The P65 is the strongest and newest machinery and is best suited to handle aluminum in large dimensions and lengths.

These extrusion lines supply profiles to both HARA-S and other destinations and actors in the Hydro Group, like Crash boxes to Hydro Automotive, Skultuna (HASK) in Sweden and Hydro Automotive, Louivere (HAAL) in France. However, the bumper factory (HARA-S) is the biggest and most important customer for HARA-N, with roughly 80 % of the profile volumes.

The manufacturing processes at HARA-N are quite simple regarding process steps, but advanced regarding technology and competence. The first two processes are loading and up-heating of the bolts, followed by the extrusion process, and heat treatment of the profiles. The processes are in a continuous loop and also relatively in the same tact, so for example when the first product is machined in the extrusion process, the second one is pre heated and so on. At the end, there is a joint package zone where all the profiles are being palletized before loading on tractors outside the building.

HARA-S, the bumper factory, has six forming lines (including the M24). In total, HARA-S produces 102 different products, where M24 only make 8 of these. This implies that M24 have relatively few products assigned compared to all other lines. However, the level of the total production is however of high (19%).

The M24 line is the most modern and automated of the six forming lines. The line has automatic tool change and the products are going continuous in the U-form line without any reloading or manual operations.

The manufacturing process at HARA-S is a little more extensive than the manufacturing process at HARA-N, and at least as advanced. The manufacturing processes at the M24 line is: Loading, device, sawing, heat treatment, forming, sizing, washing, stacking, and hardening at last. The hardening process is the only process not included in the automatic U-formed line.

Near 50 percent of the finalized beams are loaded immediately at trucks and delivered OEMs, while the other part are first transported to a local inventory point inside the Raufoss Industry Park.

The material flow, some important processes and the geographically layout of the two HARA factories are outlined in figure 110.

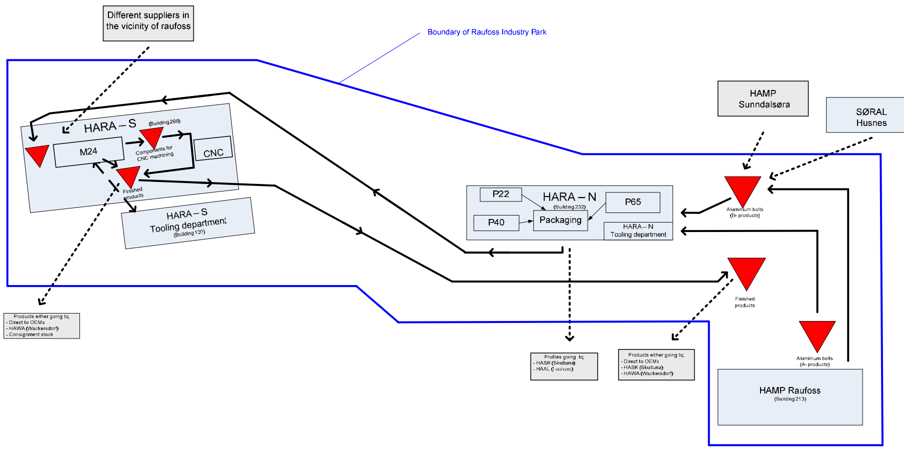

Figure 110 Material flow at HARA

8.2.5 Supply chain management and control

The “push- principle” or MRP is the major control principle used at HARA. Since there are some weaknesses with the predicted data acquisitions, HARA also controls their production after the level of the inventory at different stages in the value chain in order to provide sufficient crash managements to the OEMs.

Production planning at HARA is mainly divided into three levels:

- ***Long term planning*** (more than 6 months) - the predicted sales volumes from every OEMs taken into consideration. Based on the predicted volume from all the OEMs, the resource capacities are broken down to decide the structure for where the products should be produced amongst the available machinery. The yearly plan is broken down to ton pr press line for the extrusion lines and beams pr lines for the forming lines.
- ***Middle term planning*** (from 5 weeks to 6 months) - evaluate the progress and corrections if necessary. The most normal handling will either be to increase or decrease the number of shift pr production line in this medium length of planning horizon.
- ***Short term planning*** (4 weeks or less) - The data received from the customer are every day put into two systems, their own “deliver plan system” and the ERP- system. They are then checking if any inventory transactions have been done in any of their finished stock or consignment stocks. Then they do a MRP calculation for the whole current period, approximately one year in week periods. Every Monday there are re-planning with a four weeks horizon, where the two first weeks are frozen. They are then using the suggestion from the Oracle- system, but move it to an Excel sheet and doing some adjustment so the number of tools and batch size are more suitable for the bumper lines.

A schematic sketch of the planning and control process at HARA is given in figure 111.

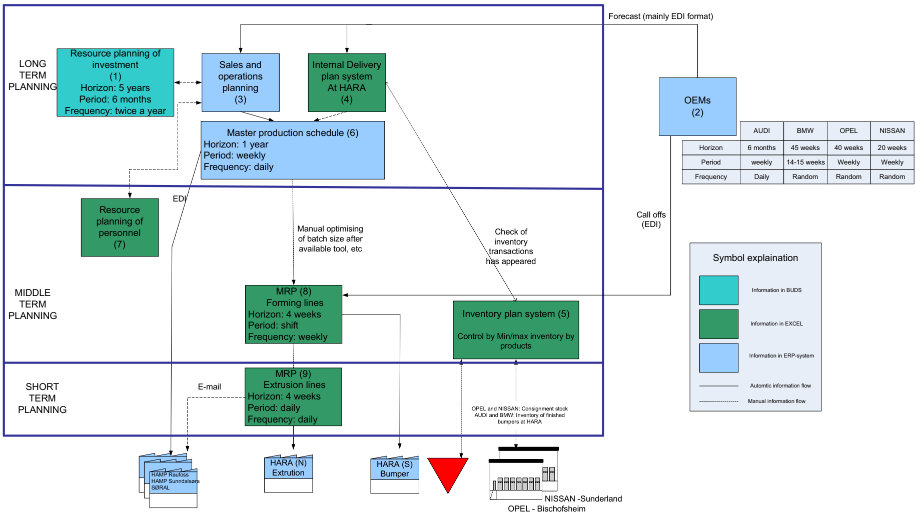

Figure 111 Planning and control at HARA

8.2.6 Information and Communication Technology systems

HARA has a set of IT- systems to serve the different needs in their operations, as illustrated in figure 112. All these IT-systems are in one or another way connected.

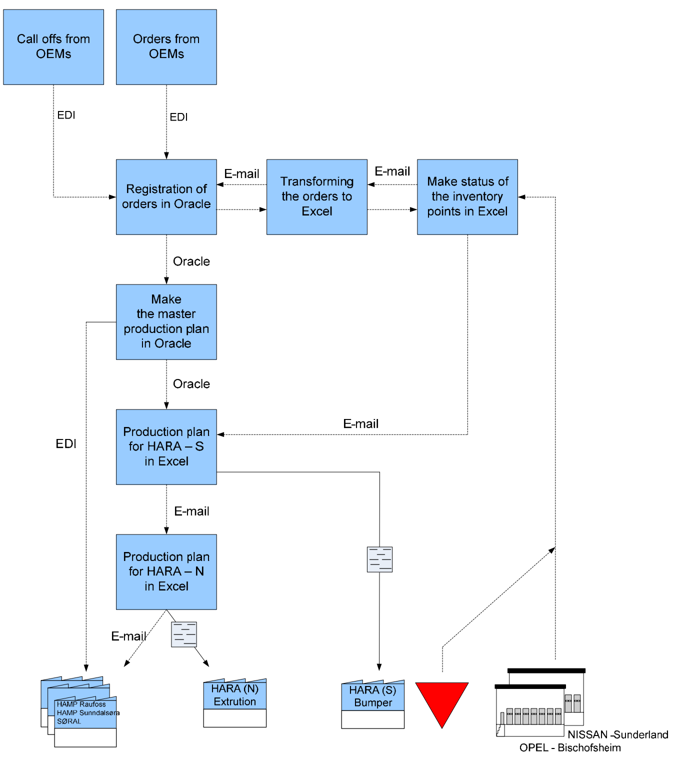

Figure 112 ICT system and information -flow at HARA

8.2.7 Performance measurement

KPI measurements are today widely used at HARA to control and evaluate production at each plant and for the group as a whole. KPI are distributed down through the hierarchy to each plant. Some KPI`s are decided from the top management, while some are decided local for each plant. Targets are set for each measurement and measured each month and presented as YTD (Year to date). The HAST in Europe is measured towards these KPI´s, see table 34.

Hydro Automotive Structures, North Europe				
DESCRIPTION OF KPIs	Target 2005	Est. 2004	YTD 2004	Actual 2003
1. TRI	5,0	6,0	6,2	6,1
2. OEE Crash Box Lines HASK	71,0 %	66,0 %	65,0 %	58,0 %
3. Cost per.man hour worked at HAWA (EUR)	55,55	67,31	n.a	n.a.
4. Cost reduction Tools	15,0 %	20,0 %	12,0 %	n.a.
5. Productivity Extrusion Lines (kg/h)	1800	1740	1726	1616
6. OEE Bumper Lines HARA	73,0 %	69,0 %	68,8 %	n.a.
7. Order intake (mill MNOK)	210	180	120	n.a.
8. Cost of poor quality (% of NAV)	2,6 %	3,1%	3,1 %	n.a.
9. Net Operating Capital Days	74	n.a.	n.a	n.a.
10. Cost reduction (1000 NOK)	21 450	22 000	19 595	n.a.

Table 34 The KPI decided from the top management

Each plant then develops their own measurements to complement their lists and to improve their own results based on their focus area. Table 35 lists the KPIs for HARA-N.

Extrusion plant (HARA N)	**Target 2004**	**YTD (July)**
TRI[68]	7,0	10,5
Sickness absence	5,9	9,9
Lye consumption (liters/ton)	16,0	21,9
OTD External customer (%)	93,0	92,8
Level prod. des 04 (Kg/h)	1915	1726
Inventory of bolt (ton)	825	527
PPM	1000	1371
Cost pr.kg. (NOK/kg)	6,20	6,82

Table 35 KPIs for the extrusion plant

Table 36 shows the equivalent list for HARA – S.

Bumper plant (HARA S)	**Target 2004**	**YTD (July)**
TRI	8,0	6,3
Sickness absence	7,5 %	6,4 %
Oil consumption pr. bumper (liter)	0,070	0,039
On Time Delivery	96	99
Up-time	75	79,8
Inventory of profiles	115' stk	138
Inventory of bumpers	130' stk	232

[68] No of lost time injuries + restricted work cases + medical treatment cases divided by hours worked by site employees, multiplied with one million (measure is on 12 months rolling basis)

Wreckages	4200´/mill	1776
PPM	550	149
Costs pr.pieces	62	55

Table 36 KPIs for the bumper plant

Some characteristics from these KPIs are that all of them are trigging some human factors, such as TRI and sickness absence. Other factors Hydro also taken into account is productivity, inventory level, quality and cost aspect. From the KPI list we can see that HARA has [uptime] at the bumper plant and [kg/hour] at the extrusion plant.

8.3 Challenges

RCT and HAST are very similar in many ways; both are located at Raufoss, Norway, both are something in-between a 1st and 2nd supplier to the automotive industry, and both produce advanced aluminum products. Hence HAST faces most of the challenges outlined in the RCT case (see chapter 7.3). There are however some important and partial particular challenges for HAST worth mentioning.

8.3.1 Market requirements

The automotive industry is probably one of the most demanding industries and sets high requirements regarding time, cost and quality etc. for their suppliers. The HAST project identified six key market requirements that imposes challenges for HAST:

- ***Reduction in sales volume*** - HAST is facing a reduction in sales volume, and not an increase. This is based on the signed long-term contracts with the OEMs and the predictions for the future.
- ***High importance of cost*** - high labor cost in Norway along with the cost of using aluminum instead of steel is a considerable challenge for HAST. This is due to the low cost focus in the automotive industry, which among others is reflected in the yearly price reduction included in every contract.
- ***Quick response time*** – HAST has long-term contracts with the OEMs, where the orders between the OEMs and HAST are executed through forecasts and call-offs. In many cases there is a mismatch between the forecast and the daily call-offs, and this require quick response time in order to handle the variations in customer demand.
- ***On-time delivery*** - there is a strict requirement to deliver bumpers to the OEMs precisely, and high fees occur if deliveries are delayed. This is due to the OEM manufacturers need to coordinate all their incoming components and parts to the assembly line.
- ***Low tolerance for defects*** – the OEMs have strict requirements regarding quality. The failure (parts pr million (PPM)) is regulated by contract. The number various from OEM to OEM, but around 10-50 parts pr million are normally the maximum failure rate pr million delivered parts. If the supplier fails to follow the PPM high fees will occur.
- ***Power squeeze*** – HAST is experiencing a power squeeze in the value chain. HAST is totally dependent of the raw-material suppliers, which based on the power status can almost do whatever they want; and this may be contradictory to HAST demands and requirements. Likewise, the OEMs possess the ultimate power in the automotive value chain, and may consequently dictate HAST in almost every aspect.

8.3.2 Internal challenges

The OEMs are giving more and more responsibility to the suppliers with high requirements regarding on-time delivery, quality and the inventory costs. From this follows that HAST needs to continue their focus on creating stable processes and develop a production system for handling the fluctuations in the demand and at the same time utilize high value of the capacity of the machinery. Further, to ensure on-time delivery without building large inventories, collaboration between the extrusion and the bumper plant is crucial. Integrated planning and increased visibility in the value chain are areas for further improvements.

The most crucial challenges in terms of production and logistics can be summarized as:

- ***Reduce inventory levels along the whole value chain*** - HAST has a high achievement level regarding delivery performance and on-time delivery. However, this achievement comes at the cost of high (unnecessary) inventory levels. The reason behind this is that HAST has long-term contracts with the OEMs, which implies that the risks of products being obsolescence is minimal. Unnecessary inventories are however associated with increasing cost, and the result is lower competitive strength in an increasingly fierce market.
- ***Improved control of the production processes*** - stable production processes are crucial in reducing inventory levels, of both final and intermediate stocks. Hence, HAST needs to focus on continuous improvement of the production processes.
- ***Improved coordination and collaboration between actors in the value chain*** - the strict demands regarding delivery precision require close value chain integration and information visibility in order to coordinate the value chain operations. HAST is in a unique position, where most of the value chain is controlled and owned by its parent company (Hydro). The ownership should simplify and foster value chain integration and collaboration. Further, as the number of customers increase and their geographic location change, the ability to coordinate and collaborate will be tested even more.
- ***New principles for production control*** – the automotive value chain is well on its way on being transformed from push to pull; with daily updates in the production plans from the manufacturer. This causes new challenges in the value chain and for HAST.

8.3.3 HAST initiatives

HAST has initialized several initiatives to overcome the challenges listed above. These initiatives may be regarded as internal projects, focusing on improving HAST competitive situation. Of these initiatives, the move towards lean production, implementing a new ERP system and closer integration with the customer, is perhaps of most significant value.

In order to meet the challenges and demands in the market, HAST has developed their own customized Hydro Automotive Production System (HAPS) based on the Toyota Production System. HAPS is a conceptual framework and contains methods that make it possible for HAST to do necessary and continuous improvements. HAPS is meant to help HAST reach a higher level of quality and competence within their own production and in their collaboration with suppliers and customers.

Hydro has decided to implement a common ERP- system for the whole enterprise. They have chosen mySAP.com, with finalizations of implementation during the first quarter of 2005 at the HARA factories. The change Oracle Application to SAP is a strategically important alteration for the company. Both the extrusion (HARA-N) and the bumper plant (HARA-S) will together with the plants in Sweden (HASK) and Germany (HAWA) now be administrated in the same ERP- system.

HAST is tending to become an assembly manufacturer, and thus achieve a closer integration with its customers. In order to coordinate the different components from Raufoss (HARA) and Sweden (HASK) to the assembly line in Germany, and to mange to deliver on time to the production line to BMW, HAST has established a consignment stock. In the future it may be other OEMs that require such solutions.

8.4 Project results and solutions

The HAST project was a relatively short project (4 months duration), with limited funding, and delimited engagement into the HAST organization. Thus, few solutions were developed. However, some important findings were identified, together with the testing of the EE Process Model, and recommendation for a new set of KPIs.

The key findings from the project can be summarized as followed:

- HAST operates with ***high inventory levels*** throughout the value chain.
- ***Up-time*** on the manufacturing processes is regarded as more important that producing accordingly to real customer demands.
- There is a ***low degree of value chain integration***, also within HAST. Which among others give expression in a limited co-planning/visualization between the actors in the value chain.
- Both the HARA-N and the HARA-S is about to ***reach is maximum capacity***.

Based on mapping and the finding above, SINTEF recommended that HAST should do the following:

- ***Standardization in tooling equipment*** - this would increase the flexibility and responsiveness of the manufacturing processes at both HARA-N and HARA-S.
- ***Reduction in aluminum alloys variants*** – this will simplify the supply of aluminum, reduce inventory levels, improve inbound delivery precision, and also minimize the internal handling efforts.
- ***Integration of production planning and control*** – HAST operates with long-term production plans, with no links to the actual situation on the shop-floor. Unexpected events may and often do occur, and with no adjustment to the plans, the plans become more as guidance than a plan to follow. Hence, HAST needs to develop a system that incorporate these short-term changes, and not at least exchange information about these events along the value chain. Further, HAST needs to adopt ICT tools supporting the operations (e.g. Dashboards, and visibility systems).
- ***Holistic KPIs*** - see chapter 8.4.3 for more information.

These four identified areas were recommendations from SINTEF, and did not result in any immediate implementation at HAST.

8.4.2 The HAST Process Model

As with the RCT case, the HAST Process Model is basically the generic EE Process Model presented in chapter 6.3, applied to HAST to develop a particular process model for HAST.

The intention for developing the HAST Process Model was three-fold:

- First, and most important, to test and validate the EE Process Model on a second case in the automotive industry.
- Second, to support the enterprise mapping done in the HAST project.
- Third, to enhance visualization of processes and operations in the value chain, and with that enable a more holistic approach to manufacturing and logistics at HAST.

As with the RCT case, the range of use and the power of EE Process Model are best utilized as a big poster on the wall, on the computer screen and/or as a computerized visualization done by projector. In a hierarchical structured document the flexibility, depth, richness, complexity and dynamic nature of the model are lost. Hence, only a detailed version of the HAST Process Model, in a value chain context, are illustrated in figure 113.

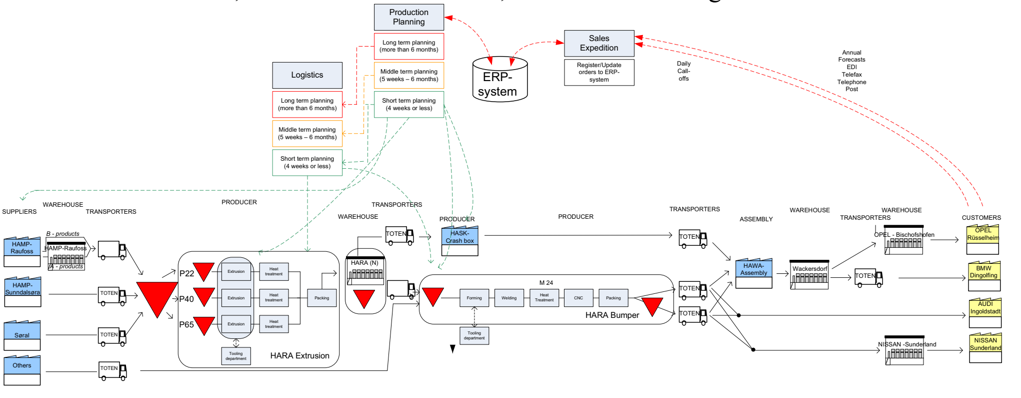

Figure 113 The HAST Process Model

8.4.3 The HAST KPIs

HAST operates with KPIs such as up-time, production level (amount), and delivery precision out. All these give incentives to produce large series and maintain high inventories. A key finding in the HAST project was that there were few holistic KPIs regarding manufacturing and logistic performance in the value chain, and KPIs regarding real demand. There are for example no KPIs related to *throughput time*, *turnover of inventories*, and *measurements of inventory of product level*.

Based on this SINTEF, recommended a Dashboard solution with a set of new KPIs for use in the operations. The new KPIs are listed in table 37.

Actors	KPIs		
Suppliers	Delivery precision	Quality	Quantity (delivered/ordered)
HARA	Delivery precision	Quality	Quantity (delivered/ordered)
	Productivity	Costs	Throughput time
	Inbound inventory level	Intermediate inventory level	Outbound inventory level
Warehouses	Delivery precision	Quality	Quantity (delivered/ordered)
	Productivity	Inventory level	

Table 37 Recommendation for new KPIs at HAST

8.5 Reflections

The HAST case is a minor case in this dissertation, where few ideas, concepts, tools and solutions have been developed, implemented and/or tested. The case is however important, because it facilitated testing and validating of the EE Process Model, the major contribution in this thesis.

Another benefit from the HAST case is the indirect verification for the rationale and objectives for developing the EE Operation Model Toolset. HAST faces almost the same challenges as RCT, and during the HAST project it became apparent that the EE Operations

Model Toolset could have been beneficial for HAST. HAST struggles with low degree of value chain integration, inadequate information sharing, sub-optimizing of processes, ineffective planning and control system, high inventories, insufficient KPIs, low degree of visualization, and absence of a system for handling/manage events and/or exceptions. By implementing the EE Operations Model Toolset, HAST can overcome many of these problems.

So, why did not HAST implement the EE Operations Model Toolset? First, the EE Operations Model Toolset was not, and is still not, a turn-key system. An implantation requires dedication of resources for some time. Second, The HAST project was limited to four months, and the candidate's involvement with the company ended after this period. Third, the HAST organization were under tremendous stress in this period, mainly because of the new ERP implementation. Fourth, HAST is a part of a huge organization (i.e. Hydro), and this made it more complex to get sufficient involvement from HAST into the EE Operations Model Toolset.

However, the HAST project initiated a closer collaboration between HAST and SINTEF. This collaboration resulted in the CRASH project (2006-2009): ***Integrated, differential, and lean value chain for aluminium products to the automotive industry***. Some of the findings highlighted in this case description is decisive in the CRASH project, and the EE Operations Model Toolset is partial represented in the objectives for the project.

8.6 References

Hydro, 2008, Automotive Products: Front/rear, Retrieved: 23. October 2008, http://www.hydro.com/en/Our-business/Aluminium/Products/Automotive-and-transport/Automotive-products/Front-and-rear/

PART V

Conclusion

The main objective of ***Part V*** *is* ***to sum up the study*** *and* ***conclude the discussion of the thesis****.*

Chapter 9 *will conclude and discuss the work presented in this thesis. A recapitulation of the starting point for this study will be given, with focus on assessing how the objectives of the thesis are met, and assessing the applicability and quality of this work. The central finings of the study will be highlighted, together with some suggestions for further research.*

Part V

Chapter 9

Conclusion

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9 Conclusion

Chapter 9 will conclude and discuss the work presented in this thesis. A recapitulation of the starting point for this study will be given, with focus on assessing how the objectives of the thesis are met, and assessing the applicability and quality of this work. The central finings of the study will also be highlighted, together with some suggestions for further research.

9.1 The research story line

The research process of this thesis has not been streamlined and easy going. An in-depth discussion of this research processes, with its various phases and elements are fully presented and discussed in chapter 1. Figure 114 illustrates a simplified version of the key elements and phases in the thesis.

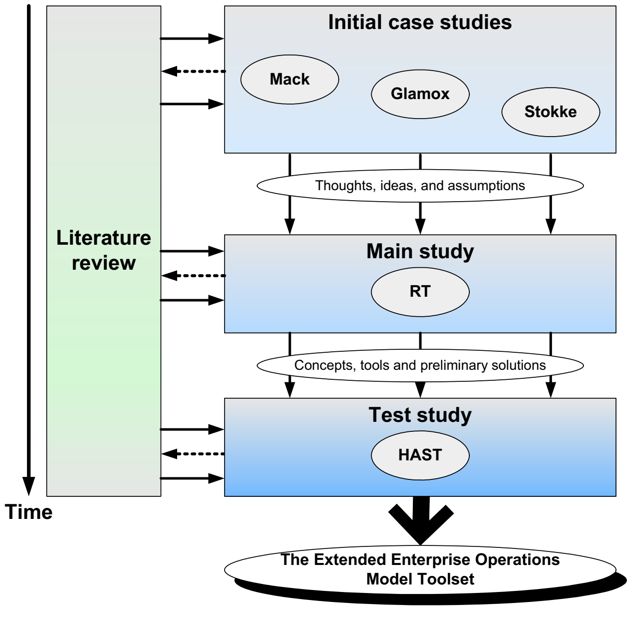

Figure 114 Key elements and phases in the thesis

For further information regarding the various stages and cases, see chapter 1 and Appendix B.

9.1.1 Key issues

The major concern of this research has been *Extended Enterprises* and the *management of (manufacturing and logistics) operations along the value chain*. The rationale has been to investigate how ICT can enable and support value chain systems and operations. The main focus has been on how Extended Enterprises can improve their operational excellence and competitiveness through the adoption and use of the *information visibility* and *visualization* concepts:

- ***Information visibility*** – is the ability to "see" (i.e. access) all relevant information, on-line and in real time, in order to manage the flow of products, services and information in an efficient and responsive manner throughout the value chain. This is achieved through a seamless flow of accurate and timely information (e.g. customer demand information and other operational, tactical and strategically information influencing the operations) within and between companies in the value chain.

- o ***Information visualization*** – is the use of computer-supported, interactive, visual representations (i.e. models) of abstract and complex data and information to enable and amplify cognition and rapid and action-oriented understanding.

The concept of information visibility and visualization are joined together in a toolset, called the ***Extended Enterprise Operations Model Toolset***. The basic logic of combining these two concepts is obvious: Information visibility will provide access to all relevant information in the Extended Enterprise, whereas information visualization will support communication, monitoring, analysis, and decision making on the basis of this information.

The objective of the Extended Enterprise Operations Model Toolset is to provide a powerful set of tools as decision support for planning and control of operations in the Extended Enterprise. The tools have been developed with a particularly focus on the manufacturing and logistics processes in the Extended Enterprise, and the aim has been to develop tools and concepts supporting the development and operation of integrated, global and responsive value chains.

9.1.2 Point of departure

The thesis started with a discussion of the current business environment, where 5 important ***business drivers*** (Globalization, ICT, Time, Cost and Customization) and six major ***business responses*** (develop global integrated value chain systems, from function to process, exploiting the opportunities offered by ICT, rethinking planning and control of operations, from product to solution, and focus on innovation and R&D) to these and others business drivers were highlighted. The thesis addresses the four first business responses.

9.1.3 Research problems

Based on the business drivers and responses, the experience gained in the initial three case studies (see figure 114), the assumptions made, and a brief review of the research area, the thesis identified a gap between the actual reality and how things should have been. These gaps were then further translated into a research problem and sub-problems:

- o The lack of formalization in the Extended Enterprise concept, and the almost total absence of tools and methods supporting the management, particular in planning and control, of operations in the Extended Enterprise.
  - There is lack of a uniform view of the Extended Enterprise
  - There is a lack of holistic thinking regarding operations in the Extended Enterprise
  - There is a lack of “true” Extended Enterprise ICT systems.
  - There is a lack of proactive principles, methods and tools for planning and control of operations in the Extended Enterprise.
  - There is a lack of easy, non ambiguous, simple and uniform modeling techniques and construct for modeling operations in the Extended Enterprise.

The research in this thesis is focused on how the gap between the ideas, visions and expectations of the Extended Enterprise (as outlined in chapter 2 and 3) on one hand, and the more grim reality in today business environment on the other hand (the “lacks” outline above), can be more aligned.

9.1.4 Research objectives

This research aims to address the challenge in the business environment and the stated research problems. The overall objective of this research is:

- To establish a toolset (or requirement for a toolset) for information visibility and visualization in the Extended Enterprise, as decision support for planning, control and monitoring of operations in the Extended Enterprise, with a particularly focus on manufacturing and logistics processes.

The overall research objective can be divided into more specific objectives:
- The research should create a common understanding of the term/concept Extended Enterprise, and contribute in the scientific development of the Extended Enterprise concept.
- The research should develop a concept for information visibility in the Extended Enterprise.
- The research should develop a concept for information visualization of operations, and than particular of processes, in the Extended Enterprise.
- The research should explore the usage of ICT in the Extended Enterprise, and ultimately how ICT can support planning, control and monitoring of manufacturing and logistics operations in the Extended Enterprise.

The research aims to unite the concepts of information visibility and visualization in order to create a powerful toolset for decision support in the Extended Enterprise. The primary objective is to provide new support solutions and/or concepts for planning, control and monitoring of manufacturing and logistics operations in the Extended Enterprise. These solutions and/or concepts should support companies in their tactical and operational decision making.

The combination of information visualization and visibility is on one hand meant to provide simple, intuitive and non-ambiguous models that structure, transform, condense, and visually display the complex structure, operations and events of the Extended Enterprise, and on the other hand to provide the models with all the necessary and updated (real-time and on-line) information regarding the operation in the Extended Enterprise.

The ambition is that this combination of information visibility and visualization into a toolset can enable companies to quickly grasp a situation, even before it happens, and act appropriately in order to avoid or minimize the consequences of the situation.

9.1.5 Research limitations

The delimitations in this thesis are mainly due to three factors: *Time*, *money* and the researcher's *competence*. Due to these three factors it has not been possible to investigate end elaborate every aspect in the thesis. Most of the relevant delimitations are specified in chapter 1.3.5 *research scope*.

The limitations in the thesis are mainly due to the chosen *research approach*:
- Firstly, the chosen research approach has been ***action research with a single case.*** Secondly, in an action research approach the researcher has ***minimal, if any, control of the environment***.
- Thirdly, the researcher role in an action research approach is ***participatory observations***.
- Fourthly, most of the research has been as ***part of a team***, and it can therefore sometimes be hard to identify the author's contribution.
- Finally, due to the ***delimitations*** (time, money and competence) ***not all concepts, tools and methods are fully developed***.

The research delimitations and limitations are fully described in chapter 1.7.

9.1.6 Research approach

The research approach in this thesis can very short be described as a qualitative research with a combination of literature review, case studies, and action research. Figure 114 outlines to some extent the research process in this thesis, and table 38 summarizes the main elements in the chosen research approach.

Design element	Chosen design
The purpose of the study	The purpose of the PhD dissertation is mainly ***descriptive***; i.e. it tires to discover answers to the questions who, what, when, where and, how.
The power of the researcher to influence the variables under study	The research can be characterized as ***ex post facto***, as most of the research has been conducted within several independent companies where the researcher has minimal, if any, control of the circumstances. Further, some of the research has also been retrospective (e.g. case studies), meaning studying phenomenons that already have happened.
The time dimension	The research can be characterized as a ***cross-sectional study***, where the research has been carried out once and not repeated in the same context. The results of the first study are however tested in a second study within similar conditions. This test is also only conducted once.
The research environment	The research is conducted under actual conditions in a ***field setting***. Initial field studies where conducted at Mack and Stokke (see appendix B), and the main research has been conducted at field studies at RCT and HAST (see chapter 7 and 8).
The research method	The research approach in the dissertation has been **qualitative** with ***a combination of literature review, case study, and action research***
	Literature review: A continual literature review has supported all research activities through out the whole PhD period. See among section II (chapter 2, 3 and 4) for literature review; also chapter 1, 5 and 6. The literature review has used both primary and secondary sources (using all listed sources in chapter 2.6.4). In addition the Internet has frequently been used as a source, primarily for obtaining information from international organizations like the UN, World Bank, IMF, WTO, etc.
	Case study: Throughout the first three years of the PhD three different case studies were conducted (see appendix B for more information regarding these case studies). These case studies help generate knowledge and formulate research challenge and objectives.
	Action research: The majority of research conducted within this PhD has been an action research with a case at Raufoss Chassis Technology (RCT) (see chapter 7 for more information). In addition, the major result from the case at RCT has been tested through an action research case at HAST (see chapter 8).
The method of data collection	The data collection method in the dissertation has been ***a combination of observation, interviews, and archival sources***
	Observations: The observation has been direct and not at least participant observation, where the researcher has been a part of the social setting and has acted as both an observer and participant.
	Interviews: Several key persons in the different companies included in the research have been interviewed (using a semi-structured interview approach) about past, current and future aspects.
	Archival sources: When needed, archival sources has been used to support the collection of data from the observation and interviews. Examples of such archival sources are annual reports, other company internal reports, prior research reports and master thesis, etc.

Table 38 Research approach

9.1.7 Research outcome

The research in this dissertation has been focusing on addressing the problems outlined and aiming at fulfilling the objectives specified. In this sense, it has endeavored to produce the following outcome:

- A broader understanding of the Extended Enterprise concepts (see chapter 2).
- Insight into the usage of ICT in the Extended Enterprise (see chapter 2-3).
- A broad presentation of information visibility concept (see chapter 3).
- A broad presentation and discussion of information visualization concept (see chapter 4).
- Insight into the cumbersome world of modeling, and how models can be used to enable visualization in the Extended Enterprise (see chapter 4).
- Specification for an Extended Enterprise information visibility and visualization system (see chapter 5).
- Information sharing requirements in the Extended Enterprise (see chapter 5).
- The Extended Enterprise Operations Model Toolset for information visibility and visualization (see chapter 6).
- The Extended Enterprise Process Model (see chapter 6 and Appendix A).

9.2 Contribution to knowledge

Research should contribute to existing knowledge with theories and constructs not yet explored in existing knowledge (Alfnes, 2005). The contribution to knowledge of this research is believed to be significant since it deals with important problems that are still not solved in a satisfactory manner. This study attempts to add significant inputs to knowledge in the area of the Extended Enterprise, by combining the fields of Operations Management, ICT and Business Modeling, and develop new concepts and solutions in the cross-section of these four disciplines. The contribution of this research corresponds to the research objectives that are defined (see chapter 1.4.4):

- The Extended Enterprise Operations Model Toolset for information visibility and visualization is established. The toolset enables support for planning, control and monitoring of operations in the Extended Enterprise, with a particular focus on manufacturing and logistics processes.

This overall contribution is based on several more specific contributions (these contributions are in-line with the specific objectives specified in chapter 1.4.4)

- The Extended Enterprise concept
- The information visibility concept
- The information visualization concept
- The role of ICT in the Extended Enterprise

These five contributions are presented in more detail in the next five sub-chapters.

9.2.1 The Extended Enterprise Operations Model Toolset

The main contribution to knowledge of this thesis is the Extended Enterprise Operations Model Toolset. This toolset combines the concept of information visibility and visualization in order to enable and improve decision support for planning and control of operations in the Extended Enterprise. The tools have been developed with a particularly focus on the manufacturing and logistics processes in the Extended Enterprise, and the aim has been to develop tools and concepts supporting the development and operation of integrated, global and responsive value chains.

This toolset addresses the lack of concepts and tools that enable companies to establish and manage an Extended Enterprise. The primary application of the toolset is to support operational and tactical decisions regarding manufacturing and logistics processes in the Extended Enterprise. However, the toolset may also be applicable in a more strategic fashion, e.g. designing and improving the Extended Enterprise.

The toolset combines information visibility and visualization concepts in a complementary manner. The information visibility concept provides an infrastructure for on-line and real-time sharing of information in the Extended Enterprise, and a recommendation of what kind of information that needs to be shared between the partners in the Extended Enterprise. Whereas the information visualization concept provides tools for a non-ambiguous and simple visualization of the shared information, aiming at improving holistic thinking, early problem detection, and a more accurate decision process.

The toolset consists of six individual, but also related tools:

- ***The Extended Enterprise Operations Model*** – is a collection of six different models, where all models represent a specific view of the Extended Enterprise. These models are further computerized in a way that enables a structured and layered access to all desired information at any given time.
- ***The Extended Enterprise Process Model*** – is one of the six models in the Extended Enterprise Operations Model. The Extended Enterprise Process Model is a four layered generic representation of all actors and manufacturing and logistics processes within the Extended Enterprise. The Extended Enterprise Process Model is a reference model, which enables each individual Extended Enterprise to develop particular process models of their own Extended Enterprises.
- ***The Extended Enterprise Process Modeling*** – is a tool enabling companies to develop their own particular process model based on the Extended Enterprise Process Model and a formalized modeling construct. This includes both a set of standardized set of symbols and notations, as well as an ICT tool for generating the particular process model.
- ***The Extended Enterprise Dashboard*** – is a visual display (e.g. charts, reports, visual indicators, etc) and alert mechanisms of the most important information needed to manage the operations in the Extended Enterprise. The Extended Enterprise Dashboard is built upon the Extended Enterprise Process Model and The Extended Enterprise Operations Model structure, and are consolidated and arranged on a single screen so the information can be monitored at a glance.
- ***The Extended Enterprise ICT Infrastructure*** – is a tool to overcome the (technological) barriers of information sharing and communication in the value chain, and thus enabling information visibility in the Extended Enterprise. Further, it should also enable computerized visualization of the shared information.
- ***The Extended Enterprise Studio*** – is a tool enabling a physical and/or virtual team-based collaborative environment for planning and control of value chain operations.

The Extended Enterprise Operations Model Toolset is basically a system for sharing real-time information, gaining access to a pool of (old and new) information, and visualization of operations (i.e. models) and performance in the Extended Enterprise for support in planning and control of operations.

9.2.2 The Extended Enterprise concept

Even though the concept of the Extended Enterprise has been around since the early 1990s (Busby and Fan, 1993; Konsynski, 1993), and is commonly used in both academic and in practice, the Extended Enterprise still lacks formalism, systems and tools (see chapter 1 and 2).

This thesis addresses these weaknesses indicated above and attempts to create a common understanding of the Extended Enterprise concepts, and further, to contribute to the scientific development of the Extended Enterprise.

The contribution to knowledge within the Extended Enterprise is a new and improved definition of the Extended Enterprise, a presentation of the history and various traditions within the Extended Enterprise concept, a description of the unique characteristics of the Extended Enterprise, a presentation of the various actors (i.e. partners) in the Extended Enterprise, and a process model of manufacturing and logistics processes in the Extended Enterprise. Further, the Extended Enterprise is discussed in context of the value chain, and compared with other similar value chain systems. And finally, the challenges with planning and control of operations in the Extended Enterprise are discussed.

9.2.3 The information visibility concept

It is now almost 50 years since Forester (1958) first published his studies of the relationships between information exchange and demand variation along the value chain. This has later been known as the Bullwhip effect (Lee et al., 1997a); how small changes in downstream demand are dramatically amplified upstream. Since then information visibility has been highlighted as an important mean to overcome this unwanted phenomenon (Slack et al., 2001; Lee et al., 1997b; Towill et al., 1992).

However, after half a century of academic study, the problem still presents challenges to researcher and industrial practitioners (Holweg and Disney, 2005). This thesis focuses among others on how information visibility can help overcome or minimize the Bullwhip effect. However, this is not the only beneficial aspect of information visibility. The concept can also contribute to reduction of lead times, eliminating or reduction of inventory, less planning and control efforts, improved service and quality, etc.

Information visibility is essential for the existence and management of the Extended Enterprise. It allows an immediate flow of correct information needed for controlling the operations in the Extended Enterprise, and gives the ability to instantly know (or even better; in advance) when, where, how and why things occur in the Extended Enterprise.

The contribution to knowledge within information visibility is mainly focused on three distinctive parts. First, a presentation and discussion, including a definition, of the information visibility concept. Second, a proposal of a conceptual ICT infrastructure for on-line and real time exchange of information in the Extended Enterprise. Third, a specification of what kind of information that is necessary to exchange between the actors in the Extended Enterprise.

9.2.4 The information visualization concept

Information visualization has been a popular and embraced concept within fields like product development, construction, architecture, medicine, meteorology, geography, etc for years (see among others Hansen and Johnson, 2005; Ware, 2004; Bederson and Shneiderman, 2003;

Card et al., 1999). However, information visualization is by many regards almost absent within the field of Operations Management, in particular within the Extended Enterprise.

Due to the complexity of the Extended Enterprises, it has become of utter importance to create models of the operations in the Extended Enterprise. The purpose of these models is to provide common understanding among users about Extended Enterprise operations and structure, to support analysis or decision-making or to control operations of the Extended Enterprise (Vernadat, 1996). Gardner and Cooper (2003) suggest that not only is there a need to visualize (create models of) the value chain, there needs to be a well-established process for building the models so that knowledge is easily transferable and exchangeable among managers and organizations as appropriate; value chain modeling. They point out that there is not yet a universal set of modeling convention to represent a value chain (ibid).

This thesis addresses these challenges, and has attempted to develop a concept for information visualization of operations, than particular manufacturing and logistics processes, in the Extended Enterprise.

The contribution to knowledge within information visualization have been to import the concept of information visualization into the field of Operations Management and Extended Enterprise, illustrate the need, use and benefits of this concept, and to develop several models enabling visualization in the Extended Enterprise. The Extended Enterprise Process Model is the main contribution in this regard.

9.2.5 The role of ICT in the Extended Enterprise

Much of the current interest in the Extended Enterprise is motivated by the new possibilities offered by ICT. However, there is no such thing as an Extended Enterprise ICT system, but rather a myriad of individual, particular and partly supplementary ICT system. The challenge is to get everyone in the Extended Enterprise onto a common platform of logistics transactions and information systems for greater inter-organizational "seamlessness" or transparency resulting in faster system response time (Boyson et al., 1999).

This thesis addresses this challenge, and has explored how the usage of ICT in the Extended Enterprise can support planning, control, monitoring and execution of operations, particular manufacturing and logistics processes, in the Extended Enterprise.

The contribution of knowledge within the Extended Enterprise ICT system is limited to a presentation of the various ICT systems in an Extended Enterprise, how these various ICT systems can be integrated into a virtual Extended Enterprise ICT system, and not at least how this ICT system can enable and support information visibility and visualization in the Extended Enterprise. The main contribution is in the later point.

9.3 Contribution to practice

Research should be practical relevant and useful to practitioners (Kasanen et al., 1993; Arbnor and Bjerke, 1997). Several field studies have been conducted by the candidate and/or at SINTEF within the context of The Extended Enterprise Operations Model Toolset over the last years. In these field studies have either the toolset, early and basic ideas of the toolset, or similar and to some extent more developed solutions been applied. Table 39 gives an overview of the companies involved, with a specification of which element of the toolset that was applied.

Company	The Extended Enterprise Operations Model Toolset						Relations to thesis
	The Operations Model	The Process Model	Process Modeling	Dashboard	ICT Infrastructure	Studio	
RCT	X	X	X	X	X	X	Included in the thesis
HAST	(X)	X	X	(X)		(X)	
Apokjeden	(X)	X	X	(X)	(X)	(X)	Not included, but performed by the candidate
Teeness		(X)	X				
Protex		(X)	X	X			Not included and performed by other people at SINTEF
Mustad	(X)	(X)	X	(X)	(X)	(X)	
Pipelife	(X)	(X)	X	(X)			
Holtung	(X)	(X)	X	(X)	(X)	(X)	

Table 39 Application of the Extended Enterprise Operations Model Toolset in companies

When examining table 39 it is important to understand the difference between the three "relations to thesis" categories:

- *"included in this thesis"* contains the empirical studies in this thesis. These are presented in chapter 7 and 8.
- *"not included, but performed by the candidate"* contains companies/studies where the author has applied some of the concepts and tools within the Extended Enterprise Operations Model Toolset, but these studies are minor and are not included in the thesis.
- *"not included and performed by other people at SINTEF"* contains companies which are (or have been) involved in research projects with SINTEF, and these projects have used the ideas or similar ideas of the Extended Enterprise Operations Models after the research in this thesis was ended.

Another important note is the use of the notation "(X)". This indicated at the tool has either been:

- only partial used (e.g. the Process Model in Teeness, Protex, Mustad, Pipelife and Holtung)
- or the needs for the tools have been identified and the solutions are under development and implementation (e.g. the Operations Model in Apokjeden - this process is now terminated), Mustad, Pipelife and Holtung; the Dashboard in HAST, Apokjeden (this process is now terminated), Mustad, Pipelife and Holtung).

The following points summarize what the author believes to be the major contribution to practice of this research:

- The Extended Enterprise Process Modeling tool has been proven highly useful in projects, particular in the primarily faces of the project; mapping and generating AS-IS models.
- The Extended Enterprise Process Model has served as a reference model for generation of particular process models in the automotive industry (RCT and HAST) and has shown usefulness in other industries as well.
- The Extended Enterprise Dashboard concept has been identified as a solution in almost every project listed in table 39, and is currently under development and implementation in many of these projects.

- o The Extended Enterprise Operations Model concept has been identified as a solution in almost every project listed in table 39, and is currently under development and implementation in many of these projects.
- o The Extended Enterprise ICT Infrastructure concept is relevant for all companies, but at the same time it is the most resource consuming and complex tool in the toolset. Hence, the limited interest among the companies in table 39.
- o The Extended Enterprise Studio concept seems relevant in every situation where there is a need for coordination of (often global distributed) value chain operations, as well as on the shop floor to support operators.

The major findings from these field studies are that the Extended Enterprise Operations Model Toolset is a powerful and highly applicable concept for companies engaged in Extended Enterprise collaboration, and can help companies to enable information visibility and visualization of operations. The concept of the Extended Enterprise Operations Model Toolset is however for the present time resource consuming and cumbersome to develop and implement, but this is expected to improve as the toolset is further developed (see chapter 9.5).

9.4 Evaluation of quality of the research

In chapter 1.6 a set of criteria to be used to examine the quality of the research was presented (see table 4). Table 40 summarizes the evaluation of this research carried out applying those criteria.

Quality criteria	Description		This research rating
Contribution to knowledge	The research should contribute to existing knowledge by disclosing hypothesis, theories and constructs not yet explored in existing knowledge.	√	In chapter 1.4 the research problem, including five sub-problems, were stated on the background of gaps/lacks identified. Chapter 5-8 clearly shows how the Extended Enterprise Operations Model Toolset, with its underlying concepts and solutions fulfils these gaps (see also chapter 9.2).
	Theory should be developed through three mechanisms: 4. As an outcome of the research process,	√	Chapter 1 outlines the research project and process, and this research process is followed throughout the dissertation. Chapter 5-8 illustrates how the Extended Enterprise Operations Model Toolset is an outcome of this process.
	5. Moving from the particular to the general in small steps	√	The outcome of this thesis has gone through three initial case studies, a comprehensive literature review, a main study, and a final test study.
	6. As a template for comparison and further development of theory	√	The research domain (rationale, scope, assumptions, and limitations), research problems and objectives, and the research process are thorough presented in chapter 1. This allows future researchers to compare and further develop the concepts and solutions presented in the thesis.
	Valid theories should be well developed and informed, comprehensive, logical, parsimonious and consistent	√	The research presented in this thesis spans over more than 10 years, and through these years the concepts and solutions have been constantly improved and further developed. The research has been presented and discussed will colleagues at SINTEF and NTNU, as well as with other international partners. Part of the research has also been published as conference papers at various conferences over the years.

Quality criteria	Description		This research rating
Contribution to practice (i.e. practical relevance and usefulness)	The research outcome should be proved to be useful and relevant to practitioners.	√	Research outcome, the Extended Enterprise Operations Model Toolset, with its underlying concepts and solutions, have proven to be very useful and relevant to practitioners (see table 9.3 and discussion in chapter 9.3).
	That is, the outcome of the research should be embraced by the organization being involved in the research.	√	Chapter 7 and 8 document how the concepts and solutions of this research have been embraced (i.e. developed, implemented, and tested) by RCT and HAST.
Theoretical foundation	The research should be based on sound knowledge of existing theories in the area of investigation.	√	In chapter 1 the background for this research was specified. Further, in chapter 5 and 6 it is indicated how the concepts and solutions of this thesis is based on existing knowledge presented in the literature review in chapter 3-5.
	Changes being studied should be triangulated.	√	In this thesis triangulation is secured through a combination of: o Triangulation of theories (see chapter 2-4) o Triangulation of methodologies (see chapter 1) o Triangulation of data (initial case studies, main study, and test study) o Triangulation of investigators, the research process has mainly been a team process involving people from SINTEF, NTNU and international partners. o Multiple projects Triangulation (MOMENT, ECOSELL, SMARTLOG, P2005 etc).
Practical foundation	Development of new theories should develop from synthesis of data, which is obtained from the use of existing theory in practice.	√	The Extended Enterprise Operations Model Toolset is developed through a long-term loop of interaction between existing theory and practice (e.g. the initial three case studies, the main study, and the test study).
Methodological coherence	The research questions must match the research method, which should match the data and analytic procedures.	√	Research questions are not employed in this thesis. However, chapter 1 clearly specifies how the research methods were chosen on background on tradition, research issue, research problems and the researcher's personal assumptions.
Investigator(s) responsiveness	The researcher should prove that he has remained open, has been creative, and has been willing to relinquish any ideas that are poorly supported.	√	The research process has endured more than 10 years, and throughout these years some ideas were abandoned whereas others were added. Chapter 7-8 illustrates some of this process.
Iterative interaction between data analysis and data collection	The research should carry out data collection and analysis concurrently in order to ensure reliability and validity.	√	The action research process has secured an iterative interaction between data analysis and data collection.

Table 40 Evaluation of quality of the research

9.5 Future research

Despite that Operations Management, ICT, Business Modelling, and partly the Extended Enterprise, has been very popular research topics during the last decades, there are still many issues in the intersection between these areas that have not yet been solved to a satisfactory degree. Considering the scope of this research and the result presented, the following areas and topic should be further explored:

- Further case studies
- Fully developed toolset, with software tools
- Expanding the process model
- Introduce "intelligence" into the Toolset
- Develop an ICT infrastructure for the Toolset

9.5.1 Further case studies

Case studies should be carried out in order to further test and modify the Toolset. The aim of these case studies should be to enrich and enlarge the area of application of the Toolset, and improve the transferability of the Toolset from one case to another. The Toolset presented in this thesis is primarily developed within the automotive industry, and further case studies should also be conducted within non-automotive industries in order to make the Toolset more generic applicable and increase the industrial independence of the Toolset. A third improvement is to develop the other views/models of the Extended Enterprise Operations Model to a level similar to the Extended Enterprise Process Model.

9.5.2 Fully developed Toolset

The Toolset, with its underlying concepts and tools, presented in this thesis are for the most part on a conceptual basis. Each of the tools (the EE Process Model, the EE Modeling tool, the EE Operations Model, the EE Dashboard, the EE ICT Infrastructure, and the EE Studio) should be developed into independent and easily integrated software tools. The aim should be to develop software tools that are easily adoptive at any given enterprise, with low threshold for use and low resource consumption associated with use and implementation.

9.5.3 Expanding the Process Model

Even though the Extended Enterprise Process Model is a powerful and useful tool in it self, its value of use will increase substantially if its functionality is expanded. A first area of expansion is to develop a supporting cost model on the basis of the process model. This will allow the Extended Enterprise to build cost models for their value chain operations, and highlight areas for improvement, and building trust and commitment in the Extended Enterprise. A second area of expansion will be to include simulation and/or optimization functionality into the process model. This will develop the process model into a powerful decision support tool for more strategic and tactical decisions in the Extended Enterprise.

9.5.4 Expanding the Toolset

The use and range of the Extended Enterprise Operations Model Toolset will increase significantly if the toolset is expanded into one or more of the following points: 1) Automation of processes, e.g. automated routines for a set of occurrences 2) Develop planning functionality into the tool, so that every member of the Extended Enterprise collaboratively can plan their operations. 3) Enable "execution" functionality, meaning that the toolset can be used to respond to events. 4) Introduce "intelligence" into the toolset, so that due to the available information and transactions occuring or not occuring, the toolset can sense and respond to events emerging.

9.6 References

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Appendix

Appendix A –

The Extended Enterprise Process Model

Appendix A – The Extended Enterprise Process Model

The Extended Enterprise (EE) Process Model has been developed at SINTEF over the decade, and was one of the deliverables in the MOMENT project (Deliverable 3.2). The work of developing the EE Process Model was done under the responsibility of the PhD candidate. The EE Process Model has been further developed and tested in the work of this thesis.

The objective of the EE Process Model is to enable Extended Enterprises to build up their operation based on standard (state-of-the-art) processes. The EE Process Model allows mapping of all actors, processes and activities in the Extended Enterprise, and thereby have a complete and corresponding description of the Extended Enterprise.

In more detail, the purposes for developing the model can be split into four categories. First, it seeks to be an efficient tool for ***mapping processes in engineering and re-engineering projects***, both in enterprises and along the value chain in the Extended Enterprise. Secondly, the model will provide ***visualization of material and information flow*** as a decision support in the planning and control of operations in the Extended Enterprise. Thirdly, it will be a ***common language*** for the Extended Enterprise. And finally, provide enterprises with a set of ***pre-defined state-of-the-art processes***.

In the MOMENT project, the EE Process Model was developed according to requirements in the automotive industry, and is not yet generic and able to support all kind of operations. The focus of the EE Process Model is processes associated with the material and information flow through the Extended Enterprise, and some supporting activities. The EE Process Model has been tested and validated in several automotive supplier cases, and to some degree in other industry (e.g. furniture, food and pharmaceutical).

The EE Process Model is developed for, and gives particularly focus on, operations in the Extended Enterprise. The EE Process Model has four levels of details:

- *Level 0 - Actors (with attributes) and group of actors*
- *Level 1 - Processes (Operate, Manage and Support)*
- *Level 2 - Sub-Processes*
- *Level 3 - Activities*

Appendix A will give an in-depth presentation of the Extended Enterprise Process Model, and its four levels.

Actors

In this thesis, as well as in the MOMENT project, does the Extended Enterprise's value chain consist of five different types of actors:

- *Suppliers*
- *Transporters*
- *Warehouse (distribution centers)*
- *Manufacturer (focal company)*
- *Customers*

The suppliers, manufacturer, and customers are the three main actors in the EE Process Model and the focus in on those three. This is due to the fact that it is these three actors that are engaged with the manufacturing part of the Extended Enterprise, and therefore are in line with the domain and scope of this thesis. A more detailed description of each actor is given in the following.

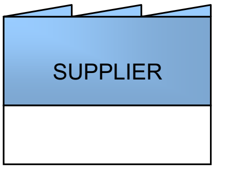
Supplier

ACTOR: Supplier

Description:

Suppliers are located up-stream in the value chain. They provides/sells physical products (raw materials and/or components) to the focal company in the Extended Enterprise.

In MOMENT is the Supplier always a 2nd Tier Supplier.

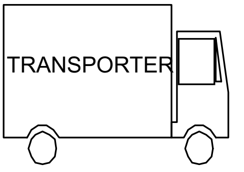


Input:	**Output:**
Materials and components from sub-suppliers	Materials, components and products for manufacturer Invoice
Preceding actors:	**Following actors:**
Supplier	Transporter Manufacturer Warehouse Customer
Information in:	**Information out:**
Forecast for upcoming orders Call-off from manufacturer Customer orders from manufacturer	Order confirmation Delivery date Status information
Main activity:	**Processes:**
Producing components or services to manufacturing company	Operate, Manage, Support

Supplier attributes:

- **Engineer-to-order**: Products are designed and produced to customer specifications
- **Make-make-to order**: Products are selected by customers from some pre-defined available. Then they are designed and produced after reception of the customer order.
- **Assembly-to-order**: Products are configured or assembled to customer order from a set of core subassemblies and components.
- **Make-to-stock**: Products are not produced according to customer order, but to stock, often in a well-known and predictable marked

Transporter

ACTOR: Transporter	
Description:	
The Transporter is the actor in the Extended Enterprise which transports goods between the other actors in the value chain. The transport forward in the EE will contain products and components, while the backward transport contains waste, End-of-life products, containers and packing. The transporter can have the responsibility of parts of the transportation in the EE, or he can have the total responsibility. The transport can be by sea, road, air and/or rail.	

Input:	**Output:**
Outbound goods from supplier Waste, etc. from the actors	Inbound goods to manufacturer
Preceding actors:	**Following actors:**
Supplier Manufacturer Warehouse	Manufacturer Warehouse Customer
Information in:	**Information out:**
Transport request Schedules for upcoming deliveries Details about quanta, senders and receivers	Order confirmation
Main activity:	**Processes:**
Transporting products	Operate, manage, support

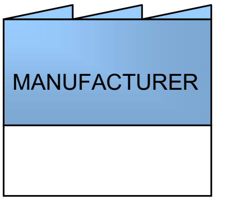
Transporter attributes:

Type:	Conditions	Medium
- **Vessel**: Transport by ship - **Truck**: Transport by truck - **Air**: Transport by air-plane - **Train**: Transport by train	-**Normal**: Normal transport conditions -**Thermo**: Cold/heathen transport conditions	- transportation in containers - transportation on sea pallets - transportation on pallets

Terms (Incoterms):

Ex-works: The buyer bears the full cost and is involved in moving the goods from the seller's location
Ex ship/Ex quay: Supplier responsible for bringing the goods to the buyer at seller's cost and risk
FOB (free on board): Supplier responsible for goods until it's on board the ship.
FOR/FOT (free on rail/truck): Same as FOB, except this is for rail and truck transport
Free carrier (FCA): For multimodal transport (containers, etc.) with same obligations as for FOB
FOB airport: This is similar to the ordinary FOB term, but applies to goods sent by air
FAS: (Free along ship) Supplier's responsibility ends when the goods is alongside the ship
CetF: Supplier pays for transport, but risk is transferred to buyer when goods is on board the ship
Delivered at frontier: Seller's risk end at the border
CIF(Cost, insurance, freight): CetF and the supplier also have to buy marine insurance for the goods
OCP: Similar to CetF, but suitable for other modes than ship
CIP: Seller buys insurance, which is similar to CIF, but this is for other modes than ship
Delivered duty paid: Seller takes all risks and expenses in delivering the goods.
Delivered duty unpaid: Seller takes risks and costs, but not the ones connected to customs/duty

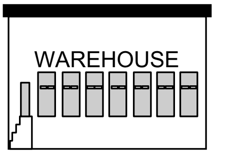
Manufacturer

ACTOR: Manufacturer	
Description:	
Manufacturers are focal companies in the Extended Enterprise. The manufacturer receives raw materials and /or components from the suppliers, processes them in a value adding way, and sells these products to the customers in the value chain. In MOMENT is the Manufacturer always a 1st Tier supplier to an OEM.	
Input:	**Output:**
Materials and components from suppliers	Products and parts for the customer- in Moment the OEM.
Preceding actors:	**Following actors:**
Supplier Transporter Warehouse	Transporter Warehouse Customer
Information in:	**Information out:**
Forecasts for future demand at OEM Call-off from OEM Order and delivery confirmation from supplier	Order confirmation to OEM Orders, forecasts and call-off to suppliers Transportation and warehousing requests
Main activity:	**Processes:**
Making the product demanded by the OEM	Operate, manage, support

Manufacturer attributes:

- **Engineer-to-order**: Products are designed and produced to customer specifications
- **Make-make-to order**: Products are selected by customers from some pre-defined available. Then they are designed and produced after reception of the customer order.
- **Assembly-to-order**: Products are configured or assembled to customer order from a set of core subassemblies and components.
- **Make-to-stock**: Products are not produced according to customer order, but to stock, often in a well-known and predictable marked

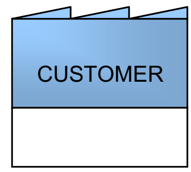
Warehouse

ACTOR: Warehouse	
Description:	
Warehouses store raw material, components and product throughout the value chain. The warehouses are located between the others actors in the Extended Enterprise of a strategic, tactical and/or operational reason.	
Input:	**Output:**
Outbound goods from one of the actors in the EE	Inbound goods to next actor in the EE
Preceding actors:	**Following actors:**
Supplier Transporter Manufacturer	Manufacturer Transporter Customer
Information in:	**Information out:**
Requests for storage from an actor in the EE Requests for pick up of stored goods	Confirmation on requests Status of stored goods- inventory level, etc.
Main activity:	**Processes:**
Storing material, components and products throughout the value chain	Operate, manage, support
Warehouse attributes:	

- **Normal**: Store products under normal conditions
- **Clean**: Store products under special clean conditions
- **Cold**: Store products in thermo conditions

Customer

<table>
<tr><th colspan="2">ACTOR: Customer</th></tr>
<tr><th colspan="2">Description:</th></tr>
<tr><td>Customers are located down-stream in the value chain. The customer receives materials and components from the manufacturer. The Customer is also a manufacturing company that sells its product to the end-user.

In MOMENT is the Customer always an OEM.</td><td>
</td></tr>
<tr><th>Input:</th><th>Output:</th></tr>
<tr><td>Products and components from manufacturer</td><td>Finished products- in MOMEMT cars</td></tr>
<tr><th>Preceding actors:</th><th>Following actors:</th></tr>
<tr><td>Supplier
Transporter
Manufacturer
Warehouse</td><td></td></tr>
<tr><th>Information in:</th><th>Information out:</th></tr>
<tr><td>Delivery confirmations from manufacturer
Delivery window from transporter</td><td>Forecasts and call-off to manufacturer</td></tr>
<tr><th>Main activity:</th><th>Processes:</th></tr>
<tr><td>Producing the finished products</td><td>Operate, manage, support</td></tr>
<tr><th colspan="2">Customer attributes:</th></tr>
<tr><td colspan="2">

Engineer-to-order: Products are designed and produced to customer specifications
Make-make-to order: Products are selected by customers from some pre-defined available. Then they are designed and produced after reception of the customer order.
Assembly-to-order: Products are configured or assembled to customer order from a set of core subassemblies and components.
Make-to-stock: Products are not produced according to customer order, but to stock, often in a well-known and predictable marked

</td></tr>
</table>

Processes

The actors in the Extended Enterprise perform three types of processes. Those are described as:

- Manage
- Operate
- Support

Manage processes

The Manage processes are defined as "The processes concerning the management activities undertaken to support the operate processes".

The processes are:

- Extended Enterprise co-ordination
- Order management
- Production and inventory control
- Procurement

Operate processes

The Operate processes are defined as "The processes concerning the physical material flow in the value chain".

The operate processes are those processes witch directly produce value for external customers (Maull et al., 1995). Value is added if activities lead directly to the fulfilment of a customer's requirements.

The different operate processes are defined as processes that require specific resources. The processes are:

- Inbound handling
- Internal transport
- Production
- Assembly
- Storage
- Packaging and labelling
- Outbound handling
- Reverse logistics
- Order picking/selection
- Transport product

Support processes

The Support processes are defined as "The processes not directly associated with the operation, but with indirectly influence of the operation".

The support processes are:

- Maintenance
- Quality
- Learning
- KPI (Key Performance Indicators)
- Industrialisation
- Localization

Sub-processes and activities

Each (operate, manage and support) processes can be broken down into slightly more detailed, but still generic, sub-processes. The sub-process provides a more accurate view of what is “going on” in the company. The suppliers, focal company and the customers are all considered to be manufacturing companies and therefore these actors perform similar sub-processes.

These sub-proceses can be further detailed into activities. Activities are the lowest and most detailed level in the EE Process Model. Activities are attached to organizations (the actors) that operate, manage and support them. Activities more than organizations are the building blocks of the Extended Enterprise. The activities can be outsourced, shifted between organizations, consolidated for the system as a whole or combined into new forms of enterprises (Schary and Skjøtt-Larsen, 2001).

The next pages will present all sub-processes, with corresponding activities, for all actors in the Extended Enterprise.

Sub-processes and activities - Manufacturer, Supplier and Customer

ACTOR:	**Manufacturer, Supplier and Customer**	
Process	Operate process	**O 1**
Sub-process	Inbound handling	
Definition	The process spans all activities directly involved with the material flow from receiving inbound transporters carrying goods, unloading the goods and put-away awaiting production.	

Nr.	Activities	Definitions
O 1.1	Reception of transport unit	"This is the activity of making everything ready for the reception of the carrier and the actual reception of the carrier. In some cases this can include showing the carrier the loading ramp. This is often a non-resource consuming activity; although in some industries there will be special requirements for disinfection of carriers etc."
O 1.2	Unload carrier from transport unit	"This is the actual activity of unloading the goods from the carrier and placing it on the intended destination (storage or production) or a temporary place waiting for other activities to be done. This can often be a time- and resource consuming activity. Most often facilitated by some kind of handling equipment"
O 1.3	Identify and verify shipment	"The activity of checking the actual delivery against the delivery note or order sheet and identify potential shortages."
O 1.4	Unpack items	"The activity of removing excessive packaging from the shipment and making it ready for use in the production or assembly area. This activity usual produce waste material that should be handled in a environmentally benign way"
O 1.5	Clean items	"This activity refers to the cleaning of components if this is required by following activities in production or assembly. Can be caused by e.g. missing packaging, poor handling or transport routines."
O 1.6	Perform quality check	"The need for this activity is dependent on the supplier relationship. If there is a high level of confidence in the quality level of the incoming goods, then a goods-in inspection may not be required"
O 1.7	Register items	"This is the activity involved with entering the status of the incoming shipment in a kind of record (database etc.). The main reason is to initiate payment and allow the stock level to be monitored. This could be done semi-automated with scanners using bar code or completely manual. Typical data entries can be the quantity of goods arrived, what goods, the status of quality, raising of shortage note, raising of defect note, raising of reject note"
O 1.8	Move items	"The activity of moving the supplied goods to the appropriate area of production, assembly or storage. This activity can be confused with P1.2 Unload carrier, but can be used when there is a movement of goods from a temporary waiting place to the final destination"
O 1.9	Store items at relevant locations	"The activity of storing the goods on suitable locations until it is needed in production"
O 1.10	Handle items	"The activity of handling waste/obsolete materials. This often implies handling of damaged goods, obsolete goods, package, pallets etc. that originated from the inbound handling process (or the suppliers)"

ACTOR:	Manufacturer, Supplier and Customer	
Process	Operate process	**O 2**
Sub-process	Internal transport	
Definition	The process of moving materials (sourced or in-process) from one point to another when this is done by dedicated resources for internal transport.	

Nr.	Activities	Definitions
O 2.1	Load on transport device	"This activity involves the picking and placement of goods to be moved on the transport device. Usually this activity can be neglected because of marginal consumption of time and resources, but in case of manually picking and placing on conveyors etc. this activity must be considered"
O 2.2	Transport	"The activity concerned with moving something from one place to another by use of a dedicated resource"
O 2.3	Unload from transport device	"Almost similar to P 2.1 Load on transport device, the only difference is the picking and placing from the transport device"
O 2.4	Register items	"This is the activity involved with entering the status of the goods after the internal transport. This could be done semi-automated with scanners using bar code or completely manual. Typical data entries can be the quantity of goods transported, what goods, the status of quality, new location of the goods and new responsibility for the goods."

ACTOR:	Manufacturer, Supplier and Customer	
Process	Operate process	**O 3**
Sub-process	Production	
Definition	The process spans the activities directly involved with the conversion of materials/components from a raw or semi-finished state to a state of greater value.	

Composed by following operate activities:	Nr.	Activities	Definitions
	O 3.1	Move items	"This could be done manually, semi-automated, or completely automated"
	O 3.2	Set-up machine	"The activity of setting up the right configuration for the machine/equipment (tool change, fixtures etc.) for the product to be produced"
	O 3.3	Perform operations	"The actual value adding transformation. The operations can be grinding, milling, drilling, extruding, painting etc."
	O 3.4	Unload machines	"The activity of unloading the produced parts from the machine"
	O 3.5	Clean items	"The activity of cleaning the components and products before production, after production or between parts of the production"
	O 3.6	Quality control	"Test produced product/part to see if it is in compliance with the defined quality measure"
	O 3.7	Handle waste materials	"The activity of handling waste/obsolete materials. This often implies handling of damaged goods, obsolete goods, package, pallets etc. that originated from the production process"

	O 3.8	Register items	"This is the activity involved with entering the status of the goods after the production. This could be done semi-automated with scanners using bar code or completely manual. Typical data entries can be the quantity of goods produced, what goods, the status of quality, new location of the goods and new responsibility for the goods."

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Operate process		**O 4**
Sub-process	Assembly		
Definition	The process spans the activities where subassemblies, or the end product, are put together.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	O 4.1	Move items	"This could be done manually, semi-automated, or completely automated"
	O 4.2	Set-up	"The activity of setting up the right configuration for the machine/equipment (tool change, fixtures etc.) for the product to be assembled"
	O 4.3	Kit items	"The activity of installing and preparing the components/product for assembly. This can involve activities like putting them into a machine, strapping them to an assembly bench, etc."
	O 4.4	Assemble items	"Assemble product from parts produced in-house or purchased from suppliers"
	O 4.5	Unload machines	"The activity of unloading the produced parts from the machine"
	O 4.6	Clean items	"The activity of cleaning the components and products before assembly after assembly or between parts of the assembly"
	O 4.7	Quality control	"Test assembled product/part to see if it is in compliance with the defined quality measure"
	O 4.8	Handle waste materials	"The activity of handling waste/obsolete materials. This often implies handling of damaged goods, obsolete goods, package, pallets etc. that originated from the assembly process"
	O 4.9	Register items	"Register products and components so that the stock-level can be updated and information about the location of the assembled goods can be retrieved"

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Operate process		**O 5**
Sub-process	Storage		
Definition	The process spans the activities of storage materials, components and products when this is done by dedicated resources for this purpose.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	O 5.1	Move items	"This could be done manually, semi-automated, or completely automated"

	O 5.2	Set-up/tune storage facilities	"Preparing the facilities for storing the products. Involves tuning temperature and humidity, making room for the goods and securing the area as well as the products."
	O 5.3	Perform store/mature operation	"Keep the goods on the chosen location for the planned time or until needed. Control the storage facilities regularly if necessary."
	O 5.4	Register items	"Register products and components so that the stock-level can be updated and information about the location of the finished goods can be retrieved"

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Operate process		**O 6**
Sub-process	Packaging and Labelling		
Definition	The process spans the activities of packaging and labelling complete products for storage or sale		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	O 6.1	Move items	This could be done manually, semi-automated, or completely automated"
	O 6.2	Pack items	"The packing of the materials/components/products can be done manually, semi-automated, or completely automated, and should be done in a way so that the goods is protected and easy to handle."
	O 6.3	Label items	"The packaged goods should be labelled properly, and this can be done manually, semi-automated, or completely automated"
	O 6.4	Register items	"Register products and components so that the stock-level can be updated and information about the location of the packaged and labelled goods can be retrieved"
	O 6.5	Store items	"Register products and components so that the stock-level can be updated and information about the location of the packaged and labelled goods can be retrieved"

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Operate process		**O 7**
Sub-process	Outbound handling		
Definition	The process spans the activities from picking the finished product (packed and labelled) to loading the products on the transport unit		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	O7.1	Pick items	"Pick products, materials and components as defined in a picking-list based on a customer order"
	O7.2	Move items	"Move products, materials and components from the temporary holding location or the finished goods location to the outbound carrier."
	O7.3	Print transport document	"The activity generates the shipping documentation"

	O7.4	Load items on carrier	"The activity involved with the loading of products onto the carrier"

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Manage process		**M 1**
Sub-process	Extended Enterprise Co-ordination		
Definition	The process of planning and co-ordinating all processes and activities needed for supply to meet demand. This includes communication with the actors in the EE.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	M 1.1	Yearly Planning (forecasting)	"The development and establishment of courses of action over specified time periods that represent a projected appropriation of resources to meet marked requirements."
	M 1.2	Co-ordination of manage and operate activities	"The activity of making sure that the planned activities are executed and completed properly, and also the activity of regulating plans and manage activities according to the progress in operate activities."
	M 1.3	Communicate and collaborate with other actors	"Communication with the actors earlier as well as later in the extended enterprise will give less uncertainty for all the actors."
	M 1.4	Establish and maintain integrated ICT-solution for the EE	"A system for sharing information like inventory level, sales prognosis, future demand, etc. should be installed and maintained to ease the communication between the actors in the EE."
	M 1.5	Reverse logistics planning and co-ordination	

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Manage process		**M 2**
Sub-process	Order management		
Definition	The process of delivering products to customers based on received customer orders		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	M 2.1	Respond to general inquiries and quotes	"The activity involves answering general to general inquiries and quotes via phone, e-mail etc."
	M 2.2	Receive call-offs	"Receive call-off orders from customers"
	M 2.3	Enter and validate order	"Receive orders from the customer and enter them into a company's order processing system. Orders can be received through phone, fax, or electronic media."
	M 2.4	Reserve resources/inventory and determine delivery date	"Inventory (both on hand and scheduled) is identified and reserved for specific orders and a delivery date is committed and scheduled"
	M 2.5	Consolidate orders	"The process of analysing orders to determine the groupings that result in least cost/best service fulfilment and transportation"

	M 2.6	Plan and build loads	"Transportation modes are selected and efficient loads are built"
	M 2.7	Schedule delivery carrier to be used	"Schedule what transporters are to be used for the transport"
	M 2.8	Send pick up order to transporters	"Send pick-up orders to transporters specifying pick-up window."
	M 2.9	Prepare and send customer invoice	"A signal is sent to the financial organization that the order has been shipped and that the billing process should begin and payment be received or be closed out if payment has already been received."
	M 2.10	Receive customer payment	"Payment is received from the customer within the payment terms of the invoice"
	M 2.11	Acknowledge customer payment	"Check and acknowledge customer payment"
	M 2.12	Update customer account	"Update customer account with payment, confirmed and delivered orders"
	M 2.13	Send Packing list to delivery department	"Send packing list to the people responsible for picking and packing the orders. The packing list provides detailed information of contents of each package in the shipment"

ACTOR:	**Manufacturer, Supplier and Customer**		
Process	Manage process		**M 3**
Sub-process	Production and Inventory Control		
Definition	The process of planning and controlling the production and inventory		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	M 3.1	Develop master production schedule	"The activity of developing a master production schedule that indicates what quantity of end items need to be completed and in what time period."
	M 3.2	Validate master schedule	"The master production schedule must be controlled and validated, and it must be confirmed that there is capacity to fulfil the plan."
	M 3.3	Maintain/update master schedule	"The activity of maintaining and updating the MPS according to new information about demand etc."
	M 3.4	Generate shop floor orders	"This is the activity of creating shop floor orders to the different departments based on the master production schedule. "
	M 3.5	Schedule shop floor orders	"The activity of planning when the shop floor orders should be sent, what they should contain,etc."
	M 3.6	Dispatch shop floor orders	"Sending the shop floor orders to the responsible departments."
	M 3.7	Monitor shop floor orders	"The activity of monitoring the shop floor orders in order to make sure that they are received and initiated."
	M 3.8	Manage inventory	
	M 3.9	Manage WIP	"The process of establishing and maintaining limits or levels, replenishment models, ownership, product mix and stocking locations for In-Process Product (WIP)."

ACTOR:	Manufacturer, Supplier and Customer		
Process	Manage process		**M 4**
Sub-process	Procurement		
Definition	The processes of manage suppliers and purchase agreement, and the processes including acquisition of materials and components.		

Composed by following operate activities:	Nr.	Activities	Definitions
	M 4.1	Maintain supplier networks	"This is the activity of maintaining and developing the relationship with the suppliers, while at the same time balancing the total supplier network. This activity is crucial when a company wants close co-operation with some of their suppliers."
	M 4.2	Develop material requirement plans based on master schedule	"Determine the need for dependent components such as raw materials, parts, subassemblies, or modules"
	M 4.3	Develop and send call-offs based on production plan and stock levels	"Make a call-off defining the needs and send to supplier"
	M 4.4	Follow up orders	"The activity of tracking orders."
	M 4.5	Authorise payment	"Authorize payment based on the status on incoming goods"
	M 4.6	Follow up purchase agreements and supply contracts (quality, delivery time, terms of delivery)	"Follow up purchase agreements and supply contracts, regarding quality, delivery time and terms of delivery"

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 1**
Sub-process	Procurement	
Definition	The combination of management, financial, engineering, building and other practices applied to physical assets in pursuit of economic life cycle cost. Its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation, commissioning, operation, maintenance, modification and replacement and with feedback of information on design, performance and costs (Hill, 2005).	

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 2**
Sub-process	Reverse logistics	
Definition	The processes spans the activities directly involved with handling of waste products, waste, wreckage, end-of-life products and used carriers and packaging.	

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 3**
Sub-process	Quality management	
Definition	Encompass the strategies, programs, methods, and organizational culture that a company uses to achieve its quality objectives (Markland et al, 1995).	

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 4**
Sub-process	Tooling	
Definition	Is the process of making the necessary tools for the operations processes, e.g. a press tool	

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 5**
Sub-process	Performance measurement	
Definition	Performance measurement can be defined as the process of quantifying the efficiency and effectiveness of action. Effectiveness refers to the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized when providing a given level of customer satisfaction (Neely et al, 1995).	

ACTOR:	Manufacturer, Supplier and Customer	
Process	Support Process	**S 6**
Sub-process	Continuous improvements	
Definition	Continuous improvements (or Kaizen) seeks continual improvement of machinery, materials, labor utilization, and production methods through applications of suggestions and ideas of company teams (Chase et al, 2004).	

Sub-processes and activities - Transporter

ACTOR:	**Transporter**		
Process	Operate process		**TO 1**
Sub-process	Transport product		
Definition	The processes of load, transfer, unload and install unit		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	TO 1.1	Load unit on transport unit	"The activity of loading the goods and preparing it for transportation."
	TO 1.2	Transfer unit from A to B	"The activity of transporting the product from the supplier to the manufacturer. Possible solutions are normally by car, train, boat and airplane, and a combination of these modes of transport might be necessary."
	TO 1.3	Unload unit	"The activity of unloading the goods in the docks at the focal company."
	TO 1.4	Install unit	"If needed, the product must be installed at the customer."
	TO 1.5	Register unit	"This is the activity involved with entering the status of the goods after the transport. This could be done semi-automated with scanners using bar code or completely manual. Typical data entries can be the quantity of goods delivered, what goods, the status of quality, confirmed delivery to customer etc."
	TO 1.6	Deliver invoice	"The activity of invoicing the transportation, and giving the invoice for the product to the customer if this is not taken care of earlier in the process."

ACTOR:	**Transporter**		
Process	Manage process		**TM 1**
Sub-process	Extended Enterprise Co-ordination		
Definition	The process of planning and coordinating all processes and activities needed for transport to meet demand. This includes communication with the actors in the EE.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	TM 1.1	Yearly planning	"The development and establishment of courses of action over specified time periods that represent a projected appropriation of resources to meet marked requirements."
	TM 1.2	Coordination of operate and manage processes	"The activities of making sure that the planned activities are executed and completed properly, and also the activity of regulating plans and manage activities according to the progress in operate activities."

	TM 1.3	Communicate with other actors	"Communication with the actors earlier as well as later in the extended enterprise will give less uncertainty for all the actors."
	TM 1.4	Establish and maintain integrated ICT-solution for the EE	"A system for sharing information like inventory level, sales prognosis, future demand, etc. should be installed and maintained to ease the communication between the actors in the EE."
	TM 1.5	Reverse logistics planning and co-ordination	"The planning and execution of all activities related to handling reverse logistics"

ACTOR:	**Transporter**		
Process	Manage process		**TM 2**
Sub-process	Order Management		
Definition	The process of delivering products to customers based on received customer orders		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	TM 2.1	Receive pick up orders	"The transporter receives the pick up orders and register them in their system."
	TM 2.2	Pricing and negotiating	"The price for the transportation must be agreed with the manufacturer. This agreement can be a long term agreement, a one-time occasion, etc. Normally the price will be subject to negotiations."
	TM 2.3	Order processing	"The activity of processing, registering and planning the initiation of incoming orders."
	TM 2.4	Invoicing	"The activity of managing the invoice to the manufacturing company. This is done according to the agreement between the actors, and can be done per transportation, monthly, etc."

ACTOR:	**Transporter**		
Process	Manage process		**TM 3**
Sub-process	Transport Planning and Control Process		
Definition	The process of planning and controlling the transport activities.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	TM 3.1	Load planning	"The load planning should make sure that the carrier is filled up as well as possible, that the weight balance is ok, that there is enough room for the specific order, etc."
	TM 3.2	Routing	"Routing plans the geographical path a vehicle will travel to complete transportation requirements."
	TM 3.3	Select modes of transportation	"This activity make sure that the best transportation mode is chosen. This can depend on distance, technical standard of the different solutions in the area, volume to be transported, etc."

	TM 3.4	Monitor shipments (tracking)	"The activity of monitoring the shipments will give better estimations of arrival of the goods, and will give a quicker response to problems with the transportation, e.g. accidents, delays, etc. It also makes possible to provide the customer with status of the transportation."

ACTOR:	**Transporter**	
Process	Support Process	**SW 1**
Sub-process	Procurement	
Definition	Same as S 1	

ACTOR:	**Transporter**	
Process	Support Process	**SW 2**
Sub-process	Reverse logistics	
Definition	Same as S 2	

ACTOR:	**Transporter**	
Process	Support Process	**SW 3**
Sub-process	Quality management	
Definition	Same as S 3	

ACTOR:	**Transporter**	
Process	Support Process	**SW 4**
Sub-process	Performance measurement	
Definition	Same as S 5	

ACTOR:	**Transporter**	
Process	Support Process	**SW 5**
Sub-process	Continuous improvements	
Definition	Same as S 6	

Sub-processes and activities - Warehouse

ACTOR:	Warehouse		
Process	Operate process		**WO 1**
Sub-process	Inbound handling		
Definition	The process spans all activities directly involved with the material flow from receiving inbound transporters carrying goods, unloading the goods and put-away for storage		

Composed by following operate activities:	Nr.	Activities	Definitions
	WO 1.1	Reception of transport unit	"This is the activity of making everything ready for the reception of the carrier and the actual reception of the carrier. In some cases this can include showing the carrier the loading ramp. This is often a non-resource consuming activity; although in some industries there will be special requirements for disinfections of carriers etc."
	WO 1.2	Unload carrier from transport unit	"This is the actual activity of unloading the goods from the carrier and placing it on the intended destination (storage or production) or a temporary place waiting for other activities to be done. This can often be a time- and resource consuming activity. Most often facilitated by some kind of handling equipment"
	WO 1.3	Identify and verify shipment	"The activity of checking the actual delivery against the delivery note or order sheet and identify potential shortages."
	WO 1.4	Register unit	"This is the activity involved with entering the status of the incoming shipment in a kind of record (database etc.). The main reason is to initiate payment and allow the stock level to be monitored. This could be done semi-automated with scanners using bar code or completely manual. Typical data entries can be the quantity of goods arrived, what goods, the status of quality, raising of shortage note, raising of defect note, raising of reject note"
	WO 1.5	Move unit	"Move products from reception to storage area. This activity is typically handled by a lift truck when pallets are used or by other mechanical means for other types of unit loads"
	WO 1.6	Move unit from reception directly to the shipping dock	"This activity is a cross-docking activity that avoid put-away, storage, and order picking"

ACTOR:	Warehouse		
Process	Operate process		**WO 2**
Sub-process	Storage		
Definition	The process spans the activities of storage different kinds of units		

Composed by following operate activities:	Nr.	Activities	Definitions
	WO 2.1	Move unit	"The activity of moving the goods to the planned storage area. This could be done manually, semi-automated, or completely automated"
	WO 2.2	Set-up/tune storage facilities (temperature, humidity, light, safe placing)	"Preparing the facilities for storing the products. Involves tuning temperature and humidity, making room for the goods and securing the area as well as the products."
	WO 2.3	Perform store/mature operation	"The activity of keeping the products at the chosen location in the warehouse until scheduled delivery to customer."
	WO 2.4	Register unit	"Register products and components so that the stock-level can be updated and information about the location of the goods in the warehouse can be retrieved"

ACTOR:	Warehouse	
Process	Operate process	**WO 3**
Sub-process	Order picking/selection	
Definition	The activities of picking and labeling goods, and making picking slips.	

Composed by following operate activities:	Nr.	Activities	Definitions
	WO 3.1	Transfer unit from storage area to picking area	"When unit loads have to be broken down for order selection, they are usually transferred from storage to an order selection or picking area. When products are large and bulky such as appliances, this intermediate movement to a picking area may not be necessary."
	WO 3.2	Pick unit	"For each order, the combination of units must be selected and packaged to meet specific customer order requirements"
	WO 3.3	Label unit	"Each unit must be labeled with the customer/receiver, the address, return address, date of delivery, etc. to make sure that the unit is sent to the right customer."
	WO 3.4	Make picking slips	"Each unit must also have packaging slips which specify what products it contains, the volume and the delays/shortages compared to the customer order. This will document the delivered amount, and will make it easier for the receiver to control the unit at arrival."
	WO 3.5	Register unit	"Register the picked products so that the stock-level can be updated and information about the location of the picked goods can be retrieved. This activity can initiate the outbound handling."

ACTOR:	**Warehouse**		
Process	Operate process		**WO 4**
Sub-process	Outbound handling		
Definition	The activities of verify orders and load goods on carriers and transport units.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	WO 4.1	Verify order	"Verification may be limited to a simple carton count or a piece-by-piece check for proper brand, size, and in some cases serial number to assure shipment accuracy."
	WO 4.2	Load unit on carrier	"Move products from the staging area into the transportation vehicle"
	WO 4.3	Register unit	"Register products and components so that the stock-level can be updated and information about the location of the goods can be retrieved. The products are ready for transportation to the customer."
	WO 4.4	Load carrier on transport unit	"Physical movement of carrier from warehouse facilities into the transport unit"

ACTOR:	**Warehouse**		
Process	Manage process		**WM 1**
Sub-process	Extended Enterprise Co-ordination		
Definition	The process of planning and coordinating all processes and activities needed for supply to meet demand. This includes communication with the actors in the EE.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	WM 1.1	Yearly planning (forecasting)	"The development and establishment of courses of action over specified time periods that represent a projected appropriation of resources to meet marked requirements."
	WM 1.2	Coordination of manage and operate processes	"The activity of making sure that the planned activities are executed and completed properly, and also the activity of regulating plans and manage activities according to the progress in operate activities."
	WM 1.3	Communicate and collaborate with other actors	"Communication with the actors earlier in the extended enterprise and with the customers will give less uncertainty for all the actors."
	WM 1.4	Establish and maintain integrated ICT-solution for the EE	"A system for sharing information like inventory level, sales prognosis, future demand, etc. should be installed and maintained to ease the communication between the actors in the EE."
	WM 1.5	Reverse logistics planning and coordination	"The planning and execution of all activities related to handling reverse logistics"

ACTOR:	Warehouse		
Process	Manage process		**WM 2**
Sub-process	Order management		
Definition	The process of delivering products to customers based on received customer orders.		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	WM 2.1	Respond to general inquiries and quotes	"The activity involves answering general to general inquiries and quotes via phone, e-mail etc."
	WM 2.2	Receive call-offs	"Receive call-off orders from customers"
	WM 2.3	Reserve resources/inventory and determine delivery date	"Inventory (both on hand and scheduled) is identified and reserved for specific orders and a delivery date is committed and scheduled"
	WM 2.4	Consolidate orders	"The process of analyzing orders to determine the groupings that result in least cost/best service fulfillment and transportation"
	WM 2.5	Plan and build loads	"Transportation modes are selected and efficient loads are built"
	WM 2.6	Schedule delivery carrier to be used	"Schedule what transporters are to be used for the transport"
	WM 2.7	Send pick up order to transporters	"Send pick-up orders to transporters specifying pick-up window."
	WM 2.8	Prepare and send customer invoice	"A signal is sent to the financial organization that the order has been shipped and that the billing process should begin and payment be received or be closed out if payment has already been received. The customer should be notified at what time the goods are incoming."
	WM 2.9	Receive customer payment	"Payment is received from the customer within the payment terms of the invoice"
	WM 2.10	Acknowledge customer payment	"Check and acknowledge customer payment"
	WM 2.11	Update customer account	"Update the customer account with the finished order, the received payment, etc."

ACTOR:	Warehouse		
Process	Manage process		**WM 3**
Sub-process	Inventory Planning and Control		
Definition	The process of planning and controlling the inventory		
Composed by following operate activities:	**Nr.**	**Activities**	**Definitions**
	WM 3.1	Capacity planning	"The activity of planning the future inventory levels to utilize the capacity and avoiding capacity problems."

	WM 3.2	Monitor inventory levels	"Monitoring the levels at the inventories. This will make it easier to give quick response to requests from customers as well as production, and will improve the regulation of the inventory levels."

ACTOR:	**Warehouse**	
Process	Manage process	**WM 4**
Sub-process	Procurement	
Definition	As long as the Warehouse does not do any production and or assembly operations, there will be no procurement activities associated with the product. The procurement process will than be associated with supporting functions.	

ACTOR:	**Warehouse**	
Process	Support Process	**SW 1**
Sub-process	Procurement	
Definition	Same as S 1	

ACTOR:	**Warehouse**	
Process	Support Process	**SW 2**
Sub-process	Reverse logistics	
Definition	Same as S 2	

ACTOR:	**Warehouse**	
Process	Support Process	**SW 3**
Sub-process	Quality management	
Definition	Same as S 3	

ACTOR:	**Warehouse**	
Process	Support Process	**SW 4**
Sub-process	Performance measurement	
Definition	Same as S 5	

ACTOR:	Warehoue	
Process	Support Process	**SW 5**
Sub-process	Continuous improvements	
Definition	Same as S 6	

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Appendix B –

Projects and cases related to the thesis

Appendix B – Projects and cases related to the thesis

The purpose of Appendix B is to give a more thorough presentation of the projects and cases related to this thesis, than given in chapter 1.2.2. In chapter 1.2.2 four projects were shortly described (P2005, Smartlog, Moment, and Ecosell) and these will be presented in a more in-depth manner.

The candidate has been heavenly involved in these four projects, and the results of this these can in many regards be partial tracked back to these projects.

In addition to these four projects, there are also three projects/cases, which in figure 9 are called initial case studies (Glamox, Stokke and Mack). In figure 10, this is elaborated to:

- PhD project at Mack
- PhD project at Stokke
- Case study Glamox

These three projects/cases have a different role. They were conducted on an earlier stage (see figure 10), and there is no link between the projects/cases and the results of the thesis. However, they have played an important role in the formulation of the research project (rationale, assumptions, problems and objectives) of the thesis. Of these three projects/cases, the work done by Glamox is of most importance. The Glamox case has been to great inspiration for the research project, and will hence been presented in full. However, the PhD projects at Mack and Stokke can in many regards be viewed as “failures”, since both projects were terminated or not launched. The presentation of these two projects will therefore be less.

The Research Program Productivity 2005 (P2005)[69]

Productivity 2005 (P2005) is a Norwegian Research Council initiative to strengthen the competitiveness of the Norwegian manufacturing industry. The P2005 program is based at the Norwegian University of Science and Technology (NTNU), and has the following philosophy: "Developing competence in the Norwegian manufacturing industry to recognized international standards will be one of the most important competitive advantages for the Norwegian industrial community in the future. NTNU will work closely with partners in research institutes and industry in setting the pace for these developments in Norway".

Productivity 2005 focuses on:

- *Globalization* - Information and communication technology will have a key role to play in developing global production.
- *Environmental issues* - Environmental considerations place new demands on product design, selection of materials and the use of production resources.
- *Process mind-set* - The process mind-set breaks with the traditional functional organization and approaches, it focuses on the processes that will meet the needs of customers.
- *Multidisciplinary approaches and team work* - Successful, competitive solutions require input from many disciplines and specializations. A particular challenge linking advanced production technology at large and the organization and management of companies.

[69] The presentation of P2005 is taken from the P2005 webpage, www.P2005.ntnu.no

- *Strategic alliances* - These can be developed in the entire value chain between companies, universities and the research community. Strategic alliances will probably be one of the most important competitive pre-requisites for the 21st century.

The priority areas that P2005 focuses upon are the most important multidisciplinary activities in the program. This is where long-competence will be developed.

- *Industrial ecology* (IØK; industriell økologi) - In nature, an ecologically sustainable system is a complex web of organisms, where all materials and waste build cycles. A society that is organized according to the principles of industrial ecology will be similarly characterized by industry and industrial products forming value chains, where energy and materials enter that loops that are kept as closed as possible.
- *Corporate alliances* (BIN; bedrifter i nettverk) - Ever-increasing global competition challenges the ability of Norwegian industry to adapt to markets, products, technology and new forms of organization. Corporate alliances and networks are means of successfully tackling these challenges to competitiveness. By pooling the resources of research scientists, management and students, they can work in a concerted effort to build up innovative know-how in a laboratory of business opportunity.
- *Product development and production* (POP; produktutvikling og produksjon) - In the future, companies will need a holistic approach to their markets, products and production lines. In Product development activities, companies must perceive and interpret the rapid changes in markets and technology, and apply this understanding to new product generations. Furthermore a flexible and effective production plant is essential for the manufacturing of continually changing products. Product development and production explores the integration between market, product development and production.

This PhD has been affiliated to the corporate alliances sub project within the P2005 research program. The research activity within the corporate alliance sub-project is concentrated around three core themes:

- *Productions and Logistics Network* (PLOG; produksjons- og logistikknettverk) – focusing on the growth, development, design and operations of parallel production networks and integrated value chains.
- *Learning in Networks* (LÆN; Læring i nettverk) – focusing on improving the learning and communication process in networks.
- *Companies and Regions* (B&R; Bedrift og region) – focusing on the importance of the company’s regional network.

Various Norwegian companies have been involved in P2005, BIN and PLOG, such as Hydro Automotive Structures, Raufoss Technology, Stokke, Kongsberg Defense and Aerospace, and Mack.

Figure B-1 illustrates the thesis position within the organizational and research structure of the P2005 research program.

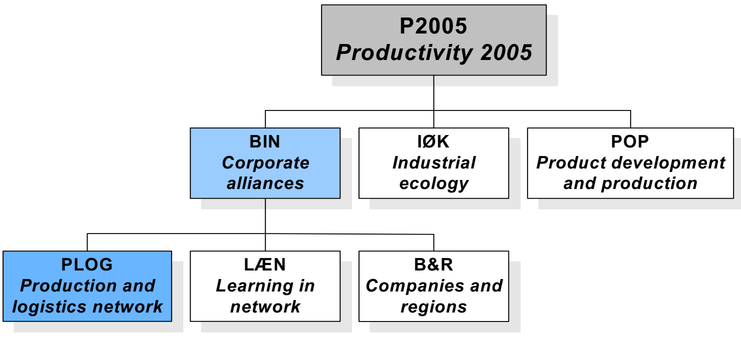

Figure B-1 This thesis position within the organizational and research structure of P2005

SMARTLOG[70]

SMARTLOG's (smart logistics for dynamic value chains) vision is to give Norwegian industry high international competence and knowledge within logistics of dynamic value chains. It aims at the same time to make SINTEF, MARINTEK and NTNU a leading national research and education arena for logistics with a technical and economical profile.

The program is performed in cooperation between several companies (partners) and research and education institutions, and a set of member companies (). The partners (HÅG, Raufoss Technology, Gilde and PipeLife) help finance the program together with the institutions and the Norwegian Research Council (MAROFF-program). The partners play a central role in the control of the program, and benefit from the results through cases and business projects. The program's most important way to disseminate acquired knowledge and results is the concept of SMARTLOG Membership (between 20-30 companies are currently members in SMARTLOG).

The research activity within SMARTLOG has been concentrated on three main topics:

- *Operations model for dynamics value chains* – the development of a set of models of the value chain for improved control of material and information flow.
- *Value chain strategy* – the development of a profiling tool for mapping and analyzing of value chain.
- *Value chain design and structure* – the development of methodologies and tools for value chain design.

MOMENT[71]

MOMENT (MObile extended Manufacturing ENTerprise) is a European research project funded by the EU Fifth Framework Programme (FP5), under the thematic programme GROWTH (Competitive and sustainable growth). The project started in May 2001, with durations of three years. Seven European partners from both industry and academia are working together, bringing in different knowledge and experience.

The MOMENT project has emerged as a response to the competitive pressure in the automotive sector. Original Equipment Manufacturers (OEMs) are seeking global first tier suppliers that are able to co-develop components for global product platforms, and fulfil requirements for just in time deliveries and continuous cost reductions (Morrel and Swiecki,

[70] The description of the SMARTLOG project is copied from www.smartlog.no

[71] The description of the MOMENT project is based on the *Description of Work (DoW) of the MOMENT* project (classified) and the paper *The Mobile Extended Manufacturing Enterprise* by Busi et al. (2003)

2001). Considering the actual competitive situation, companies must be able to relocate their production facilities in any place the customer could require and operate them in the most efficient way. A situation where manufacturers must establish several plants to produce almost identical products to globally distributed OEMs is becoming more and more common in the automotive supplier industry. In turn, this means that the whole value chain of one extended enterprise have to be re-designed, set-up, and operated; issues such as selection of suppliers, distributors, transporters, etc. must be analyzed in the shortest time possible and in the less costly manner.

The main achievement of MOMENT is a methodology to support rapid establishment and efficient operations of new Extended Manufacturing Enterprises in the European automotive and electronics supplier industry. The methodology will consist of methods, models, and tools that can be customised to local industrial conditions anywhere in Europe. The objectives of the MOMENT project can be divided into more specific objectives:

1. To develop a conceptual framework for the Mobile Extended Manufacturing Enterprises, i.e. mobile in the sense that processes and knowledge in existing Extended Enterprises can be rapidly transferred and implemented at new locations.
2. To develop an approach for the utilisation of performance indicators in Extended Enterprise environments.
3. To develop an operations model that enables standardised and high performance processes that are replicable and transferable.
4. To develop a software toolkit supporting strategic decisions and investment analysis for mobile Extended Enterprise establishment.
5. To develop the MOMENT methodology that consists of methods, models, and tools for the Mobile Extended Manufacturing Enterprise that can be customised to local industrial conditions at different sites in Europe.
6. Carry out comparative study of the transferability of the MOMENT methodology to other industries.

Figure B-2 illustrates the work-packages of the projects and the various projects phases, as well as the respective outcomes.

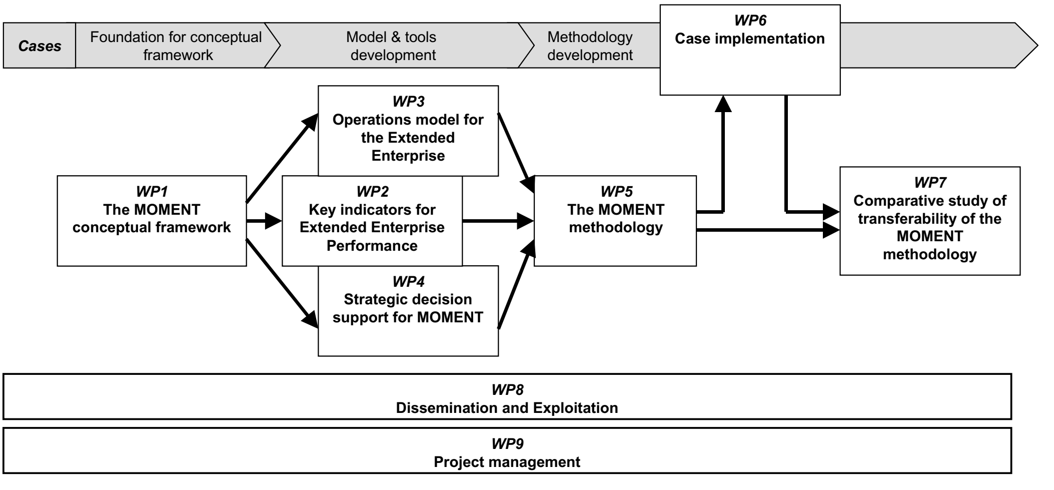

Figure B-2 Scheme of work-packages (WP) and project phases

ECOSELL[72]

ECOSELL (Extended Collaborative Selling Chain) is a European research project funded by the EU Fifth Framework Programme (FP5), under the thematic programme GROWTH (Competitive and sustainable growth). The project started in January 2003, with duration of 30 months.

In a world where the customer has become the new king, companies have to be fully customer- oriented, - customised and -governed in order to maintain their competitive advantage. Companies have to boost their added-value by aggregation of their own value proposition with those of other complementary value chains, building the so-called extended value proposition (EVP).

ECOSELL is about providing Extended Value Proposition based on the coordination of multiple selling points with multiple supply chains, where partners are willing to collaborate by integrating and coordinating through the use of IT systems. To build a successful meta[73]-selling chain, collaboration must be achieved at three levels (where each level builds on top of its underlying one and meta-value chain collaboration can only be achieved when all three domains become fully collaborative, see also figure B-3):

- The lower level is the company domain; the focus is put here on each single enterprise within the EE and leads to the collaborative enterprise
- The second level is the selling chain domain; the focus is put here on each selling chain within the EE and leads to the collaborative selling chain (COSELL)
- The higher level is the selling chains network domain; the focus is put here on the set of selling chains within the EE and leads to the extended collaborative selling chain (ECOSELL)

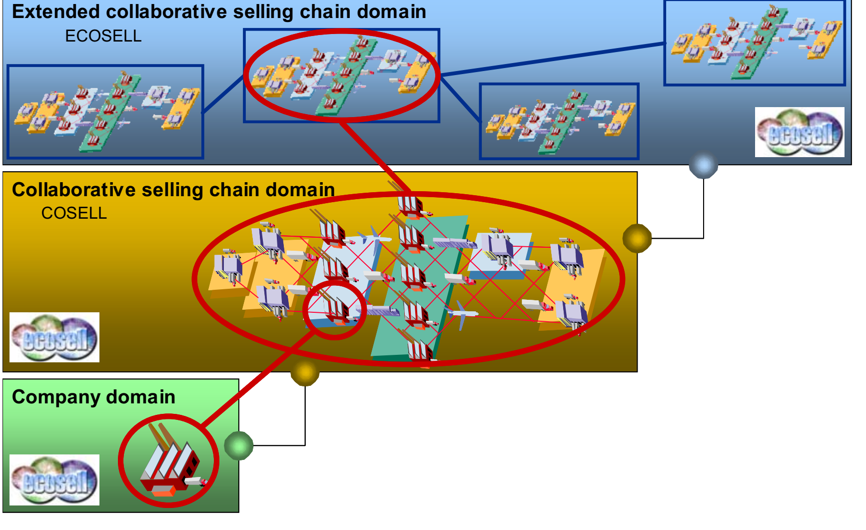

Figure B-3 Three levels of collaboration in the ECOSELL

The objectives of the ECOSELL project can be divided into more specific objectives:

[72] The description of the ECOSELL project is based on the *Description of Work (DoW) of the ECOSELL project* (classified)

[73] The prefix meta is used here to represent a higher level entity (i.e. the meta-value chain is a set of linked value chains).

- o Understand and analyse the selling chain and extended collaborative selling chain needs that arise for companies that face the challenge of building or joining an extended collaborative selling value chain.
- o Develop a general framework accessible and affordable both for large companies and especially SME, to help them in building a successful extended collaborative selling chain or in joining successfully an existing extended collaborative selling chain.
- o Cover the full life cycle of the engineering and operation of two pilots extended collaborative selling chains in the tile/furniture/glaze and tyres sectors.
- o Provide a methodology to define the requirements that a company which wishes to join an extended collaborative selling chain must fulfil, and assess the gap that will lead from their AS-IS to their TO-BE state.
- o Analyse and apply recent technological innovation trends to solve extended collaborative selling chain execution needs.

Table B-1 lists and describes the tangible outcome, i.e. products of the ECOSELL projects.

Product	***Description/Characteristics***
ECOSELL Architecture	It will be the global project architecture. It must be accessible and affordable both for large companies and especially SME, to help them in modeling a successful meta-selling chain.
ECOSELL Life-Cycle Management	It will be the global project methodology
ECOSELL Checklist	The result obtained in the project is a Word document that explain that points must be analyzed in order to achieve the Migration from AS-IS state towards TO-BE state to obtain the Business Modeling. This Checklist has been followed to carry out the improvements identification presented in this document.
ECOSELL Reengineering	The result obtained in this point will be Word document that will describe the necessary steps to achieve de ECOSELL Reengineering (roles, responsibilities, phases in the reengineering, etc.) in order to develop a Extended Collaborative Selling Chain.
Collaborative Order Management	Application developed to manage orders in real time for product pack components in order to offer a better service to the final client.
Collaborative Forecast Management	Application developed to manage and to show forecast for product pack components in order that every partner can optimize its production planning.
Extended Performance Management	Application developed to measure and manage performance along the extended collaborative selling chain
Extended Distribution Management	Application developed to manage distribution orders (preparation, load and transport orders) in real time for product pack components in order to offer a better service to the final client.
Collaborative Exception Management	Application developed to manage exceptions not to obstruct the daily production.
ECOSELL Cockpit	Application developed to be able to realize follow-up and continuous improvement of logistic and quality parameters when different partners works together.
Knowledge Management	Knowledge networks and repositories development to share knowledge with Consortium partners.

Table B-1 ECOSELL Products

Glamox

Glamox is a Norwegian industry group developing, manufacturing and distributing professional lighting solutions worldwide. Glamox is an international company with production capacities in 5 countries across Europe, Asia and North America, a turnover of approximately 1.3 billion NOK and 1,250 employees. The group is divided in two separate sales divisions: European Professional Lighting (EPL) and Global Marine Offshore (GMO). European Professional lighting is the sales division for the countries where Glamox has established franchise companies themselves. In these markets the company has two brands: Glamox and Hövik. The GMO division focuses on e.g. marine/offshore installations, an area where Glamox is one of the most significant deliverers in the world. The GMO division also works with lighting projects based ashore all around the world.

Revitalizing Glamox – Reclaiming the industrial leadership

In 1998 the strategy process "Revitalizing Glamox – Reclaiming the industrial leadership" was launched, see figure B-4. This process was based on a pre-study done in 1997. The pre-study aimed to analyze the market situation, both present and in the future, and map the strengths, weaknesses, possibilities and threats for Glamox. Based on this pre-study it was formulated business and economical goals, as well as detailed strategies for the company.

The background for starting up this project was Glamox's bad function towards customers, with failing communication and an ineffective value chain. The objective for this strategy process was to achieve a profit margin of 8% (or at least 100-mill NOK operating profit) within two years. Lost market share should be regained and the customers should experience Glamox as the leading company in the chosen core business areas.

The project (Revitalizing Glamox – Reclaiming the industrial leadership) had two cornerstones:

- Market Strategy Portfolio Analysis
- Value Chain Reengineering

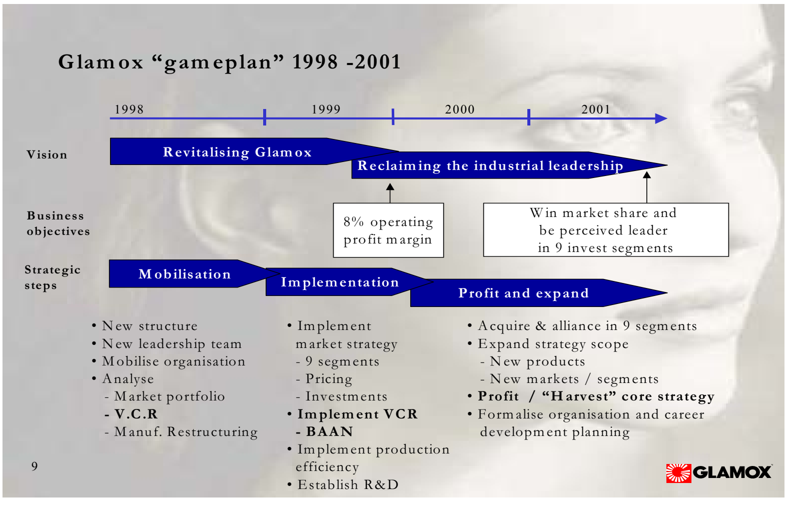

Figure B-4 Revitalizing Glamox – Reclaiming the industrial leadership

The first element, "Market Strategy Portfolio Analysis", was based on the McKinsey Industry attractiveness-Business strength portfolio matrix and the M.E. Porter's five-forces and value chain models (Porter, 1980, 1985), where all of Glamoxs business areas were systematically and thoroughly analyzed. This concluded in an action-oriented market strategy, with 9 segments as future core business areas.

The second element, "Value Chain Reengineering" (VCR), aimed to totally rearrange the value chain in order to achieve a simple, efficient and comprehensive value chain. The reason for this project was the inefficient value chain, the lack of ability to satisfy the customers and a frustrating environment for the employees. The VCR project aimed to implement digital work processes throughout the company. The purpose of the digital work processes was that all communication between customers, sales personnel, logistic centers, production plants and suppliers were meant to be digital as illustrated in figure B-5. The VCR project was mainly an ICT-project with 7 sub-projects, whereby implementing Baan (ERP-system) and making Glamox e-business ready were two of them.

Glamox believes that e-business can increase the turnover for the company, contribute to gain market shares and rationalize the internal value chain. E-business is regarded as important for the business, and the first company to launch it in the market will get a lead.

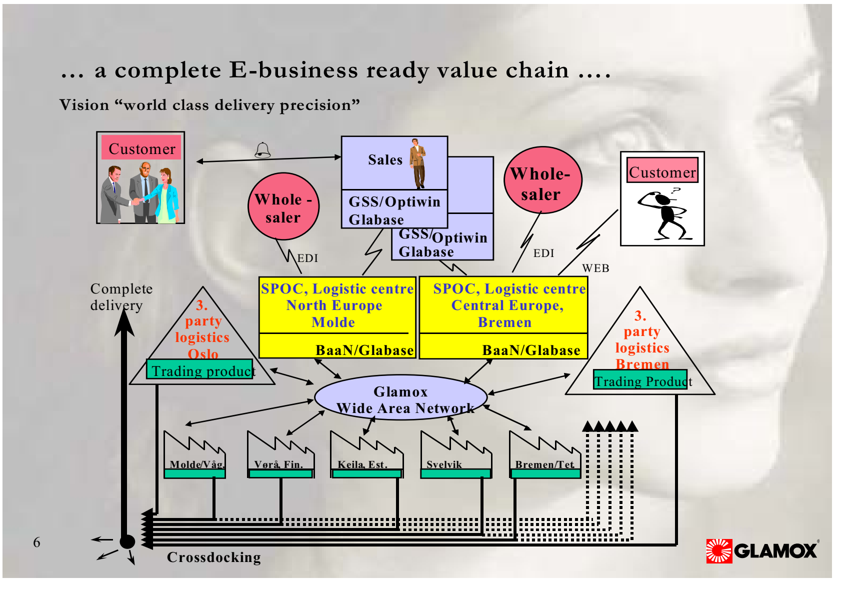

Figure B-5 A complete e-business ready value chain

Even though Glamox claims that the VCR-project was mainly an ICT project (in regards of investments), it would not have been carried out without the necessary restructuring of the value chain. It was the restructuring of the value chain that triggered the other parts of the project. A crucial element in the restructuring was the change of manufacturing strategy. Firstly, the company had done a focusing of the factories, based on products families and competence, see figure B-5. Secondly the principles of manufacturing have also been changed, from make-to-stock to make-to-order.

E-logistics at Glamox: Going from a "brick and mortar" to a "click and mortar" company

The logistic division is built around two logistic centers, see figure B-5. The purpose of these two centers is that they should function as a single point of contact (SPOC) for the customers. They are responsible for the order processing, logistic coordination and to coordinate the deliveries. In addition they are also responsible for support and divergence on orders. The distribution are executed by use of two 3. Parts warehouses and cross docking (from the different production plants and the 3. Parts warehouses).

In the following we will highlight some of the results and consequences from executing the VCR project. We will primarily focus on the internal and external integration that have taken place in order to make Glamox so called e-business ready.

The new internal electronic value chain

Earlier the company had 25 different ICT systems installed within the company. During the project these were replaced by one ERP system (with three special programs in addition) with one common database for all the plants. Thereby all employees are using the same system and the knowledge, integration and co-ordination between the different plants are increased.

The Value Chain Reengineering project was a typical business process reengineering project, a BPR project, confer theoretical part, were the goal is to dramatically change and improve the business structure of a company. There were four important conceptual elements in the reengineering of the value chain at Glamox.

The vision of “the mobile salesman” has been the cornerstone of the restructuring and simplification of the value chain. This means that the process from order to delivery has been redesigned and standardized in order to find the optimal way of serving the customers the best possible way. Now each salesman is equipped with portable computers installed with a customer relationship management (CRM) system, called Glamox Sales System (self developed). The salesman connects to the network and the main system either via mobile or fixed communication, and is able to transfer information electronically to the BaaN ERP system and to get out on-line information.

The second element is the idea of “Single Point Of Contact” (SPOC). From all points of the network Glamox employees have access to all kind of information and are able to carry out all types of transactions. This has made it possible to centralize logistics information to two main logistics centers. The sales representatives work now directly towards their “Single Point Of Contact” at one of the logistic centers. The SPOC is the sales representative’s permanent contact person and takes the responsibility from order entry through the delivery chain until the order is delivered and invoice sent.

The third element is the concept of “Modular Products”. All new “high end” products developed in Glamox lately, demanding a considerable extent of flexibility, are now constructed on modular basis production. This means that with a few basic common components various complete products can be assembled in a short time, and only the basic modules are stored (“mass customization”).

The last element is the idea of “Complete deliveries to customers direct from factories and 3. party stock via cross docking”. The modular product design philosophy makes it possible to deliver directly from factories, or should an order consists of products manufactured by several factories and stocks, it is possible to make all products to meet somewhere on the road to the customer, through the cross docking system. In this way the customer receives a complete delivery and one invoice.

The new external value chain

Glamox is now in the project phase to undertake the electronic integration of external co-operation partners, that is customers and suppliers. The aim is gradually to obtain the same degree of seamless integration with the company's surroundings as they have achieved internally between the different companies in the Glamox group. The biggest customers in Norway have already been connected to make transactions through EDI solutions. Internet and Extranet solutions will also play along in this integration process. The company has the intention of launching an e-service menu with priority.

Glamox has approximately 150 suppliers of critical components for the production. Of these 150 suppliers about 10 are chosen to contribute in the research and development tasks. These are supposed to be tightly integrated into the value chain with high degree of exchange of information. The most important suppliers are now ready to interact digitally with Glamox (either by EDI or other IT-solutions).

Stokke

Stokke AS is a Norwegain company with headquarters located in Ålesund. The company was established in 1932 and has historically produced a wide range of furniture for different needs and target groups through the years, focusing on ergonomics, uniqueness and functionality.

The PhD project at Stokke was supposed to be in two stages:

1. A material flow re-design project at one of the five Norwegain factories.
2. A production network strategi project, including all factories.

Phase two of the projects was never launced, so the project was terminated after the material flow re-design project was finished.

However, the ideas from the production network strategi projects gave later inspiration to the reseach interest in "planning and control of manufacturing and logistics in the Extended Enterprise".

Mack

Mack (A/S L. Mack's Ølbryggerie & Mineralvandgabrik) is the world most northern brewery, located in Tromsø, Norway. The company was established in 1877, and are today one of the few independent small brewery left. At the time of the PhD project Mack had a market share of 4% of the mineralwater/soda market and 7% of the beer market in Norway, and there was one dominate actor in the market (60% market share).

The PhD project at Mack focused on how Mack was more or less forced to form an alliance (within procurement) with some of its competitors to be able to compete against the big and dominate actor. This alliance was a great success and gave Mack (and the other small breweries) huge cost cuts and prices equally to the big actor.

However, the project was terminated after some months. But still, the success of collaboration between independent companies, gave motivation to further focus on collaboration in the value chain.

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Appendix C –

Reseach methods (case, action and literature review)

Appendix C – Reseach methods (case, action and literature review)

The reseach method in this thesis is a combination of case study, action reseach and literature review. Appendix C will give a more in-depth presentation of these reseach methods, than the presentation that was given in chapter 1.

Case study

A case study is "*an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*"(Yin, 1994). Further, the case study inquiry (Yin, 2003):

- copes with the technically distinctive situation in which there will be many more variables of interest than data points, and as on result
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- benefits from the prior development of theoretical propositions to guide data collection and analysis.

In other words, the case study as a research strategy comprises an all-encompassing method, covering the logic of design, data collection techniques, and specific approaches to data analysis (ibid). Eisenhardt (1989) highlight five important characteristics of the case study approach that are much in line with Yin:

1. The case study is a research strategy which focuses on understanding the dynamics present within single settings
2. Case studies can involve either single or multiple cases, and numerous levels of analysis
3. Case studies can employ an embedded design, that is, multiple levels of analysis within a single study
4. Case studies typically combine data collection methods such as archives, interviews, questionnaires, and observations.
5. Case studies can be used to accomplish various aims: To provide description, test theory or generate theory.

Case studies can be used for different purposes. Yin (2003) distinguishes between three types of case studies: 1) An *exploratory case study* is aimed at defining the questions and hypotheses of a subsequent study (not necessarily a case study) or at determining the feasibility of the desired research procedure. 2) A *descriptive case study* presents a complete description of a phenomenon within its context. 3) An *explanatory case study* comprises data bearing on cause-effect relationships, explaining how events happened. And Yin (op cit) also present at least four applications of the case study method: 1) to explore situations in which the intervention being evaluated has no clear set of outcomes; 2) to explain complex causal links in real-life phenomena; 3) to describe real-life context within which the phenomenon exists; and 4) to describe the phenomenon itself.

Although case studies are typically considered to be qualitative studies, they are not necessarily only qualitative. Quantitative methods may be appropriate as well (Näslund, 2002). Thus, case studies can be based on both quantitative and qualitative evidence, sometimes only quantitative (Bryman, 1989, Eisenhardt, 1989, Yin, 1994, 2003, Ellram, 1996, Meredith, 1998).

One of the most frequently discuss issues regarding case studies, are the debate about the use of single or multiple cases in the case study. Stake (1994) argues that a case study is mainly about what can be learned from the in-depth investigation of a single case. Stake (op cit) states: “Generalizations from differences between any two cases are much less to be trusted than generalizations from one”. A single case is suitable when that case represents a critical case to test well-formulated theory, an extreme or unique case, or a case which reveals a previously inaccessible phenomenon (Ellram, 1996). Other authors like (Bryman, 1989, Eisenhardt, 1989, Ellram, 1996, and Yin, 2003) argue that multiple cases are preferable in some situations. Multiple cases are a powerful means to create theory because they permit replication and extension among individual cases (Eisenhardt, 1991). Replication simply means that individual cases can be used for independent corroboration of specific propositions. This corroboration helps researchers to perceive patterns more easily and to eliminate chance associations. Extension refers to the use of multiple cases to develop more elaborate theory (ibid).

According to Näslund (2002) there seems to be paradigm divide when referring to case studies between authors like Yin (1994), Eisenhardt (1989) and Ellram (1996) who all seem to belong to a positivist paradigm, and authors like Silverman (1993), Stake (1994), and Van Maanen (1995) who seems to be less positivist.

Benbasat et al. (1987) identify three outstanding strengths of the case study approach: 1) The phenomenon can be studied in its natural setting and meaningful, relevant theory generated from the understanding gained through observing actual practice. 2) The case method allows the much more meaningful question of why, rather than just what and how, to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon. 3) The case method lends itself to early, exploratory investigations where the variables are still unknown and the phenomenon not at all understood. The case study approach is also meet with criticism and scepticism. Some of the difficulties of doing case research are the requirements of direct observation in the actual contemporary situation (cost, time, access hurdles), the need for multiple methods, tools, and entities for triangulation, the lack of controls, and the complications of context and temporal dynamics (Meredith, 1998). Another serious disadvantage of the case method is the lack of familiarity of its procedures and rigor by our colleagues (ibid). Aldag and Stearns (1988) point out that qualitative research in general is commonly perceived as exhibiting a tendency for construct error, poor validation, and questionable generalizability.

Action research

Action research can be seen as a variant of case research/study (Bryman, 1989; Westbrook, 1995; Näslund, 1999). However, in action research the researcher does not remain an observer outside the subject of investigation but becomes a participant in the action, and the process of change itself becomes the subject of research (Checkland, 1993).

Action research is an approach to applied social research in which the action researcher and a client collaborate in the development of a diagnostics of and solution for a problem, whereby the ensuing findings will contribute to the stock of knowledge in particular empirical domain (Bryman, 1989). The emphasis tends to be upon the need to understand a total system in conducting such an analysis, so that many action research projects are in fact special kinds of single case study, though there are examples of multiple case study projects (ibid).

Action research is a generic term, which covers many forms of action-oriented research approaches. Within the broad family of action research there a couple of different approaches. Kemmis and McTaggart (2005) lists seven different approaches of action research: 1) Participatory research, 2) critical action research, 3) classroom action research, 4) action learing, 5) action science, 6) soft systems approaches, and 7) industrial action research. However, and as proclaimers of different schools clearly stress, the similarities between the different approaches far outweigh the difference (Näslund, 1999).

The main characteristics of action research are summarized as follows (Gummesson, 2000):

- *Action researchers take action*. Action researchers are not merely observing something happening; they are actively working at making it happen.
- *Action research always involves two goals*: solve a problem and contribute to science.
- *Action research is interactive*. Action research requires co-operation between the researchers and the client personnel, and continuous adjustment to new information and new events.
- *Action research aims at developing holistic understanding* during a project and recognizing complexity. As organizations are dynamic socio-technical systems, action researchers need to have a broad view of how the system works and be able to move between formal structural and technical and informal people subsystems.
- *Action research is fundamentally about change*. Action research is applicable to the understanding, planning and implementation of change in business firms and other organizations.
- *Action research requires an understanding of the ethical framework, values and norms within which it is used in a particular context.*
- *Action research can include all types of data gathering methods*. Action research does not preclude the use of data gathering methods from traditional research. Qualitative and quantitative tools such as interviews and surveys are commonly used.
- *Action research requires a breadth of pre-understanding of the corporate environment, the conditions of business, the structure and dynamics of operating systems and the theoretical underpinnings of such systems.*
- *Action research should be conducted in real time*, though retrospective action research is also acceptable. While Action research is a "live" case study being written as it unfolds, it can also take the form of a traditional case study written in retrospect, when the written case is used as an intervention into the organization in the present.
- *The action research paradigm requires its own quality criteria*. Action research should not be judged by the criteria of positivist science, but rather within the criteria of its own terms.

Action research is applicable with highly unstructured problems which can be dealt with in an exploratory research design (Müller, 2005). Coughlan and Coghlan (2002) recommend the use of action research "when the research question relates to describing an unfolding series of action over time in a given group. Community or organization; understanding as a member of a group how and why their action can change or improve the working of some aspects of a system, and understanding the process of change or improvement in order to learn from it".

Action research follows a cyclic process. According to Kemmis and McTaggart (2005) the process of action research is generally thought to involve a spiral of self of self-reflective cycles of the following: a) planning a change, b) acting and observing the process and consequences of the change, c) reflecting on these processes and consequences, d) replanning, e) acing and observing again, f) reflecting again, and so on. This is in line with Coughlan and

Coghlan (2002) who claim that the action research cycle comprises types of meta-steps (se also figure C-1):

1. *A pre-step*: In this step, two questions are important: What is the rationale for action and what is the rationale for research?
2. *The main step* is divided into six other steps: Data gathering, data feedback, data analysis, action planning, implementation, and evaluation.
3. *The last step* is monitoring. Monitoring occurs through all cycles, and all action research continually monitor.

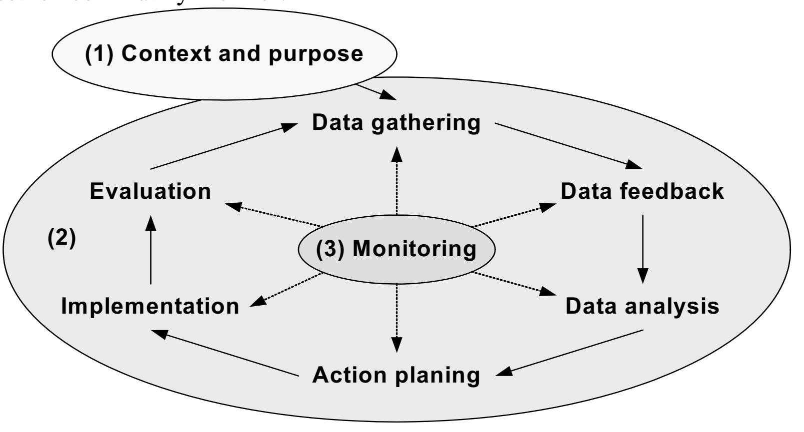

Figure C-1 Action research cycle
Adapted from Coughlan and Coghlan (2002)

Action research is based on a desire to escape from the traditional passive researcher role (Karlsen, 1991). Action research is rooted in the positivistic conflict between positivistic science and critical theory (Müller, 2005). Although it is possible to conduct action research in a positivist way, for example by attempting to change the organization from the outside and then measuring the results, in mot respects it derives from ideas that are alien to positivism (Easterby-Smith et al, 2002). As already mention in chapter 1.5.1 does Denzin and Lincoln (2005a) highlight action research as one of four main paradigms. This is supported by Müller (op cit) who point out that action research has been labeled as a paradigm since the 1970s.

Action research is often met with criticism from the more traditional research paradigms/researchers. The main criticism of action research is that the findings produced are just anecdotal evidence, and transferring the knowledge acquired in one research project to another context is difficult and sometimes even impossible (Blumberg et al., 2005). Another substantial criticism concerns the problems associated with the direct participation of the researcher and attempts to integrate research with organizational goals, which neglects the critical distance of a researcher essential for conducting good academic research (ibid). Further, although action research is design to change the environment, the researchers rarely have full control over the environment. And finally, action research is often wrongly accused for simply being consultancy (Westbrook, 1995).

Literature review

A literature review is a systematic, explicit, and reproducible design for identifying, evaluating, and interpreting the existing body of recorded documents (Fink, 1998). Literature reviews involve an in-depth analysis and critical summary of previously collected data (e.g., secondary data) for the purpose of identifying a research "gap" that needs to be addressed through future studies. Often used in exploratory and conceptual studies, a review of relevant literature assists researchers with producing a meaningful "map" depicting the existing connections between the different areas of literature and the research gaps identified relating to this research (Frankel et al., 2005). A literature review fulfills two specific functions (Seuring et al., 2005a):

- First, it helps to generate ideas for research and summarizes existing research by identifying patterns, themes and issues. This way, the literature provides a starting point for research.
- Second, any contribution to research, be it from conceptual or empirical work, has to be enfolded against existing theories (Saunders et al., 2003) as a means of thought organization (Brewerton and Millward, 2001).

Blumberg et al. (2005) support this and stress that a literature review help establish the context of the problem or topic by reference to previous work, synthesize and gain a new perspective on the problem, and show what needs to be done in light of the existing knowledge.

A literature review is basically an iterative process of three tasks (ibid):

- Searching information (literature)
- Assessing the information obtained
- Synthesizing the assessment of information

It is likely that the preparation of a literature review will start with a ***literature search***. A literature search calls for the use of a library's online catalogue, and one or more bibliographic databases or indexes. Literature can be found in both primary and secondary sources (ibid). *Primary sources* are full-text publications of theoretical and empirical studies, and represent the original work (e.g. journals (refereed academic or professional and trade), books, newspaper and public opinion journals, conference proceedings/unpublished manuscripts, reports, and theses). *Secondary sources* are compilations of information, either in printed or digital form (e.g. dictionaries, encyclopedias, handbooks, directories, and databases such as EBSCO, IEEE Xplore Journals, Intertaconnect.com, ISI Web of Science, Science Direct and SpingerLink, and Wiley Interscience Journals). In addition to these two forms of sources, have the Internet become an important source of information over the last years (Easterby-Smith et al., 2002, Blumberg et al., 2005).

When ***reading an evaluating research*** there are two important questions (Blumberg et al., 2005): 1) Is the reading relevant for the study? 2) If it is relevant, does it add to the arguments or information addressed in the study? More specific there are at set of criteria one should consider when assessing the information (ibid):

- Prominence of information (article/book), documented by citations or the source
- Recency of the information
- Methodological quality of the information
- Comparability of the arguments in the study with the arguments put forward in the information
- Uniqueness of the information

A literature review is a piece of academic writing and it must be ***logically structures and clear***. Any review of literature requires you to deliver an appropriate summary of prior work. However, is more than a well-structured summary of the literature; a good review also contains considerable insight from the writer, as it is not only a précis, but a well-reasoned piece of criticism too (ibid).

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