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SUPPLY CHAIN COORDINATION – STUDIES ON PLANNING AND INFORMATION SHARING MECHANISMS

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Abstract

Supply chain information flow significantly influences material flow behaviour. To improve supply chain performance, efficient information sharing practices are largely recommended. However limited knowledge exists on how companies should choose their supply chain planning approaches and the extent to which information is required. Additionally, current literature does not give answers to the question of which situations, or during which supply chain phase, vendor managed inventory, VMI is an efficient replenishment mechanism.

This research treats the selection of coordination mechanisms, especially supply chain planning and VMI, for manufacturing companies. The coordination theory is applied to provide a theoretical basis to consider how companies can jointly manage business processes across the supply chain. The research questions are (1) how to select operational coordination mechanisms to match demand and supply in manufacturing companies, and (2), how reach the balance between information flow and material flow by the use of chosen mechanism. The thesis consists of six studies, which contain three empirical case studies and three studies where both modeling and case study research approaches are used. The studies are reported as six research papers.

A framework on selecting the supply chain coordination mechanism is developed based on literature findings. The framework suggests that the selection should take place according to the match between execution flexibility and information abundance. Information sharing should target on providing accurate and good-quality information for the decision-makers. Flexible operations should be supported with frequent planning practices that capture information quickly. If execution flexibility is low, it needs to be supported with more stable planning. This framework is used as a tool to analyse the results from papers.

Two main reasons for the imbalance between material flow and information flow was identified. Frequent plan updates according to demand changes, varying planning prosesses and horizons caused planning nervousness. This phenomenon caused bullwhip and large volume changes at the supplier. The other reason was lack of planning capability, inadequate information or inability to use shared information. Planning nervousness can be reduced with stabilising planning and synchronising information sharing between supply chain players.

The suitability of VMI was measured with supplier's reaction time. The time benefit for the supplier is dependent on the delays caused by order batching. It was observed that suppliers' long production planning horizon and infrequent production makes benefiting from VMI more challenging for manufacturers. Improving the quality of shared VMI information takes place by offering the right information and improving downstream planning.

Keywords: Supply chain, supply chain coordination, coordination theory, supply chain planning, information sharing, vendor managed inventory (VMI).

Tiivistelmä (Abstract in Finnish)

Toimitusketjun tietovirta vaikuttaa oleellisesti materiaalivirran toimintaan. Toimitusketjun tehostamiseksi on esitetty laajaa ja läpi ketjun ulottuvaa kysyntä- ja muun operatiivisen tiedon jakamista. Kirjallisuus ei kuitenkaan tarjoa riittävästi tietoa siitä, miten toimitusketjun suunnittelutavan ja tiedonjakotavan valinnalla parhaiten tuetaan materiaalivirtaa. Lisäksi kirjallisuus käsittelee vain rajallisesti sitä, missä tilanteessa ja toimitusketjun vaiheessa toimittajan hoitama varastotäydennys (vendor managed inventory, VMI) on tehokas toimintamalli.

Tämä tutkimus käsittelee toimitusketjun koordinaatiomekanismien valintaa valmistavien yritysten näkökulmasta. Koordinaatioteoriaa sovelletaan tutkimuksessa teoriapohjana sille, miten yritykset voivat yhdessä hallita liiketoimintaprosesseja toimitusketjun läpi. Tutkimuskysymykset ovat 1) kuinka koordinaatiomekanismi valitaan yhdistämään kysyntää ja tarjontaa valmistavissa yrityksissä ja 2), kuinka valittujen mekanismien avulla saavutetaan tasapaino tietovirran ja materiaalivirran välillä. Tutkimuksessa keskitytään kahden mekanismin tarkasteluun, jotka ovat toimitusketjun suunnittelu ja VMI. Väitöskirjaan sisältyy kuusi eri tutkimusta: kolme empiiristä tapaustutkimusta, ja kolme tutkimusta, joissa mallinnus ja tapaustutkimus vuorottelevat tutkimusotteena.

Kirjallisuuden perusteella kehitettiin viitekehys, jonka mukaan toimitusketjun koordinointimekanismi valitaan ketjun jouston ja tiedon määrän mukaan. Tiedon jakaminen tähtää täsmällisen ja laadukkaan informaation tuottamiseen ketjun päätöksentekijöille. Joustavaa toimitusketjua täytyy tukea nopeasti ja tiheästi reagoivalla suunnittelutavalla, mikä edellyttää runsasta, tiheää ja laajaa tiedon jakamista ketjun sisällä. Joustamatonta toimitusketjua sen sijaan tuetaan parhaiten stabiililla suunnittelulla, johon riittää harvempi tiedonvaihtorytmi ja suppeampi tietomäärä. Tämä viitekehys on työkalu, jolla eri tutkimuspapereiden tuloksia analysoidaan.

Tutkimuksessa havaittiin kaksi syytä tietovirran ja materiaalivirran epätasapainoon. Tulosten mukaan hermostunut suunnittelutapa toteutuu tilanteessa, jossa suunnitelman päivitykset ovat tiheitä verrattuna materiaalivirran reagointikykyyn. Syitä tähän ovat toimitusketjun toimijoiden toisistaan poikkeava suunnittelutiheys, erilaiset suunnitteluprosessit ja eripituiset suunnitteluhorisontit. Tämä ilmiö voimisti toimitusketjun piiskavaikutusta ja aiheutti suuria volyymivaihteluita toimittajalla. Toinen syy epätasapainoon oli suunnitteluosaamisen puute, riittämätön tiedon määrä tai kyvyttömyys hyödyntää jaettua tietoa. Suunnittelun hermostuneisuutta voitiin vähentää stabiloimalla suunnittelua ja synkronoimalla tiedon jakamista toimitusketjun osapuolten välillä.

Tutkimuksessa VMI-toimintatavan soveltuvuutta ja hyötyä mitattiin toimittajan reagointiajalla. Toimittajan aikahyöty riippuu tilausten muodostamisessa syntyvästä tiedonvälitysviiveestä, ja on suurimmillaan harvoin tilattavien tuotteiden kohdalla. Huomattiin, että toimittajan pitkä suunnitteluhorisontti ja harva tuotantorytmi vähentävät VMI-toimintamallin hyötyjä. Onnistunut VMI toteutus edellyttää oikean tiedon jakamista ja suunnittelun laadun parantamista ketjun alavirrassa.

Avainsanat: Toimitusketjun hallinta, toimitusketjun koordinointi, koordinaatioteoria, toimitusketjun suunnittelu, tiedon jakaminen, täydennysyhteistyö (vendor managed inventory, VMI).

Foreword

It took a long time after my Master's degree in 1988 before I even considered starting post-graduate studies. I was working in a retail and wholesale company when a colleague encouraged me to attend a Licentiate's seminar at Helsinki University of Technology. Each Wednesday evening after work we drove in his terrible old car through Helsinki to Otaniemi to listen to Professor Eloranta and the participants in the seminar, who presented their research plans. After the seminar my studies proceeded slowly, until I happened to see an announcement for a grant for full-time postgraduate studies. I applied, Professor Eloranta wrote a recommendation, and to my great amazement a one-year scholarship was granted to me. I took time off from work, and suddenly I was alone at home and had to start studying. After nine months I had passed exams worth 35 credits and written my Licentiate's thesis. Then I took a month's holiday and went back to my work.

Again, time passed by. I had secretly planned to continue, but did not know how. I had been offered a promotion and worked long hours and no time was left for studies. When I was on maternity leave with my first kid, the phone rang. It was Professor Tanskanen, my Licentiate's thesis supervisor, who offered me a job in a new research project at Helsinki University of Technology. During the phone call he said the magic words: 'Now that you have a baby, note that we have free working hours here.' I accepted his offer right away, because I had already become worried about the challenge of combining a small kid and a demanding job. I guess Professor Tanskanen did not have any idea how much I would use this opportunity.

Starting to work as a researcher was not easy. I felt I had a huge knowledge gap to fill, even through I had plenty of work experience. Furthermore, I worked part-time and my research progressed slowly, which was difficult to tolerate. Fortunately, I had competent supervisors from whom I could get help and expertise on how to direct my research, and, unlike when I was writing my Licentiate's studies, I had colleagues who offered the chance of discussions and gave advice. Little by little I got a grip on the research work and I was fortunate enough to participate in interesting projects with companies. In the end the research turned out to be pleasant and rewarding, and, during the writing of this thesis, even enjoyable.

Acknowledgements

I wish to thank Professor Kari Tanskanen, the leader of the Logistics Research Group, for offering me the opportunity to work at Helsinki University of Technology. Professor Tanskanen has the capability to analyse and discuss different studies in a skilled and constructive way. His professional skill really became evident when he was commenting on my dissertation. I am indebted to Dr Jan Holmström, my instructor, who has helped me in many ways during these years. He offered his expertise in scientific work and in publishing research results. He has the ability to identify interesting and novel ideas and to push them forward. The advice he gave me during the writing of this thesis was valuable. Without his contribution this thesis would have taken a quite different form.

I am also grateful to the pre-examiners of the thesis, Professor Jan Olhager and Professor Ulla Tapaninen, for their valuable and encouraging comments on my thesis manuscript. Professor Eloranta I thank for positive comments during writing papers.

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I also wish to give my thanks to the logistics experts in companies I have got to know in various research projects. Of them I am especially grateful to Helena Hartiala, Mikael Hellström, Santtu Kallionpää and Hille Korhonen,who have all contributed to my research as co-authors. I thank Miikka Andersson, Esko Eerola, Pentti Halminen, Johanna Pakkanen, Jukka Rahikainen, Esko Rinne, Petri Soininen, Nina Tuomikangas, and Jyri Weiste for the time and effort they have given to the research projects. In all these persons I admire the enthusiasm and fire with which they are pushing supply chain management forward in the companies they represent.

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Otaniemi, October 2007

Riikka Kaipia

Roads go ever ever on

Roads go ever ever on,
Over rock and under tree,
By caves where never sun has shone,
By streams that never find the sea;
Over snow by winter sown,
And through the merry flowers of June,
Over grass and over stone,
And under mountains in the moon.

Roads go ever ever on
Under cloud and under star,
Yet feet that wandering have gone
Turn at last to home afar.
Eyes that fire and sword have seen
And horror in the halls of stone
Look at last on meadows green
And trees and hills they long have known.

J.R.R Tolkien , The Hobbit

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1 INTRODUCTION

1.1 Background

Coordinated upstream and downstream integration in the supply chain can improve and differentiate supply chain performance (Frohlich and Westbrook, 2001). In manufacturing companies, managing capabilities and resources across companies boundaries' becomes increasingly important and, therefore, should be an important element in manufacturing strategy. This, however, presumes that firms integrate their production and distribution networks, instead of merely the resources of an individual company. However, an integrated supply chain system is not always the main interest of individual members of the system. Consequently, supply chain coordination mechanisms are needed to change the behaviour of individual partners in the supply chain to improve supply chain performance (Li and Wang, 2007; Dyer and Singh, 1998).

Information flow significantly influences material flow behaviour. Traditionally, companies have operated in environments characterised by inadequate information (Patnayakuni et al., 2006). The placing of periodic orders has been the primary information-sharing mechanism. Supply chain choices, for example production and inventory decisions, have been made based on local information at the site of activity. This has led to operational inefficiencies in the form of excess inventories, increased operational costs and additional coordination costs (Li and Wang, 2007).

Supply chain managers are increasingly recognising the need to eliminate supply chain inefficiencies, and align the decisions and their execution more closely between the trading partners in order to achieve balance between supply and demand (Simchi-Levi et al., 2003; Fisher et al., 1994). Due to improved information availability, integration has become an alternative for supply chain parties. Companies are increasingly striving towards supply chain management (SCM), which can be defined as the coordination of the traditional business functions and the tactics deployed across these business functions (Mentzer et al., 2001).

1.2 The state of supply chain integration – gap between SCM theory and practice

The operational practices used to manage supply chains do not resemble the underlying principles of supply chain management theory (Fawcett and Magnan, 2002). According to Andraski (1998) only one in fifteen grocery supply chains utilize the opportunities of modern supply chain management to their advantage. A study among leading European companies revealed that the pace at which many companies are moving towards more integrated supply chains has been slow (Edwards et al., 2001). The study indicated that companies are more involved in internal integration than in external inter-organizational cooperation. Successful supply chain programs are rare and few companies are engaged in supply chains that are managed from suppliers' suppliers to customers' customers. This result is stunning, since a large international survey across a number of industry sectors clearly indicated that effectively managing a complex, global supply chain has a clear positive impact on a company's financial performance (Deloitte 2002, p. 3, 7-8). As a result, some companies have put *visibility* and *coordinating multi-tier supply chains* at the top of their priorities when striving towards supply chain excellence (Aberdeen Group, 2006, p. 2).

The lack of integrated end-to-end supply chain planning indicates that many companies have not yet properly understood the role of planning processes in managing their supply chain operations (Kumar, 2004). This may appear in difficulties in managing the operations, and consequently lead to inefficiencies such as high safety stocks, inability to manage seasonal demand patterns, long planning horizons or lack of processes to capture supply constraints such as in capacity and availability. Petersen et al. (2005) emphasize the principles of effective collaborative planning in improving supply chain and firm performance. Matching short-term demand and supply should be a fundamental component of the daily operations in manufacturing and service companies. However, our knowledge regarding process orientation and advanced planning across company borders is still in its infancy. The main research in this area has focused on the integration of individual organisations in two-level supply chains, not on integration across supply chain stages (Croom et al., 2000).

The barriers to implementing supply chain management principles in practice are recognised in several research articles. Moberg et al. (2003) name seven barriers: lack of trust, lack of understanding SCM principles, differences in goals and objectives, inadequate information systems and aiming at short-term shareholder value. One barrier, according to Moberg et al. (*ibid*), is the fear of losing competitive information or benefits gained from development work when companies are involved in multiple supply chains. In a USA-based study, the continual existence of functional silos, resistance to change, and poor communication are identified as barriers to adopting collaborative relationships between supply chain partners (Mentzer et al., 2001).

Furthermore, data-related barriers to integration have also been identified. The first problem is the abundance of transactional data for the purposes of managerial decision-making (Shapiro, 2001). The problem has become more acute during recent years because advance in information technology offer access to transactional data throughout the supply chain, and this increases the amount of available data. The second problem is confusion on how exactly each type of transactional data can be used. There may be confusion on how to integrate activities internally or externally with vendors or customers and how to benefit from the available information in achieving supply chain coordination. A further problem is connected to the growing role of demand forecasts as input data for decision making in planning processes. Frequently adjusting demand forecasts, in accordance to changing demand, can lead to dramatic changes in plans. This phenomenon is referred to as *planning nervousness* (Stadtler, 2005, p. 208).

Lack of integration initiatives cannot be blamed for the slow progress in supply chain-integration efforts. Initiatives to foster collaboration, such as collaborative planning, forecasting, and replenishment (CPFR) programs, offer multistage guidelines on how to implement deeper collaboration practices in a supply chain. Efficient consumer response (ECR), promotes excellence in four operational areas of the grocery industry: promotions, replenishments, store assortments and product introductions. Programs such as vendor managed inventory (VMI), quick response (QR), and continuous replenishment (CR) are targeting more efficient replenishment based on improved visibility of demand data (Barrat and Oliveira, 2001).

The use of supply chain planning and control tools and techniques has however, been moderate, and their use is mainly internal (Olhager and Selldin, 2004). The survey revealed that the ability to coordinate the supply chain was, on average, mediocre among the studied manufacturing companies, and that integration in supply chains concerns more commonly customers than suppliers. One reason for the low adoption rate of collaboration initiatives seems to be their complex structure, which makes the implementation of such initiatives a heavy and resource-consuming process (Småros, 2005, p. 130-132). This indicates that there is a need for simple supply chain coordination and integration solutions that take into account the available resources and capabilities to realise the changes in supply chains.

1.3 The focus and scope of the study

This research aims at identifying mechanisms for manufacturing companies to better coordinate their physical flow and information flow and to improve the match between upstream and downstream phases of their supply chains.

This thesis addresses coordination mechanisms at the operational level that match supply and demand in manufacturing companies. Operational coordination mechanisms include logistics synchronisation and information sharing (Simatupang et al., 2002). Coordination mechanisms that are concerned with organisational linkages, such as contracts, prices, discounts, and incentives are excluded in this study. The scope of this study is on long-term supply chains, and not project deliveries. Furthermore, the study focuses solely on manufacturing companies, not on service providers or distributors. Manufacturing companies are chosen because they occupy a central position in the supply chain and, as brand owners, have an interest to improve the supply chain performance. Contract manufacturers are not treated in this thesis, as they have little opportunity to control the supply chain. Centralised decision making is not treated in this thesis. The focus is on commercial supply chains, and coordination mechanisms to manage their decentralised decision-making and on the operational linkages between supply chain actors.

The study deals with two specific supply chain coordination-mechanisms in detail. The first is supply chain planning, or more specifically, managing the interface between demand

and supply, and the second is vendor-managed inventory (VMI). Both these mechanisms are treated from two perspectives: in which situations the mechanisms should be used and, second, how the mechanism can be used more beneficially. These mechanisms are studied in-depth for several reasons. The mechanisms include essential features to improve the balance between demand and supply, which make them attractive solutions for manufacturing companies. In addition, our understanding and knowledge of these mechanisms is not yet sufficient. For example, knowledge about the information-sharing benefits on supply chain performance is studied in the context of theoretical model-based research. Empirical research on the area is less prevalent. Previous research does not provide sufficient empirical evidence for practitioners on how to benefit from incremental information sharing in supply chains.

1.4 Theory applied

The coordination theory (Malone and Crowston, 1994) is applied in this thesis to provide a theoretical basis to consider *how* companies can jointly manage business processes across the supply chain. Coordination is more problematic in supply networks where business boundaries and supply chain phases cross. In such networks, focal companies may act as coordinators and link downstream and upstream operations and subsequently interact with them (Danese et al., 2004).

Coordination mechanisms provide a system for supply chain members to collectively create value and achieve improved supply chain performance (Lewis and Talalayevski, 2004). There are three means of doing this: sharing decision responsibility, sharing information, and logistics synchronization (Lee, 2000). Sharing decision responsibility refers to redeployment of decision rights, work, and resources to the best-positioned supply chain member. Logistics synchronization refers to organizing the supply chain according to the market: to mediate customer demand and to adjust inventory management, production, and transportation to meet the demand.

There are two principal methods to share authority within the decision-making process. The first is centralised decision making, where a single entity manages the network. The second is coordination with decentralised decision-making (Pugh et al., 1969a, 1969b;

Whang, 1995; Lee and Whang, 1999). Centralised decision-making requires that the decision maker has access to all relevant information concerning supply chain performance; which is rarely the case in reality (Li and Wang, 2007). Instead, each actor operates based on local and often asymmetric information and improves its own performance and pursues its own targets.

The focus of coordination may be on operational or organisational supply chain linkages (Figure 1). The mutuality of coordination requires sharing responsibility in achieving better performance. This can be achieved in two ways: by adding complementarity (how chain members collectively increase value) or coherency (creating common understanding). Coordination may focus on organisational linkages, and sharing benefits and risks. This type of coordination is needed to reward or penalize decision makers according to how their actions support reaching common targets. Coordinating collective learning means spreading knowledge and capabilities across organizational borders, targeting those capabilities that implement logistics improvement initiatives (Simatupang et al., 2002).

		Mutuality of coordination	
		Complementarity	***Coherency***
Focus of Coordination	Operational linkages	Physical Flow Coordination Object: products, services or logistics processes	Information Sharing Object: information
	Organisational linkages	Incentive Alignment Object: benefits and risks	Collective Learning Object: knowledge and capability

Figure 1. Modes of coordination (adapted from Simatupang et al., 2002).

A key focus of this thesis is on the coordination of operational linkages in a supply chain. These linkages concern information sharing and synchronising logistics processes. The latter coordination mode, synchronising logistics processes is also called physical flow coordination, (for example Sahin and Robinson, 2002), and this term will be used throughout this thesis. The focus in flow coordination is products or services and the logistics processes. Coordinating information sharing among supply chain members aims to give relevant, timely, and accurate information available for decision makers.

1.5 Structure of the thesis

This document comprises a bundled thesis. The thesis includes six research publications (Table 1), in addition to this compendium.

Table 1. Publications included in the thesis.

Paper	***Paper title***
1	Kaipia, R., Holmström, J., Tanskanen, K. (2002), "VMI: What are you losing if you let your customer place orders?", *Production Planning & Control*, Vol. 13, Iss. 1, pp. 17-25.
2	Kaipia, R., Holmström, J., Hellström M. (2007), "Measuring the benefit of changing the value offering in grocery supply chains", *Production Planning & Control*, Vol. 18, Iss. 2, pp. 131-141.
3	Kaipia, R., Korhonen, H., Hartiala, H. (2006), "Planning nervousness in a demand supply network: an empirical study", *The International Journal of Logistics Management*, Vol. 17, Iss. 1, pp. 95-113.
4	Kaipia, R., Holmström, J. (2007), "Selecting the right planning approach for a product", *Supply Chain Management – An International Journal*, Vol.12, Iss. 3, pp. 3-13.
5	Kaipia, R., Kallionpää S. (2007), "Exploiting VMI to increase flexibility in package material supply", in review in *The International Journal of Production Economics.*
6	Kaipia, R. (2007) "The effects of delivery speed on supply chain planning" forthcoming in the *International Journal of Logistics: Research & Applications*.

This compendium is organised as five chapters. Chapter 2 provides the theoretical background of the thesis: coordination theory, supply chain planning and VMI, and selected features of information flow and material flow. The final section of the chapter summarises into a framework the findings from the literature. Chapter 3 includes research questions, the methodology, short descriptions of each paper and the role of each paper in answering the research questions. Chapter 4 uses the framework derived from the literature survey to present results from Papers 1-6. Chapter 5 presents conclusions, discusses the results in the light of previous literature, and suggests further research. Discussion on the limitations of the thesis is included in Chapter 5.

2 THEORETICAL BACKGROUND

The theoretical background of this thesis includes the following topics: coordination theory, supply chain coordination, supply chain planning, information sharing, and supply chain flexibility. The chapter concludes with a framework that describes the relationship between the information flow and the material flow of a supply chain.

2.1 Coordination theory

Coordination is the management of dependencies between activities (Malone and Crowston, 1994). The purpose of coordination is to achieve collectively goals that individual actors cannot meet. Coordination capability is affected by two main issues: information sharing and allocating decision rights across channel members (Anand and Mendelson, 1997).

There are two approaches to achieve coordination. The first is to centralise decision making to a single entity, which attempts to optimise the network. The second type is decentralised decision making that utilises coordination mechanisms (Sahin and Robinson, 2002). Pugh et al. (1969a; 1969b) do not separate these approaches, but consider concentration of authority in relation to different contextual factors. The range of decision-making situations extends from detailed repetitive problems that can be solved with pre-established programs to non-programmed situations that concern non-repetitive strategic situations (Cyert et al., 1956).

Dependencies between activities are a prerequisite for coordination; if there are no dependencies, there is no need to coordinate. These dependencies stem from the lack of ability to control all the conditions necessary to achieve an action or a desired outcome (Petersen, 1999, p. 44). *Activities* may be organisations, processes, organisational units, or human beings that act in computational, human, biological, or other systems (Whang, 1995). Coordination may take place within operations, across functions (cross-functional coordination) or between organizations (interorganisational coordination).

The methods used to manage the interdependencies between activities are the coordination mechanisms. Coordination mechanisms provide tools for effectively managing interactions between people, processes, and entities that interact in order to execute common goals. A coordination mechanism consists of 1) the informational structure defining *who* obtains *what* information from the environment and *how* this information is processed and then distributed among different members participating in the mechanism itself; and 2) the decision-making process that helps to select the appropriate action to be performed (Marcshak and Radner, 1972, p. 45-47). Crowston (1997) extended the basis of interdependence to include tasks and resources.

Coordination theory extends and uses ideas from computer science, organisational theory, operations research, and economics. Coordination research in these disciplines has treated sharing resources, managing information flows, transaction costs, scheduling and queuing policies and techniques for making optimal resource-allocation decisions. Organisational researchers, for example Thompson (1967) and Galbraith (1977) target the question of how to achieve efficient and effective coordination among the activities in business processes and functions within companies. In Table 2, the types of coordination are matched with types of interdependence.

Table 2. Types of coordination.

Author	***Type of coordination***	***When used***
Thompson, 1967 Galbraith, 1970	Coordination by Standardisation	Establishing routines and rules for stable or repetitive situations, generalised interdependence. Requires least communication and low decision making effort.
Thompson, 1967 Galbraith, 1970	Coordination by Planning	Setting targets and schedules to govern the actions in interdependent units. Should be used in more dynamic situations than standardisation with sequential interdependence. Requires intermediate effort.
Thompson, 1967	Mutual adjustment	Involves new information transmission during the process or action, reciprocal interdependence, demands more effort.
Van de Ven and Delbecq, 1976	Team arrangement	Needed when interdependence increases.

Galbraith (1977, pp. 35-57) presents the concept of task uncertainty, which is defined as the absence of information or having information that is inadequate for performing the task. Effective organisations fit their information-processing capacities to the level of information they have. If an organisation is unable to accommodate the uncertainty with hierarchical solutions or with rules or procedures, it has two choices. It either has to reduce the amount of information to be processed for task execution or increase the capacity for processing information. Based on this principle, Danese et al. (2004) have added information-processing capability to coordination theory. They state that adoption of liaison devices, which include, for example, planning experts, enhances the information-processing capacity at the interface between units.

Grandori and Soda (2006), who present optimal coordination mechanisms under different dependencies (Figure 2), further develop these principles. The framework indicates how dependencies can be classified and which mechanisms companies should use to manage each class. Initially, slack resources are used to absorb the variability of demand, although it is a costly mechanism. If resources are constrained, as invariably they are, work queues that use time as a resource can be used. In this case, waiting time is the non-monetary pricing form for customers. The next class includes situations where actions can be specified according to contingencies under which a certain type of uncertainty will occur. Procedures and programs can manage these. If the uncertainties cannot be connected to special circumstances, i.e. they cannot be classified; a more adaptive mechanism to adjust to uncertainties is needed. In this situation, the efficiency of actions (referred to as A-uncertainty) cannot be predicted, and *ad hoc* communication is required. If A-uncertainty is combined with resource constraints, an information broker or central decision maker is needed to solve the problem of using pooled resources in an efficient manner. Last, more resource consuming mechanisms such as joint decision-making solutions, team arrangements or negotiation-type problem solving are used in situations where a central decision maker cannot be provided with all the knowledge relevant to the problem.

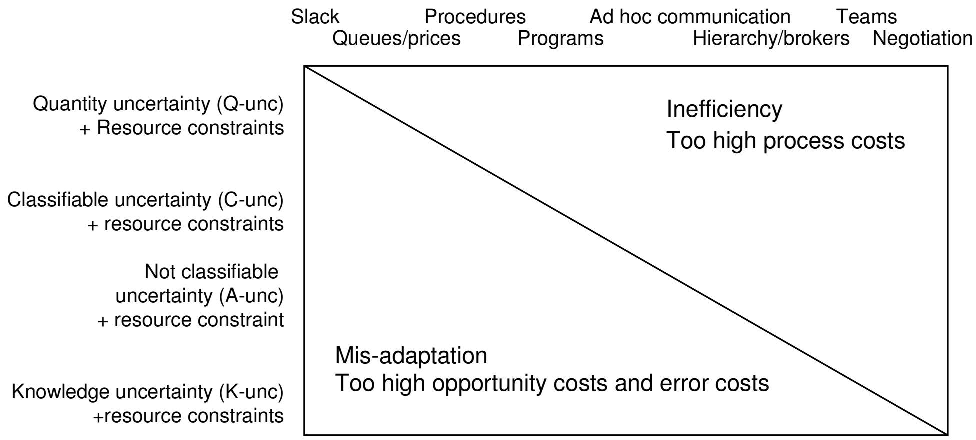

Figure 2. Optimal coordination mechanisms under different conditions of interdependence (Grandori and Soda, 2006).

In coordination theory, the information processing perspective of organisations is adopted (Galbraith, 1977, p. 35-57). This approach treats organisations as communication systems and decision-making systems that deal with uncertainty. Information processing in organisations includes the gathering of data, the transformation of data into information, and the communication and storage of information (Egelhoff, 1991). When expanding this view to supply chains, the information-processing capabilities can be expressed as capacities to transfer information within an organisation, to move it across the boundaries of an organisation and to access specific kinds of knowledge and decision-making capabilities to transform the data (Huber, 1982).

Characteristics of a generalisable theory include uniqueness, parsimony, fecundity, internal consistency, empirical risk, and abstraction (Wacker, 1998). What here is termed "coordination theory" does not fulfil all the needs of a theory. Malone and Crowston (1994), for example, refer to this topic as an 'emerging theory'. The theory is used in, for example, Crowston (1997) for analysing and redesigning processes, or Danese et al. (2004) in supply chains. The operations management research, likewise, even though it has widely treated coordination problems, does not consider this field as a fully developed theory.

2.2 Coordination in supply chains

Coordination is realised when a decision maker in the supply chain, acting rationally, makes decisions that are efficient for the supply chain as a whole (Gupta and Weerawat, 2006). Companies forming a supply chain are dependent on the performance of other organisations. The need to manage these dependencies and different resource flows is important for a company's success (Danese et al., 2004; Patnayakuni et al., 2006). Supply chain coordination is a vehicle for redesigning decision rights, workflow, and resources between supply chain members to leverage improved performance (Lee, 2000). Good coordination in the supply chain reduces uncertainty in manufacturing networks (Simatupang et al., 2004), which in turn translates into reduced variability. Some authors argue that coping with uncertainty is the primary motivation for supply chain coordination (Simatupang, et al., 2004).

Supply chain coordination offers a means to understand and analyse a supply chain as a set of dependencies. These dependencies exist both in physical flow, which is the flow and storage of goods, and informational flow, which deals with the storage and flow of information associated with those goods (Lewis and Talalayevski, 2004). In the traditional design of interacting flows, when the physical flow has been the basis for designing the supply chain, information flow may result in inefficient decision-making and movement of information. Advances in information technology have made it possible to separate the design of information flow from the physical flow by, for example, shortening the information flow. By such changes, the number of decision points can be reduced and the quality of decisions can be improved.

Coordination mechanisms provide tools for effectively managing interactions between people, processes, and entities that interact in order to execute supply chain objectives (Xu and Beamon, 2006). They are specific tools designed to address particular coordination problems (Fugate et al., 2006). According to Li and Wang (2007), an important supply chain coordination-mechanism is an operational plan to coordinate the operations of individual supply chain members and improve system profit. An additional coordination mechanism addressed here is VMI, where decision authority is allocated to the supplier.

VMI affects the match between supply and demand by eliminating one decision making phase in the supply chain.

2.2.1 Supply chain coordination vs. integration

This chapter discusses the relationship between coordination and supply chain integration.

Lee (2000) proffers three dimensions of supply chain integration (Table 3). The first dimension is 'information integration', when demand information, inventory status, capacity plans, production schedules, promotion plans, demand forecasts, and shipment schedules are shared. The 'coordination' dimension in the framework results in redeployment of decision rights, work, and resources to the optimal-positioned supply chain member. An example of this type of relationship is VMI. The final dimension, 'organisational linkages', includes channels of communication, common performance measures and incentives.

Table 3. Dimensions of supply chain integration (Lee, 2000).

Dimension	***Exchanges***	***How***
Information integration	Information, knowledge	Information sharing; collaborative planning, forecasting and replenishment
Coordination and resource sharing	Decisions, work	Decision delegation, work realignment, outsourcing
Organisational relationship linkage	Accountability, risks/costs/gain	Extended communication and performance measures, incentive realignment

In this integration framework, information sharing is treated differently than in coordination theory. Here, information integration is the foundation of broader supply chain integration. Lee (2000) states that, ' to coordinate material, information, and financial flows, companies must have access to information reflecting their true supply chain picture all the times'. In this approach, sharing of information and knowledge sharing are preconditions for commencing coordination. Only after these are realised, is coordination implemented. Coordination theory, instead, asserts that managing the information flow is one mechanism to realise supply chain coordination.

Supplier and customer relationships are presented as an integration continuum in Figure 3 (Spekman et al., 1998). The model indicates how a supplier may develop into a partner. In the first stage, the relationship is based on price negotiations and an adversarial relationship. In the 'cooperation stage', long-term contracts are established, and the number of suppliers is actively reduced. In 'coordination', (the next stage), information linkages enable wider and more routine information exchange. In most supply chains, all key supplier and customer relationships have achieved cooperation or coordination stages in their integration efforts.

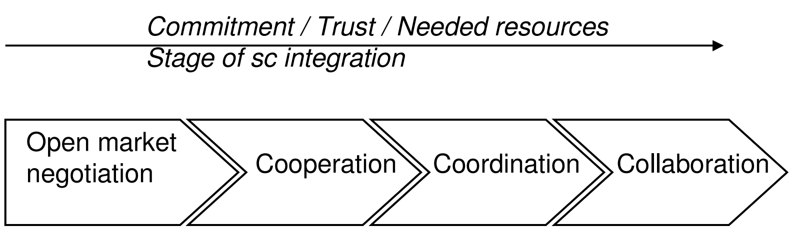

Figure 3. Continuum of integration from cooperation to collaboration (adapted from Spekman et al., 1998).

Hines et al. (2000, p. 320-322) present another example of coordination stages. They present a coordination framework for supplier development consisting of four phases. The first phase is labelled 'no-coherent strategy', when price is the primary buying criterion, and companies are not cooperating, nor developing a common way of working. 'Piecemeal coordination', the second phase, describes a situation where departments or instances are functioning with the relevant department in the supplier company. The third phase, 'systematic coordination', occurs when companies are working proactively to eliminate waste. 'Network coordination', the fourth phase, is realised if companies are developing methods and procedures to maximise benefit along the total supply network.

A similar integration model of Bacon et al. (2002), concentrates on informational linkages, and addresses levels of customer collaboration. The first level is a 'transactional relationship', which is the traditional way of operating, i.e. exchanging orders and invoices. In an 'information-sharing relationship', additional information, such as inventory levels or order status is shared. In the 'joint planning and development of business plans', the shared information is used interactively. The CPFR initiative aims to achieve this last form, whilst VMI can be described as an information-sharing relationship.

All three authors agree that integration improves supply chain performance, but implementing such a relationship is a challenge. Integrative linkages require trust, commitment, and resources that are not always possible to allocate to a specific supply chain relationship. However, not all relationships need to target the highest level of integration, but rather need to find an appropriate level to ensure an efficient supply chain. Most contemporary relationships are at the transactional or information-sharing levels. These observations concur with research results from an empirical study (Edwards et al., 2001), that suggests that few companies are externally integrated, and that higher level of integration requires new sets of skills and capabilities.

2.2.2 Supply chain coordination studies

Most supply chain coordination studies concentrate on pricing and contracting as coordination mechanisms; which are not in the scope of this research. A different stream of research concentrates on decision-making at different levels of centralization. A summary of studies concerning supply chain coordination is collected in Appendix 1. The most relevant recent studies on selecting supply chain coordination mechanisms are discussed next.

Sahin and Robinson (2005) studied the impact of five different information-sharing levels and physical flow coordination levels in a make-to-order supply chain. Under full coordination, one decision maker coordinates replenishments of the manufacturer, transportation provider, and vendor to obtain an efficient replenishment schedule. The other extreme is the traditional replenishment process with no information sharing except orders. Their simulation study indicated that costs are reduced on average by 47 per cent when shifting from a traditional to a fully integrated system, and that the cost savings are particularly due to improved coordination of decisions. Information sharing without decision-making coordination clearly has less impact on costs.

Xu and Beamon (2006) present a process for selecting a coordination mechanism. The selection was completed according to environmental factors that are expressed as interdependencies between organisations, uncertainty, and information technology. The features of a desired coordination mechanism are described using resource-sharing structure, level of control, sharing risk and decision style as the attributes. Then possible mechanisms to meet these features are listed. In the example given in the article, selection is carried out on market pricing, quick response, supplier-managed inventory (SMI) and strategic alliances. The coordination mechanism is selected that gives the desired features.

Simatupang et al. (2004) present a case study on how coordination mechanisms are carried out in practice, compared to theory. In their investigation in a fashion firm, they found that there was lack of shared vision and end-to-end supply chain planning and execution that impeded the adoption of coordination mechanisms.

Zimmer (2002) considered order and delivery decisions in a just-in-time environment, with one supplier and one producer. The target of the study was to find a coordination mechanism to improve decentralised decision-making. The model-based study revealed that in a decentralised decision making situation without coordination, the supply chain's total costs are higher than in a centralised system. When employing a coordination mechanism with information sharing and incentives, the decentralised system performance was at the same level as that of a centralised one. This result indicates that in supply chains with decentralised decision-making, the correct use of coordination mechanisms enables optimal supply chain performance.

2.2.3 Observations from coordination literature

Coordination theory is not widely applied or developed in the area of supply chain management. A selection of studies is discussed here that concern the selection of a coordination mechanism. Sahin and Robinson (2002) state that literature on supply chain coordination focuses on using pricing and discounting, as well as contracting, as coordination mechanisms. Supply chain coordination literature, however, does not, consider information sharing and physical flow coordination at the operational level.

Most coordination studies are model-based investigations into a strictly pre-defined problem, and studied in such a manner that the basic underlying tradeoffs can be modelled analytically. The literature describes the supply chain at a highly aggregated level and typically considers inter-firm coordination or a two-level supply chain. Multilevel investigations are rare; exceptions are multilevel inventory policy studies such as Clark and Scarf's (1960) research.

Coordination mechanisms have not been developed for a volatile supply chain system; for example, when demand and lead-time are stochastic. Frohlich and Westbrook (2001) state that there is lack of knowledge concerning the forms of integration that manufacturers should use to link with suppliers and customers. Additionally, how to connect available information to coordination mechanism is not addressed in the coordination literature.

2.3 Supply chain planning

In this section, literature concerning supply chain planning and VMI is discussed. The focus of this discussion is on supply chain planning literature that treats planning as a phenomenon. For example, the body of literature addressing information system solutions for supply chain planning is excluded. Furthermore, the wide stream of operations management literature focusing on separate planning phases, for example scheduling or inventory management, is excluded.

Supply chain planning is the set of activities that focus on evaluating demand for material and capacity, and formulate plans and schedules based on meeting the demand and company goals. Supply chain planning is concerned with the coordination and integration of key business activities undertaken by an enterprise, from the raw material procurement to the distribution of finished products to customers (Gupta and Maranas, 2003).

Planning may take place on strategic, tactical, and operational levels, which differ by time horizon, planning frequency and scope. Strategic or long-term planning models aim to identify optimal timing, location, and extent of investment in supply or distribution networks. Strategic planning involves resource decisions over the long term. Mid-term or tactical planning models address planning horizons of 1-2 years. They encompass, for example, inventory planning, and resource planning (Shapiro, 2001). The outcome of the tactical or mid-term planning process is a multi-period plan that includes (Zoryk-Schalla et al., 2004):

- products to be sold in a particular period of time; allocated to different markets; customers, sales offices or geographical regions;
- products to be manufactured at each facility in a particular time period;
- labour required to produce the products;
- raw material and inventory required to produce the products;
- products for which market demand exceeds production capacity;
- performance measured in terms of expected level of inventory at the beginning and end of the period; and inventory movements during the period;
- financial performance measures such as revenue, cost, and profit.

Short-term planning forms the link between medium-term planning and its execution; and it includes the exact sequencing of the manufacturing tasks, as well as resources and timing (Gupta and Maranas, 2003; De Kok et al., 2005).

Hierarchical planning describes the principle of consistency and coherence among supply chain decisions at various levels of planning (Shapiro, 2001). The planning phases are developed into a matrix of hierarchical supply chain planning activities, which uses information from, and provides information for physical activities in the short, middle and long term (Stadtler and Kilger, 2002; Stadtler, 2005, pp. 81-93). In the first instance, strategic, tactical, and operational planning levels are integrated. Another aspect of hierarchical planning, also referred to as inter-temporal planning, is supply chain planning for the product's life cycle. This planning covers aspects of initial design, introduction, and growth, with continuation to maturity and retirement.

Supply chain planning is the process that balances customer requirements with supply capabilities. Demand planning captures information on market demand and inventories, and then combines it with supply capabilities and constraints to develop a plan for future demand. The goal of the process is to capture sales opportunities and to reach business targets (Jordan, 2003). With suitable processes in place, management can proactively match supply with demand and execute the plan with minimum disruptions. The process includes forecasting, synchronising supply with demand, increasing flexibility, and reducing variability (Lambert, 2004). Supply chain planning starts with demand forecasting and demand planning. A demand forecast is the prediction, projection, or estimation of expected demand over a specified future period (Moon et al., 2000). Planning is the process of establishing management commitments that will allow the company to efficiently, and effectively, respond to the demand forecast.

One feature of supply chain planning is connected to the delays associated with information flow and the physical flow. De Kok and Fransoo (2003), who define an 'effectuation lead time', address this. This is the elapsed time between the decision taking and the time when consequences of the decision are observed in the operations of a supply chain. During these times, changes in the environment may have taken place and the decision may no longer support those circumstances.

There are multiple terms used to describe the process that, in this thesis, is titled *supply chain planning*. For example, Lambert (2004) uses the term *demand management*, and defines it as a balancing process between supply and demand. Compared to *supply chain management*, the term *demand chain management* emphasises consumer pull instead of supplier push. The latter is a useful term to emphasize the role of customer demand in managing the supply chain. Sometimes it is useful to differentiate between the demand chain, which creates demand, and the supply chain, which fulfils it. A demand chain is presented as the sequence of activities through which the supplier recognizes customer demand (Hoover et al., 2001). When the connection between the demand chain and supply chain is emphasized, the terms demand-supply chain and *demand-supply planning* may be used.

The process in which demand and supply are associated is referred to by at least five terms: balancing demand and supply (Stadtler, 2005), matching demand and supply (Fisher, 1997; Vitasek et al., 2003), synchronizing demand and supply (Edwards et al., 2001), integrating demand and supply (Reary, 2002) and aligning supply and demand (Lee, 2002). This process may be performed collaboratively as part of a decentralised decision-making solution (Dudek and Stadtler, 2005), or as a centralised decision. In this thesis, we use the term matching demand and supply.

2.3.1 Current supply chain planning practices

Innovative supply chain planning solutions have been presented in several recent studies. For example, Jordan (2003) describes a case study where both execution and planning processes are addressed. The purpose of the change, at a component manufacturer, was to match supply with demand as accurately as possible, while maximizing company profits. The article describes the change process, from a 'planning-based push strategy' to a 'lean pull supply chain' philosophy. Two large changes in the factory were implemented. The first was to modify machines to allow radically smaller production runs, and the other was to change the factory layout to reduce production lead times. An additional change was to synchronize production and replenishment to customer demand. In the system a component's production starts when at least two pieces of the component are withdrawn from the warehouse. Suppliers' replenishments are triggered as parts are consumed by production. With this *pull method*, the inventory levels remain relatively stable. The solution was therefore to use production rather than inventory to synchronize supply with the uncertain demand.

Additional successful supply chain planning cases have been described in several studies. These cases deal with, for example, challenges of integrated planning and scheduling (Reeder and Rowell, 2001; Kreipl and Pinedo, 2004), demand planning in electronics industry with short product life cycles and long supplier lead times (De Kok et al., 2005; Akkermans et al., 2004; Langabeer and Stoughton, 2001), and integrating demand and supply (Reary, 2002).

However, the current planning process in most companies is highly fragmented: the steps in the process take place independently and at different time intervals (Makatsoris and Chang, 2004). According to the authors in a typical planning process orders are received randomly, inventory availability is checked periodically, master planning and material requirements planning takes place weekly or every two weeks, production scheduling is daily or weekly, and raw material purchases are made periodically. Typically, the planning process is a mixture of automated and manual processes, and the decisions concern different product hierarchy levels; which consequently increases the variability of the total process. The current planning processes in companies may be complex and include multiple stages. Few companies have departments to carry out end-to-end supply chain planning, instead they are relying on separate (un-connected) forecasters, procurement planners, and production planners. Targeting a particular part of the process, for example increasing forecast accuracy, will not improve the response rate of the production process. In addition, knowledge regarding process orientation and advanced planning across company borders is still in its infancy phase (Croom et al., 2000).

The lack of an integrated planning process leads to many supply chain inefficiencies. These include high safety stocks, difficulties in managing seasonal demand patterns, insufficient demand forecasting, a long planning horizon, or inability to capture supply constraints concerning capacity or materials availability (Kumar, 2004). To this list can be added stock-outs, dissatisfied customers and poor financial performance (Jordan, 2003). Problems in matching demand and supply may lead to excessive levels of inventory created by unpredictable demand and difficulty in forecast accuracy. Planning complexity also increases when planning encounters problems of obsolescence caused by short product lifecycles and the growing demand for shorter lead times (Vitasek et al., 2003).

2.3.2 Studies on selecting a supply chain planning solution

This section presents studies that treat the question of how supply chain planning solutions should be selected. It commences with the selection of production processes in accordance with the product-process matrix (Hayes and Wheelwright, 1984). Although this framework does not address planning, it adds understanding to the evolution of supply chain strategies and their selection. This section continues with Fisher's (1997) framework on selecting the appropriate supply chain strategy; and draws on two studies where the framework is applied. Lastly is presented two approaches where a specific supply chain planning approach is chosen. A summary of the studies is depicted in Table 4.

Table 4. Studies on selecting a supply chain planning solution.

Author(s)	***Focus of the study***	***Determinants***	***Finding / Result***
Hayes and Wheelwright 1979a, b	Coordination and finding a match between product and process	Product volume and mix	A product-process matrix
Schmenner and Swink 1998	Selecting the type of production process	Speed of flow (thoughput time) and demand variability	A variation of the product-process matrix
Fisher 1997	Selecting the right type of supply chain for a product.	Product features, supply chain features	Effective supply chain should be chosen for functional products and market-responsive supply chain for innovative products
Li and O'Brian 2001	Selecting the supply chain with a mathematical model	Product types, 3 supply chain strategies	Presents quantitative evidence for Fisher's (1997) ideas, except when production capacity is low.
Lee 2002	Selecting supply chain strategies	Demand and supply uncertainties	Efficient, responsive, risk-hedging, and agile supply chains in different levels of demand and supply uncertainty can bring competitive advantage.
De Treville et al. 2004	Comparing three levels of demand information transfer with lead time reduction	Demand information transfer, lead time reduction	Improvement in lead times should be prioritised over demand information transfer.
Hvolby and Trienekens, 2002	Planning solutions for small and medium-sized companies (SMIs)	Supplier lead times, customization stage	The use of electronic markets, VMI, supplier hubs, classical purchasing and advanced planning systems
Childerhouse 2002	Focused supply chain strategies for a case company	Demand volume, responsiveness of order cycle, life cycle length, demand variability, product variety (DWV3)	Chosen determinants brought a desired strategy selection outcome and increased the competitiveness of the company.
Wong 2006	Supply chain strategy for innovative and seasonal products	Forecast uncertainty, contribution margin, demand variability	Three strategies that differ in the level of responsiveness.
Kajiwara and Miyabashi, 2006	Finding a balance between the capabilities	Planning capability, production capability	High production capability should be supported with high planning capability, and low production capability can be supported with lower level of planning capability

Product and process coordination is examined using the product-process matrix developed by Hayes and Wheelwright (1984, pp. 197-227). This matrix treats the relationship between product volume and mix and the characteristics of the production process. The production process is described along the continuity of the process that ranges from a job shop to a continuous flow process. The product-process matrix proposes the optimum match between process character and product volume. One variant of the product-process matrix is expressed along one axis as 'demand variability' and the other axis as 'as speed of flow' (Schmenner and Swink, 1998). The matrix proposes operations that are least productive: specifically, producing commodity products with steady demand in a job shop production environment or using high-speed continuous flow for products with high demand variability.

Fisher (1997) proposed that alternative product demand characteristics require different supply chains. There are two different supply chains: effective, which aims at cost-effectiveness and lean operations and, responsive, which aims at adapting the supply chain according to customer demand. The model is further developed by Li and O'Brian (2001), Collin (2003) and de Treville et al. (2004). All these studies conclude in a suggestion to add more supply chain types to the framework. Lee (2002) argues that the primary criteria for supply chain strategy choice are aligning demand uncertainties with supply uncertainties.

Two studies treat the problem of how to study different product characteristics and how to choose the appropriate supply chain strategy for each. Childerhouse et al. (2002) investigated the design of focused demand chains of an electric lighting manufacturer. Five product characteristics were chosen to form uniform product groups, namely: annual demand volume, responsiveness of order cycle, life cycle, demand variability, and product variety (referred to as DWV^3). The products were grouped according to parameters, and a focused demand chain strategy for each cluster was developed.

A similar study is presented by Wong et al. (2006). They studied innovative toy products with volatile and seasonal demand. The determinants that were used to define appropriate levels of responsiveness were: forecast uncertainty, contribution margin, and demand variability. The researchers found that most products required market responsive operations, as they had high forecast uncertainty, demand variability was at a medium or high level, and the contribution margin was also at a high or medium level.

Planning solutions are considered in the framework presented by Kajiwara and Miyabayashi (2006), who propose that planning capability and production capability need to be synchronised (Figure 4). The approach suggests that both planning and production capabilities should support each other. If planning reacts more quickly than the production capability, the company is in a mismatch situation; resulting in frequent changes to planning and a waste of planning resources. In the lower left quadrant (see Figure 4) resources are wasted on the physical capabilities; as for example in the form of flexible production capacity that cannot be utilised due to inadequate information.

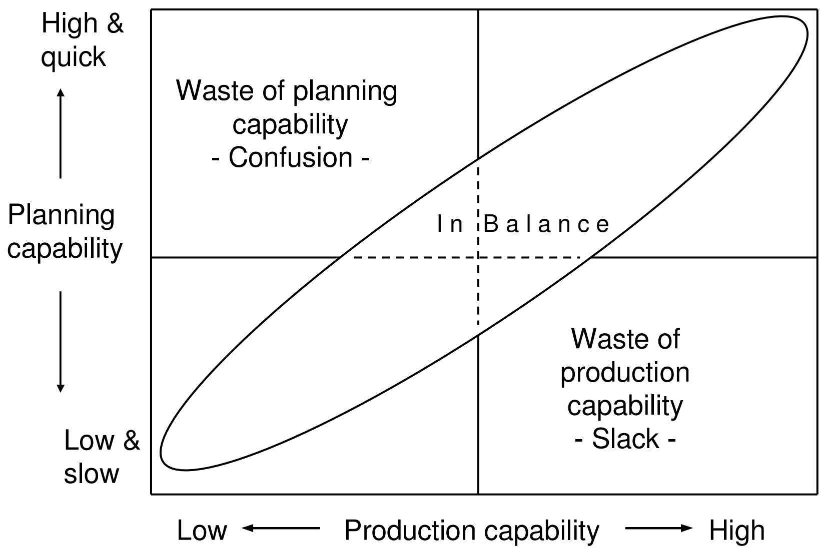

Figure 4. Balance between production capability and planning capability (adapted from Kajiwara and Miyabayashi, 2006).

The final solution discussed here proposes how to choose planning solutions for small- and medium-sized companies (Hvolby and Trienekens, 2002). These companies face more challenges in their planning and control systems for customized solutions due to the changes in markets. The choice is made according to supplier lead-times and customization between vendor-managed inventory (VMI), supplier hubs, electronic markets, and advanced planning systems. VMI is one way to simplify the supply chain planning process, as stock management is handled by suppliers. The second solution involves supplier hubs, which provide logistics services and store components from suppliers and delivers these to manufacturers. The benefit for planning is a reduced number of actors in the planning procedure. 'Electronic markets' offer a reduced transaction cost and the ability to reach a large number of suppliers and customers. Electronic markets are suitable for commodity products, that can be purchased unseen, and which have volumes that are suitably large when compared to transaction costs. Electronic marketplaces offer a way for spot purchasing and balancing demand and supply with price changes. At their best, advanced planning systems (APS) offer a way to include suppliers and customers in the planning procedure and to improve the performance of the whole supply chain. The goal of these systems is the allocation of production capacity, allocation of materials, planning of goods flows, and integrated stock management.

In summary, it is recognized that the determinants that affect the choice of a planning approach are related to market and product characteristics. Demand and product variability, and customisation, appear to be crucial determinants for the selection of supply chain strategy and supply chain-planning solutions. Interestingly, no studies address aspects related to information sharing as a determinant in considering a planning approach. Clearly, it is assumed that all relevant information is available.

2.3.3 Vendor managed inventory

Vendor-managed inventory (VMI), is an alternative to traditional order-based replenishment practices. VMI gives the supplier both responsibility and the authority to manage the entire replenishment process. The customer-company provides the supplier access to inventory and demand information, and sets the targets for availability. Thereafter, the supplier decides *when* and *how much* to deliver. Several similar operative models that express a certain feature of VMI have been presented. Examples of such models are, continuous replenishment program, CRP, (Clark and Stoddard, 1996), co-managed inventory, CMI (Winters and Lunn, 1996), and supplier managed inventory, SMI (Pohlen and Goldsby, 2003).

In this thesis, the term VMI is used according to the definition of Kauremaa (2006, pp. 20-21). The term is used for supply chain operative models where:
1) the supplier is responsible for the replenishment decision;
2) the supplier receives or collects the data needed for the replenishment decision.

The benefit of the VMI-mode of operation is that it eliminates one decision-making point and one level of information distortion from the information flow. VMI can totally remove two groups of causes for the *bullwhip effect*: first, those caused by ordering cycles, economic order quantities and time delays in ordering, referred to as the Burbidge effect (based on Burbidge, 1978); and, second, gaming and over-ordering to ensure availability in shortage situations, referred to as the Houlihan effect (based on Houlihan, 1987). It also reduces other sources of bullwhip, particularly noticeable where there is low-volume and high-volume products (Disney and Towill, 2003a; 2003b).

In VMI, the measure of a supplier's performance is no longer its delivery time and accuracy, but rather it is availability and inventory turnover (Hoover et al., 2001, p. 37-53). The benefits of VMI generally include improved service level and reduced supply chain costs, reduced customer-demand uncertainty, reduced stock-outs and stock-out frequency, and reduced bullwhip (Blatherwick, 1998; Waller et al., 1999; Disney and Towill, 2003a; Småros et al., 2003).

Mixed results on the benefit of VMI implementations are also reported. Vergin and Barr (1999) identify that among ten consumers product manufacturers studied, only two companies were able to benefit in manufacturing, and one company had been able to lower inventories. Benefits had been gained at the customer level in the form of improved availability and lower stock levels. Results from Cooke (1998) and Lapide, (2001) also support the finding that manufacturers have difficulties in benefiting from a VMI relationship. Småros et al. (2003) simulated a situation where the supplier had only partial access to customer's demand data. This is a common situation for a manufacturer with several customers, because typically only a fraction of the customers is engaged in a VMI relationship. The results indicate that even partial access to demand data improves the possibilities manufacturers have to benefit from the improved visibility, especially when the production-planning horizon is short and planning rounds are frequent. Additionally, they found that products with low replenishment frequency benefit most from increased visibility.

Mishra and Raghunathan (2004) present a further motivation for retailers to join a VMI relationship. Their results from a model study indicate that VMI intensifies competition between suppliers, as they want to ensure the availability of their own brand product at the retail store. To avoid situations where customers choose a substitute product due to stocks-outs, the suppliers raise stock levels to ensure availability. This leads to improved availability in the retail store and improved retailer profits. Danese (2006) studied an extended VMI mode of operation. In the case study, VMI was extended both upstream and downstream in order to coordinate the material and information flows among a number of suppliers, manufacturers, and distributors. Such an approach allows the manufacturers' and suppliers' plants to increase flexibility and reduces inventory investment at distribution centres.

Kauremaa (2006) studied empirically VMI implementation in five supplier-customer dyads through an interview study. The results indicated that the motivation for manufacturers to implement VMI was two-fold. First, VMI can be a strategic service-type mode of operation for suppliers operating in an environment with several competing suppliers. VMI is offered to the customers as a service to achieve a tighter relationship and to generate more sales. Second, motivation was evident to establish a VMI relationship as a natural continuum of long-term close relationship. In all cases studied, the benefits of VMI were operational; it reduced order-handling work at both the manufacturer and the retailer, and lowered inventory levels. However, further benefits of shared information remained unclear, which was explained by the relative constant demand in all the cases. Shared VMI information did not improve visibility to such extent that already well-performing relationships might be further improved.

2.4 Impact of information sharing on supply chain planning

2.4.1 Downstream information sharing

The design of information flow in supply chains has traditionally followed the physical flow along the chain (Lewis and Talalayevski, 2004). Sub-optimal supply chain performance, in many cases, has been the result of lack of information sharing. Increased market pressure grows the importance of information sharing in improving supply chain performance. At present companies are widely adopting information systems to transact efficiently information in their supply chains. These systems are expected to improve the quality of information and to facilitate the information flow across company boundaries.

In creating demand-forecasts, it is stated that there is no reason to complain anymore about the *scarcity of data*, but the challenge is in achieving good-quality information (Wagner, 2002).

The benefits of information sharing on supply chain performance have been dealt with in several studies. Shared information can improve decisions with regard to the quantity in a supplier's orders and the allocation of the supplier's inventory across retailers (Lee and Whang, 2000; Lee et al., 2000). Several studies have modelled information-sharing benefits; but they present somewhat differing results, depending on the model parameters and assumptions. These vary according to the number of studied supply chain echelons, the degree of centralized decision-making, demand characteristics, and capacity constraints. Chen (1998), for example, finds that by centralising decision-making, supply chain costs can be lowered on average by 1.75 per cent. Gavirneni et al. (1999) find that suppliers' costs can be reduced by 1 to 35 per cent by sharing customer inventory information. If the supplier is able to use the customer's demand information, instead of customer's order information, supply chain costs in one study were lowered by 23 per cent (Lee et al., 2000), and in another case by a maximum of 13.8 per cent (Cachon and Fisher, 2000). Zhao et al. (2002) state that, under certain conditions, total supply chain cost savings may be even 60 per cent due to information sharing and ordering coordination. Yu et al. (2001) conclude that both expected inventory level and associated costs can be reduced through information sharing. Further model-based evidence on the benefits of information sharing can be found in Raghunathan (2001), who states that intelligent use of historical data can be used to substitute demand information sharing. Chen et al., (2000) showed that the bullwhip effect could be reduced, but not completely eliminated, by centralizing demand information. Gavirneni (2006) shows supply chain cost savings of between 1 and 16.3 per cent when a supplier knows daily inventory levels of its customer.

Several studies support the view that demand information sharing becomes more beneficial when demand variance is high (Gavirneni et al., 1999; Li et al., 2001). Additionally, Lee et al. (2000) support the notion that manufacturers obtain larger reduction in inventory levels and reduce costs when demand variability is high and highly correlated over time.

Steckel et al. (2004) concludes with quite a contrary conclusion: sharing end-customer sales data was harming the supply chain performance in an experimental simulation study, when demand was assumed to be changing continuously. In that situation, the sales data were distracting the distributor from other information. When demand followed the step-up demand pattern, sharing demand data was beneficial. Moreover, reducing lead times was highly beneficial for decision making in the experiment. Similar result were achieved by De Treville et al. (2004), who state that the benefits from lead time reduction are greater than the benefits from capturing demand data.

Empirical evidence is as convergent as is the analytical findings discussed above. For example, in a case study (Byrne and Heavey, 2006) the savings gained from improved forecasting and information-sharing techniques were highlighted. Potential cost savings were 9.7 per cent, and other supply chain performance measures were improved. A survey between 54 food and consumer packaged goods companies was conducted to study the benefits of information sharing and collaboration. The results indicated that the majority of benefits were derived from collaborative initiatives rather than from information sharing (Kulp et al., 2004). Arriving with a result contrary to that of Steckel et al. (2004), Småros (2005, p. 50-71) presents results from an empirical study concerning updating forecasts based on point-of-sale data (POS data) for recently introduced consumer products. The results show that access to early sales data was essential, because the forecast could be corrected several weeks earlier when observing solely retail order data. However, the case companies considered that in the product maturity phase, visibility achieved through a VMI system was adequate to cover the operative information needs.

In the information sharing literature, typically only the expected benefits are treated, not the associated costs. One exception is the study by Chu and Lee (2006), who investigated an asymmetric information-sharing situation in a two-stage supply chain. The retailer reveals or withholds the information, depending on the cost of sharing the information and the nature of the market demand signal that the retailer receives. Reducing the cost of sharing information facilitated information sharing. In addition, the demand characteristics affect the benefits. If variation in demand is high, information sharing is beneficial only if customer demand is correlated.

2.4.2 Upstream information sharing

Upstream suppliers need to provide information on capacity, lead times, and costs for supply chain planning purposes (Chen, 2003). Lee (2000) argues that inventory levels, capacity positions, and shipment schedules as being the information that upstream sites can share with downstream sites. Sharing upstream information gives downstream partners a clear picture of the supply conditions. Furthermore, a supplier can share information with second- or third-level suppliers and, in a deeper relationship, supply knowledge on forecasting, for example. However, studies appear lacking on upstream information sharing for the needs of supply chain planning. Two studies on the value of upstream information sharing are presented, the first targets on pricing, the other compares the impact of downstream and upstream information on the bullwhip effect.

Li, Lin, Wang and Yan (2006) study in their modelling research the value of upstream information sharing. They quantify the impact of production disruption taking place in the upstream stages of a supply chain. They study how soon disruption in the upstream stage impacts the availability of materials in the downstream stages. They find that if the company makes pricing decisions based only on local information, it can adjust prices only when the disruption impacts its operations. If timely information is available, it can be pro-active. The value of timely information sharing was proved even greater when the model was applied to manufacturing of refrigerators: namely, the time that a disruption is alerted not only determines the decision a firm can take, but also shapes the attitude of the firm to the disruption.

Another paper, (Croson and Donahue, 2005), reports the results of an experiment to examine whether giving supply chain partners access to downstream inventory information is more effective in reducing bullwhip and its associated costs, than similar access to upstream inventory information. It was found that only downstream information sharing leads to significantly lower order oscillations throughout the supply chain.

2.4.3 Information quality and bullwhip

The key to enhanced supply chain operations does not lie solely in efficient information transfer and sharing, but also in information availability and timeliness (Kehoe and Boughton, 2001). The quality of shared information has a clear impact on the planning result (Petersen, 1999, p. 69-88) and is critical to the effectiveness of decision making (Petersen et al., 2005). Furthermore, Simchi-Levi et al. (2003, p. 11) see supply chain management being concerned with utilising the data and the sophisticated analyses of this data. The primary issue is *what* data should be transferred and *what* part of the data can be ignored. There are, however, few research results on how the quality of shared information affects the performance of supply chains.

Information quality is defined as the degree to which the information meets the needs of the organisation. Information quality includes such aspects as accuracy, timeliness, adequacy, completeness, credibility, ease of access, and compatibility across users (Monczka et al., 1998). Petersen uses five characteristics of information quality: information currency, accuracy, completeness, consistency and ease of access (Petersen, 1999). English (2001) presents information quality according to the needs of the decision maker, and argue that the right data in a complete form and in the right context is needed. The data need to be accurate and objective, and the decision maker should have a single version of the information. The data should be in such a form that it could be used efficiently and effectively, and at the right time and place for the right purpose.

Li and Lin (2006) study the impact of environmental uncertainty, intra-organisational facilitators, and interorganisational relationships on information sharing and information quality in supply chain management. Data were collected in a field survey from 196 companies. The researchers find significant support for the hypothesis that information sharing is positively impacted by top management support, trust, and shared vision between supply chain partners. Supplier uncertainty had a negative effect on information sharing and also on information quality. Customer uncertainty, supplier uncertainty and technology uncertainty lowered the level of information quality and information sharing.

The demand amplification effect, based on Forrester (1961), is a well-known and largely studied phenomenon in supply chains. Therefore, it is widely known that information suffers from delays and distortion as it moves up the supply chain (Chen et al., 2000). This phenomenon has been named the bullwhip effect by Lee et al. (1997a; 1997b).

The reasons behind the bullwhip effect relate to order batching, demand signalling, price changes or shortage gaming (Lee et al., 1997a; 1997b), because they cause uncertainty and delays in the information flow and lead to more fluctuating demand information when information moves towards the upstream phases of the supply chain. These reasons lead to inefficient decision making, which can be reduced by, for example, information sharing, and through a VMI operations mode (Disney and Towill, 2003a). Supply chain coordination, in general, offers ways to reduce these fluctuations (Wong, 2005, p. 8).

2.5 Flexibility as a material flow characteristic

Flexibility has become one of the most important performance characteristics of operational systems, in addition to costs, quality, and reliability (Bertrand, 2003). The reason for this is the growing demand-uncertainty at the product variant level. This is due to the competitive situation requiring companies to compete on product innovation and differentiation. This increases the requirement for flexibility of manufacturing systems, as well as whole supply chains. Flexibility precedes excellence in two ways. First, it provides the abilities to cope with uncertainty. Second, it can create a competitive advantage for companies.

Several other terms are used to describe flexibility features within supply chains. Fisher (1997) uses the terms 'market-responsive' and 'physically efficient' supply chains as primary types. Similarly, agility and leanness of supply chains have become common terms in supply chain management literature (for example in Christopher, 2000; Aitken et al., 2002). Agility is the ability to respond rapidly to changes. A lean supply chain, in contrast, targets effectiveness by eliminating waste, and simply doing more with less. Additionally, a combination of lean and agile paradigms has been proposed, labelled 'leagility' (Mason-Jones et al., 2000). This approach proposes different supply chain characteristics to be used in different parts of supply chains.

2.5.1 Flexibility types and dimensions

Flexibility is a multidimensional and complex concept that has been studied extensively from the viewpoint of manufacturing systems. Manufacturing flexibility can be defined as the capacity of a manufacturing system to adapt successfully to changing conditions, coming from within the system as well as from the environment (Das and Abdel-Malek, 2003). The definition includes the specific feature of manufacturing flexibility, which is the single-company view. Upton (1994) provides a general definition of flexibility as the ability to react or transform with minimum penalties in time, cost, and performance. The definition stems from the internal and external reasons to create flexibility. Extensive literature reviews on manufacturing flexibility and taxonomies have been presented; for example by Sethi and Sethi (1990), Vokurka and O'Leary-Kelly (2000), and Koste and Malhotra (1999). A conceptual framework on manufacturing flexibility is presented in Gerwin (1993), and further developed, for example, in Beach et al., (2000). Some writers have widened the comprehension of manufacturing flexibility and addressed flexibility in relation to the marketplace (for example Slack, 2005; Olhager and West, 2002).

The term *flexibility* is used for many purposes, each of which describes a different capability of a system. Appendix 2 discusses a sample of different types of flexibility shared into three classes: input, output and process flexibility. Another solution to treat flexibility is to divide it to internal and external aspects. Internal flexibility includes the types of flexibility within one plant, such as a machine, labour, materials handling, operation and routing flexibility. External flexibility describes the output of the system, for example, volume, mix, or new product flexibility. A further approach used to classify flexibility is as a hierarchy between operational and strategic levels (De Toni and Tonchia, 2005), or between company performance, manufacturing performance and resource level (Slack, 1988). Flexibility on each of these levels defines the flexibility requirements and needs on the other levels of the hierarchy.

2.5.2 Sources of flexibility

Bertrand (2003) suggests that flexibility stems from three sources. The variety of manufacturing technologies is the first source, and defines how a large variety of different products can be produced. Second, the amount of capacity available for production may limit the volume of products delivered to the markets. Third, there is inflexibility in the timing of production batches and frequency of production that are often restricted by changeover or set-up costs. Inflexibility in timing and frequency of production lead to high inventories, and work-in-process, and, to long lead times for introducing new product variants.

In several studies, relationship between uncertainties and flexibility is addressed (Gerwin 1993; Kara and Kayis, 2004; Pagell and Krause, 2004). One approach to balance internal and external uncertainties is to use *buffers* (Newman et al., 1993). The buffers that are used to achieve this balance are 1) building inventories, 2) carrying excess capacity or 3) quoting longer lead times. These buffers - inventory, capacity and lead time - are used to achieve and maintain the dynamic equilibrium between the manufacturing process flexibility and external uncertainty. This framework is further studied in Pagell et al. (2000) using three case companies. They conclude that the case companies use buffers efficiently to balance between uncertainty and flexibility, at least in the short-term. However, the researchers state that in the long-term buffers should be replaced with infrastructure investment and a more flexible workforce.

To increase flexibility, three different characteristics of flexibility types, which managers should consider, are identified (Upton, 1994):

- *Dimensions of flexibility*: exactly why flexibility is required.
- *Time horizon*: what is the time horizon over which changes should occur.
- *Elements of flexibility* include range, mobility, or uniformity.

'Range element' refers to the ability to produce different sizes, volume, or variations of products. 'Mobility element' is the cost or time that it takes to change between these range elements. The last element, uniformity, is the ability to produce similar results within a range determined by performance measures such as quality or yield.

2.5.3 Supply chain flexibility

In this section, we study literature on supply chain flexibility, whilst concentrating on tactical and operational flexibility. Supply chain flexibility extends the concept of flexibility of manufacturing systems to the whole supply chain. Supply chain flexibility can be divided into process flexibility of each supply chain firm, and logistics flexibility, which considers the possible connections between suppliers, assemblers and markets (Aprile et al., 2005). Supply chain flexibility not only encompasses the manufacturing flexibility, but also the flexibility of different processes and functions across the supply chain. Flexibility needs to be considered from suppliers' perspectives, referred to as input flexibility, to processes (process flexibility), and from customers' point-of-view, where output flexibility types are essential (Vickery et al., 1999; Sawhney, 2006). Thus, when considering supply chain flexibility, the manufacturing flexibility dimensions that take place at the plant level are of particular interest, and they need to be considered for each of the plants involved in a supply chain. Based on a literature review, Stevenson and Spring (2007) provide a four-tiered hierarchy of flexibilities, which proposes that supply chain flexibilities take place at the network level, the other levels being firm level, plant level and shop floor level.

Relevant flexibility dimensions at the supply chain are identified in Bertrand (2003):

> *Volume flexibility*: The ability to increase and decrease production in response to customer demand within the minimum planning period.
> *Mix flexibility*: The ability to produce a wide range of product lines within the minimum planning period.
> *New product flexibility*: To introduce many new products and product varieties within the minimum planning period.

Vickery et al. (1999) adds two types of flexibility in customer focused supply chains:

> *Access flexibility*: The ability to spread products to the market.

Responsiveness to the target market: The ability to meet or exceed customer requirements.

A recent article (Sawhney, 2006) discusses the competing uses of flexibility. First, it is a coping mechanism against uncertainty in the organisation's internal or external environment, and, second, it provides a competitive advantage for companies. The article presents a framework on exchange of flexibilities along the supply chain; between the above-mentioned input stage, process stage and output stage. The framework expands the single-company perspective by considering the feedback loops in the supply chain. Sawhney suggests that flexibility can flow upstream and downstream, and supply chain partners are transferring flexibility and uncertainty to their suppliers and customers, as companies maximize their profits.

A similar approach is taken in an empirical study that investigates the impact of different demand types on flexibility. Aprile et al. (2005) address supply chain flexibility by focusing on process and logistics flexibility. They study different supply chain configurations under demand variability and production capacity uncertainty using a model-based study. They conclude in an interesting finding: the higher the demand uncertainty, the more beneficial is flexibility at the supplier level. This suggests that process flexibility at the supplier stage allows higher demand uncertainty to be faced without sacrificing supply chain efficiency.

Time is treated from two perspectives in the flexibility literature. It may be considered as the *time horizon* that it takes to implement a change. The other view is timing flexibility. In a modelling study, it is shown how the type of demand process to which the supply chain is responding influences the value of quantity and timing flexibility. Timing flexibility is of most value in the case of standard demand. The value of quantity flexibility was at its greatest, when demand was volatile. When demand was evolving, the value of quantity flexibility depended on supply lead-time: The value was high when lead times are short, and low in the case of long lead times (Milner and Kouvelis, 2005).

To sum up, a supply chain is flexible in nature if it can cope with changes from the environment. Furthermore, adapting should be made with minimum penalties in supply chain resources. These can be measured as time, costs, or quality. Supply chain flexibility consists of flexibilities in each supply chain phase, and these flexibilities can be transformed and exchanged between supply chain partners. In contrast, an inflexible supply chain is characterized by fixed and restrictive key components, for example long order cycle, constrained capacity, infrequent production or fixed order and transportation quantities, and which all lead to long planning lead times (Jenkins and Wright, 1998; Bertrand, 2003). Supply chain flexibility takes the forms of volume flexibility, mix flexibility, new products flexibility, responsiveness to the target market, and access flexibility. Compared to the terms 'agility' and 'leanness' as supply chain characteristics, the term 'flexibility' is a wider concept and can be classified by multiple types. Flexible supply chains can mean the same as agile supply chains, but an inflexible supply chain is not necessarily lean.

2.6 Framework development on balancing information flow and material flow

The findings from the literature review are formulated into a framework. This framework considers operational coordination modes, which are physical flow coordination (referred to also as logistics synchronization) and information sharing as presented in Figure 1. The framework examines the match between selected information flow characteristic and material flow characteristic. This framework will be used to analyse the results from Papers 1 to 6 in Chapter 4.

In addition to coordination theory, this framework builds on the ideas from Kajiwara and Miyabayashi (2006) of combining planning capabilities and production capabilities (Figure 4). It is also closely related to Fisher's (1997) approach concerning the selection of a suitable supply chain according to product features. It also draws on Lee's (2002) principles on aligning supply and demand uncertainties. Furthermore, the matrix is related to the model from Grandori and Soda (2006), who present optimal coordination mechanisms under different levels of uncertainty.

Two terms need to be defined before presenting the framework. The two operational coordination modes, 'flow coordination' and 'information sharing', form the basis for these terms (Simatupang et al., 2002). The object in flow coordination, which the writers call 'logistics synchronization', is the logistics processes. In information sharing the objective is to make relevant, timely, and accurate information available for the decision makers. Based on these the most important characteristics of information flow and physical flow that affect the selection of coordination mechanism are defined.

The first term is *information abundance*, which describes the existence, extent, and availability of data. The term also includes three features of information flow: speed, frequency, and volume of information. These features are needed and used in supply chain planning to cope with changes in the environment. This term is closely related to the term information quality, when it is understood broadly, in a meaning that how well information supports the needs of decision maker.

The second term is *execution flexibility*, which expresses the magnitude of material flow flexibility in a supply chain. It describes the physical flow capability to adapt to changes. This term is defined using two elements of flexibility: range and mobility from Upton (1994). Execution flexibility means the ability to produce different sizes, volumes, or variations of products. The second element that defines execution flexibility is the cost or time that it takes to change between these range elements. It contains the aspects of volume, mix, timing, and new product flexibility, as well as responsiveness to the market, which were identified to be the most important aspects of supply chain flexibility (Bertrand, 2003; Vickery et al., 1999). It also describes the time for how long it takes from planning to execution; which was called 'effectuation lead time' by De Kok and Fransoo (2003).

A matrix is developed (Figure 5), where material flow and information flow are considered along the axes. Material flow capability is considered on the x-axis as 'execution flexibility'. In the left side of the matrix, supply chain flexibility is at a low level; in other words the supply chain is inflexible. These types of operations are identifiable as having long order cycles, constrained capacity, low production frequency or fixed quantities in transportation or orders, and long planning lead times. In the right side of the matrix, physical flow is flexible, meaning that the supply chain is capable of producing multiple variants in varying quantities fast and efficiently. In this matrix, execution flexibility includes the flexibility in the production process, also in the supplier stage that influences the supply capability of the suppliers.

Information flow is considered on the y-axis, and is described as *information abundance*. The axis expresses the availability of meaningful information. In the lower part of the matrix there exists a small amount of data, even scarcity of data. In the upper part of the matrix there is extensive information from multiple sources and it can be received frequently. Information may be available to such an extent that it can be described as an overabundance of data.

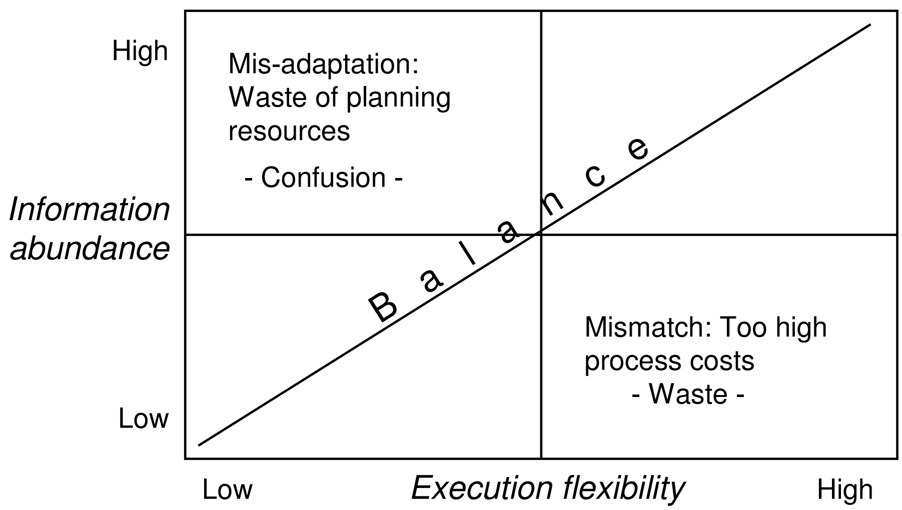

Figure 5. Information abundance – execution flexibility framework.

The basic principle is that each location inside the matrix represents the use of different operational coordination mechanisms. Different locations in the matrix describe different levels of available information and different levels of material flow flexibility. The locations are, for instance, different supply chain planning approaches. The model suggests that the balance between execution flexibility and information abundance is along the diagonal line. Volatile information should be used in coordination only if execution flexibility is high. In other words, flexible operations should be supported with such planning that captures demand quickly and makes frequent re-planning rounds (Kaipia and Hartiala, 2006; Paper 4). If execution flexibility is low, it needs to be supported with more stable planning.

Notable is that the balance line in the matrix forms a diagonal, which infers that those companies that are located in the lower left quadrant are *not* necessarily performing less efficiently. This location means that their planning and execution are *in balance*. In contrast, closer to the upper right corner of the matrix, more information is needed, and more frequently. In this balance location, planning frequency should be high to support execution efficiently. However, this requires more planning resources.

Two mismatch locations are marked in the matrix. The first is in the upper left quadrant of the matrix, where volatile planning with frequent capturing of demand information is used despite relatively low-level of execution flexibility. This approach wastes information sharing and planning resources, because information and frequent re-planning cannot be responded to by the production. The other mismatch location is in the lower right quadrant, where planning is not capable of supporting the potential flexibility in material flow execution.

3 METHODOLOGY

This chapter describes how the research was conducted. It starts with presenting the research questions. The research design is then presented, and the use of coordination theory in analysing results is briefly discussed. Next, the applied methodology - case studies and analytical modelling - is discussed at a generalised level. The final section describes the individual papers and their methodology.

3.1 Research questions

Supply chain coordination in manufacturing companies, at the operational level, is chosen as the focus of this thesis. Two research questions are formulated based on the identified gaps in the literature.

The first gap is related to the selection of approaches taken in supply chain planning. How to choose a suitable supply chain strategy according to demand and product features has been investigated in several studies. These studies, for example Fisher (1997), Lee (2002), Li and O'Brian (2001) and Wong et al. (2006), have classified product and demand features and selected different types of supply and demand chains to match these features. These papers, however, do not consider supply chain *planning* solutions to support the supply chain types. There is inadequate understanding of how supply chains with different levels of complexity and uncertainty can be supported with planning and information sharing. A single proposal focusing on supply chain planning solution selection was found. The paper suggested planning approaches for small and medium sized companies within the context of supplier lead-times and the customization stage (Hvolby and Trienekens, 2002).

A further lack of knowledge concerns the applicability of VMI. The literature does not address the question of which situations, or during which supply chain phase, VMI is a profitable mode of operation.

Based on these findings the first research question (RQ1) is formulated as:

How to select operational coordination mechanisms to match demand and supply in manufacturing companies?

This question aims to identify efficient means to coordinate supply chain operations, and to identify the key situational factors that affect the choice. Manufacturing companies, in particularly brand owners, are the supply chain players who are well positioned to coordinate the supply chains, because they decide on the production quantities of finished goods and often possess the required knowledge from the market. In many cases it is in the best interests of manufacturers to improve the performance of the chain and to reduce overall system costs.

When we consider this question (RQ1) in the information abundance – execution flexibility framework presented in Chapter 2.6, this question aims at selecting the right location inside the matrix. The study deals with two supply chain coordination-mechanisms: supply chain planning and vendor-managed inventory (VMI).

The second research question originates from a gap in literature that concerns benefiting from supply chain visibility in the planning approach. There is inadequate empirical evidence on how to make the best use of available information to improve supply chain performance. For example Kulp et al. (2004) concludes that supply chain benefits came from collaborative initiatives rather than from information sharing. Some studies show disadvantages of information sharing; or prefer lead-time reduction over capturing accurate demand information (Steckel et al., 2004; De Treville et al., 2004). Similar findings have been identified in VMI studies, where it is pointed out that suppliers are having difficulties in benefiting from incremental visibility in their production (Cooke, 1998; Lapide, 2001; Vergin and Barr, 1999; Kauremaa 2006). The benefits of information sharing are widely treated in theoretical studies (for example in Lee et al., 2000; Yu et al., 2001; Cheng and Wu, 2005) and also to some extent in empirical studies, for example in Byrne and Heavey's case study (2006) and Småros et al.'s (2003) study on sharing point-of-sale data. Only limited knowledge exists on how companies should choose the extent to which information is required and how to benefit from shared information in decision-making.

An additional observation on studies of supply chain information sharing is that information is assumed perfect. An exception is bullwhip literature that has widely addressed information transformation when demand-information flows through the supply chain. Yet, information quality may be understood broadly, as is presented by

English (2001) and Petersen (1999). Information quality is expressed in terms of how well the data meets the needs of a decision maker. The decision maker should have all the data and it should be in a form that the decision maker understands and can rely on. The data should present only a single version of the truth and be used for the right purpose. It is notable that access to data, which is in many cases a problem in real-life supply chains, is considered as one attribute of information quality.

The second research question (RQ2) is formulated as:

How to reach the balance between information flow and material flow?

The goal in the second research question is to study how companies can enhance their benefits from a chosen coordination mechanism. It is related to the use of information and planning resources in companies to efficiently support the production capabilities. This question addresses how information sharing practices and physical flow capabilities can be developed to make more efficient use of existing coordination mechanisms and resources.

In the information abundance – execution flexibility framework (presented in Chapter 2.6), this question addresses which movements need to done in the matrix to reach the balance line and how these movements can be realised. Again, supply chain planning and VMI are treated.

3.2 Research design

This thesis is formed of six studies that are reported in six research papers. The studies contain three model-based studies and three empirical case studies. One multiple case study, one two-case study, and one single case study are included. On the other hand, in this compendium a framework is developed based on literature to be used in analyzing case results. How the different parts of this thesis are linked with each other, how the research questions are connected to the framework, and how they are answered based on the studies, is illustrated in Figure 6.

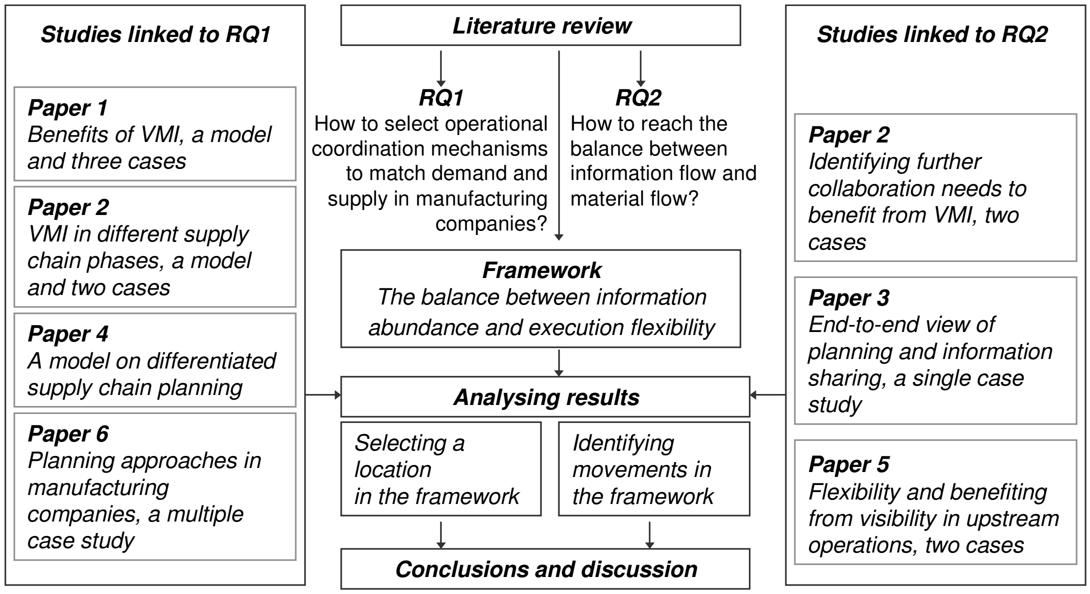

Figure 6. Overview of the thesis.

Research question 1 is addressed in 4 papers: Paper 1, Paper 2, Paper 4 and Paper 6. Papers 1 and 2 study through case studies the applicability of VMI into specific supply chains. The cases use an analytical model that measures the benefits of VMI as available reaction time. Paper 4 investigates the need for differentiated supply chain planning, and presents a model to select planning approaches according to product features. Paper 6 provides answers to research question 1 by studying planning approaches in six case companies.

Research question 2 is addressed in three papers: Paper 2, Paper 3 and Paper 5. Paper 2 studies if a VMI relationship needs to be enhanced by collaborative practices. The paper studies two cases and identifies how and when a VMI supplier can offer more value to the customer beyond the replenishment service. In Paper 3 a large single case study aimed at identifying means to benefit from supply chain visibility in planning processes. Based on a detailed analysis of an implemented VMI model, it was suggested ways to balance the VMI relationship. Paper 5 studies two supplier cases to identify how the available information can be better utilized to benefit from a VMI relationship in a supply chain upstream phase.

Coordination theory is applied in this thesis to consider the results from the research papers. The theory asserts that coordination can be seen as a process of managing dependencies between activities (Malone and Crowston, 1994). Coordination theory offers a framework for identifying and classifying different types of dependencies and the processes that can be used to manage these dependencies (Lewis and Talalayevski, 2004). As applied to this research, this theory is used to explain the selection of coordination mechanisms in repetitive decision-making situations in the demand-supply interface in supply chains. The selection criteria are chosen from the coordination literature, where the connection between information flow and physical flow is considered. Furthermore, the theory is used to explore how decision-making can be improved by developing information sharing practices and physical capabilities.

The results from the papers are considered through using the framework developed in Chapter 2.6. The information abundance – execution flexibility matrix is used to 1) identify operational dependencies as informational linkages and material flow linkages and suggest coordination mechanisms to manage the dependencies and 2) intensify the use of the coordination mechanisms in certain decision-making situations to improve the supply chain performance.

3.3 Research approaches used

3.3.1 Case study research

A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not evident (Yin, 1994). Case studies cover contextual conditions and allow them to be considered in a broad manner. Case-study design is a comprehensive research strategy, as it allows specific data-collection approaches and data-analysis techniques to be employed. The advantage of a case study is that the phenomenon can be observed in its natural setting as the actual practice is studied. The understanding of what the case study offers, embraces the complete phenomenon, and therefore it is suitable for exploratory investigations of a new phenomenon (Meredith, 1998). Case-study research offers useful approach in early stages of a theory-building process. This approach is capable of explaining and understanding a complex phenomenon and is therefore suitable for many supply chain problems (Handfield and Melnyk, 1998).

The case studies in this thesis follow the case study design by Eisenhardt (1989). The rationale for the use of case studies can be found in the explorative nature of the research. Case studies offer novelty, testability, and empirical validity and are suitable for new research areas or research areas for which existing theory seems inadequate (Eisenhardt, 1989). The goal of an inductive case-study approach is to chart and understand the explanatory situational factors in each case and to seek similarities and differences between cases. Therefore, case studies are appropriate in situations when little is known about the phenomenon or when current perspectives seem inadequate in that they lack empirical substantiation or conflict with each other or common sense.

Case studies and empirical research methods have been criticised in terms of, for example, the extent of their generalizability, lack of control, or poor validation (Meredith, 1998). In addition, Yin (1994) points out the difficulties to generalize from one case to another due to the failure to create a case-study database apart from the case-study report. This distinction is important for understanding the difference between evidence from case studies and interpretation of the evidence. Another shortcoming of case-study research is it being subjective (Yin, 1994). According to Miles and Huberman (1994), this is, however, the strength of multiple case studies, as they provide a purposive sample and the potential for generalizability. Eisenhardt (1989) names two main weaknesses of theory building from cases. First, intensive use of empirical evidence can yield theory, which is overly complex. Using rich data can result in theory that is rich in detail but lacks simplicity in its overall perspective. The other weakness is that theory may become too narrow. Building theories from cases is a bottom-up approach, and there is a risk that the researcher will be unable to raise the level of generality of the theory.

According to Yin (1994), both multiple and single case studies are possible, but in research design it should be taken into account. Eisenhardt (1989) proposes that a suitable number of cases should range from four to ten in number. If there are very few cases, complex theory building becomes unconvincing. This can be avoided if mini cases exist within cases. Handfield and Melnyk (1998) suggest that the alternative case study research strategies should be selected according to the stage of theory development. The selection takes place between few focused case studies, in depth case studies, multi-site case studies or best-in-class case studies. This offers a rationale for using several types of case studies in this thesis.

3.3.2 Modelling research

Quantitative models are based on a set of variables that vary over a specific domain, while quantitative and causal relationships have been defined between the variables (Bertrand and Fransoo, 2002). Quantitative model based research approaches can be classified as a rational knowledge generation approach. This area is called rationalist research in preference to the term theoretical research, because all research can be theoretical (Meredith, 1998).

The benefit of rationalist research, as in modeling, is that it offers a solution to studying a phenomenon that exists, independent of the specific research context or assumptions of a case (Meredith, 1998). In addition, modeling can be used to study a non-existing system. Rationalist research methods are used to explain what happens and how it occurs. Using this kind of research method, the phenomenon, relationships of variables, and observations can be controlled by the researcher. One benefit of rationalist research is precision, which increases reliability and testability. A further advantage is the use of standard research procedures, which may become widely accepted and known, as is the case in particular in the area of operations research (Meredith, 1998).

Disadvantages of rationalist research methods, according to Meredith (1998), are sampling difficulties, the inability to produce information beyond the model or the abstract character of key variables. In modeling, the phenomenon is studied in a simplified form. Additionally, Bailey (1992) points out that, despite the precise and measurable nature of the data, the data provided may appear to be trivial. This issue has been realized in the area of operations management, where quantitative modeling was relied on for a long time. For example, Swamidass (1991) emphasizes the need for empirical theory building in operations management in addition to modeling.

This shortcoming is addressed by Mitroff et al. (1974), who present a diagram of modeling in problem solving in operations research. According to the diagram, illustrated in Figure 7, the operations research consists of four phases: conceptualization, modeling, model solving, and implementation. They state that the research process can be started at any point in the diagram. Conceptualization means making a conceptual model of the problem situation. In this phase, the variables are selected to define the nature of the problem. In the next stage, the researcher builds the quantitative model, which means that the causal relationships between the variables are defined. In the model-solving phase, the mathematical solutions are created. In the next phase, the results are implemented. Two feedback loops are included in the model. The degree to which the scientific model corresponds with reality is expressed as validation in the diagram. The vertical connection between conceptual model and solution is named as feedback in the narrow sense. This suggests that if a researcher follows the loop from solution to conceptual model, the feedback comes from model solving, not from implementation. According to Mitroff et al. (1974), this is a major flaw in modeling research, because researchers do not observe reality and therefore do not critically consider their initial assumptions.

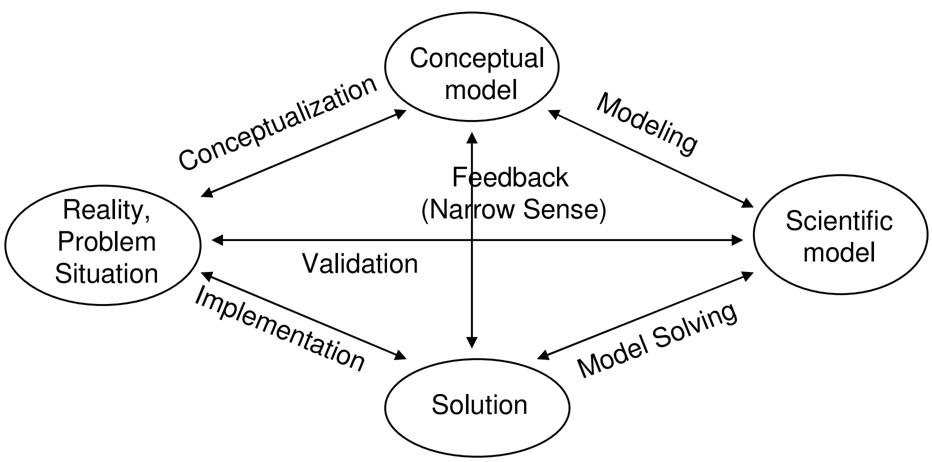

Figure 7. A research model of problem solving (Mitroff et al., 1974).

Bertrand and Fransoo (2002, 2007) use this model and compare it with their classification of modeling research. They classify research into axiomatic and empirical research, where both can be descriptive or prescriptive (Table 5). In axiomatic research, the primary concern is to achieve results within the model, which is described by the authors as an idealized model that studies an idealized problem. This type of research has been widely discussed in the literature, but the writers state that the reality in operations management cannot be captured if only axiomatic research is conducted. In axiomatic descriptive research the modeling process is central, and it typically only considers the modeling phase in Figure 7. Axiomatic prescriptive research covers the phases modeling and model solving. If the researcher follows the path from conceptualization to scientific modeling and validation, the research is descriptive empirical research. This type of research is primarily interested in creating a model that adequately describes the causal relationships that may exist in reality, which leads to understanding of the processes going on. The most complete form of research is, according to the writers, empirical prescriptive, which uses all four steps in the diagram. It aims at developing policies, strategies, and actions and to improve the current situation. In many cases, the researcher may build upon earlier published research, and will not follow modeling and model solving phases.

Table 5. Classification of quantitative model-based research types (Bertrand and Fransoo, 2002; 2007).

	Prescriptive	***Descriptive***
Axiomatic research	AP	AD
Empirical research	EP	ED

Bertrand and Fransoo (2002) suggest that modeling should be directed towards quantitative model-based empirical research. This type of research is concerned with testing the validity of scientific models (the Validation -link in Figure 7) or with testing the usability and performance of solutions from quantitative theoretical research in real-life solutions (the Implementation -link in Figure 7).

3.4 Description of the studies and papers

The methodology used in the six research papers is summarised in Table 6. Next, each paper is briefly described. How the individual papers answer to research questions, the methodology used, as well as each author's contribution to the paper, is explained. In addition, in Appendix 3 is a more detailed description of each author's role in the paper in each research phase.

Table 6. Research method applied in each paper.

Paper	*Research method*	*Sample / Unit of analyses*	*Data collection*	*Data*	*Analyses*
Paper 1 **Time benefit** **RQ 1**	Analytical model, three cases	Information flows in three manufacturer - distributor dyads, product level	Data requests	Order flows and replenishments from two supply chain echelons	Time benefit analyses with developed model
Paper 2 **Time benefit** **RQ 1, RQ 2**	Analytical model, two cases	Relationships between manufacturer and retailer, and manufacturer and two suppliers	Data requests, interviews of key persons	Order flows and replenishments from two supply chain echelons in each dyad, operational models in each relationship	Time benefit analysis, analyses of value offering in demand-supply interfaces
Paper 3 **Planning nervousness** **RQ 2**	Single case study	A company's planning process, data flow of two product groups from end customers to second tier suppliers	Interviews, data requests	Decision making and planning phases, forecasts, actual transactions concerning two products	Quantitative analyses on plan accuracy in six supply chain echelons and bullwhip in three echelons
Paper 4 **Selecting planning approach** **RQ 1**	Selection model and a case	Product features and planning approach features	Benchmark study and literature survey, product features	Product types with different demand and supply features. Data requirements for each planning approach	Testing the framework in one case, Testing the suitability of the selection criteria
Paper 5 **Upstream flexibility** **RQ 2**	Two-case study	Solutions to increase flexibility in two manufacturer – supplier relationships	Interviews on operative models & planning practices, data requests	Forecasts and actual data flow on demand, production data, stock levels, lead times	Quantitative analyses on plan accuracy and nervousness, statistical analyses and simulation, qualitative cross-case analyses
Paper 6 **Planning in manufactur-ing companies** **RQ 1**	Multiple case study	Planning process in six manufacturing companies	Structured Interviews using a questionnaire	Planning and information sharing and collaborative practices, plan quality	Within-case analyses and cross-case analyses on explanatory factors for planning approach

Paper 1: VMI: What are you losing if you let your customer place orders?

Paper 1 focuses on research question 1, which addresses the selection of operative coordination mechanism to match demand and supply in manufacturing companies. This research paper studies VMI, and how its benefits can be estimated at the product-level in certain supply chain settings before the operations model is implemented.

The paper presents an analytical model, called time benefit model, for calculating the suitability of the VMI operations model. A procedure using the time-benefit model was presented, through which the applicability of VMI in customer-supplier relationships can be analysed. The model uses length of time as a measure. It compares data flows from two supply chain echelons to discover the additional response time for the supplier in VMI. The time-benefit study was a part of a two-year project concerning supply chain management for electronic commerce, which was funded by The National Funding Agency for Technology and Innovation and the participating companies.

The validity of the model was ensured by multiple tests by the researchers in the Logistics Research Group. Five researchers checked the model principles during different studies. Test runs were carried out to ensure the correct level and form of source data. During the case studies, special attention was directed towards data collection; to illicit the correct data flows in the correct content and from a suitably long enough time to ensure reliable results.

Three cases that concerned grocery manufacturers and their customer companies were studied with this model. In the cases, two situations are treated. First, order-based replenishments are compared with the VMI operations model. Second, VMI is compared with frequent purchase orders, which are called in the paper just-in-time, JIT, purchases. The purpose of the latter analyses was to investigate how the responsibility of replenishment decisions affects the benefits of a replenishment model. In each case, real-life information flow data were collected from the case company databases from two supply chain levels.

Analytical modelling was chosen for studying VMI, because it offers a method to provide reliable and precise results from a complex phenomenon. This research design combined empirical and theoretical approaches and qualitative and quantitative analyses. It ensured extensive understanding of the phenomenon, VMI, and at the same time achieving accurate quantitative results on VMI relationships. According to the classification of quantitative research models in Table 5, this study appears as empirical prescriptive and covers all the four phases in the diagram in Figure 7.

The role of the doctoral student was to carry out the case studies, data collection, and the mathematical analyses; and to ensure the mathematical model validity. The principles of the analytical model were established earlier by Dr Holmström. The paper is written by the doctoral student. The two co-authors, Dr Holmström and professor Tanskanen, assisted in the writing process by commenting several times on the manuscript.

Paper 2: Measuring the benefit of changing the value offering in grocery supply chains

Paper 2 addresses both the selection of a coordination mechanism and the more profitable use of the mechanism; and therefore provides answers to both research questions. This paper studies VMI operations model.

In this paper, the time-benefit model that was presented in Paper 1 was used in two cases. The first consisted of a manufacturer and a customer, and the second case concerned a manufacturer and two suppliers. Data were collected from the case companies for the time-benefit analyses and interviews were used to map the operational models in the cases. The cases were analyzed more rigorously than in Paper 1 to identify *how* value can be increased in each relationship. These analyses aimed at identifying the extent of collaboration needed in the relationship.

The role of this paper is to point out differences in using the time benefit model in different parts of the supply chain. It expands on Paper 1 by targeting more accurately on different demand features and identifying the factors that affect the benefits of a VMI system. Similarly to Paper 1, this study is empirically prescriptive according to Bertrand and Fransoo's (2002) classification (Table 5). In addition, it strengthens the link between the scientific model and reality in the diagram in Figure 7, because it provides new empirical cases.

There are three authors in the paper. The doctoral student designed the paper and was responsible for analysing the cases. Dr Holmström reviewed the paper. Mr Hellström undertook the individual case studies.

Paper 3: Planning nervousness in a demand-supply network: an empirical study

The study reported in Paper 3 was focusing on the end-to-end visibility in an electronics company and its demand-supply chain. The initiative to study the subject came from the case company. The project participants came from the case company, from two suppliers and the university. The project consisted of four phases: current state analysis, a visibility concept and process formulation, verification and enhancement of the identified concept principles in pilot projects, and formulating visibility-development recommendations.

Paper 3 focuses on planning nervousness and planning accuracy throughout the supply chain and provides answers to research question 2, on how to improve the use of a coordination mechanism. It addresses the current planning practices in the company and how the available incremental visibility can be utilised in supply chain planning. Another paper from the same study (Kaipia and Hartiala, 2006) treats the topic of information sharing and describes the findings concerning visibility, various information sources, and the use of visibility in supply chains.

The in-depth single case study was an appropriate method because the desire was to study the topic, end-to-end visibility and planning processes, deeply. The use of single case study offered a solution for rich data collection and achieving large understanding of the phenomenon. The participants wanted to explore contextual conditions in the upstream and downstream phases of the demand-supply network and not solely the focal company. One goal was to study alternative data sources and its uses throughout the supply chain, as well as the data flow across supply chain stages. To ensure validity, the results were considered in frequent project-group meetings.

Data collection in the case focused on operational modes, planning practices, information sharing practices and the use of available data. Data collection was performed through key person interviews and through collecting data in the company information systems. Interviews were carried out in six supply chain phases in four countries. The data analyses were carried out at a detailed level concerning two product groups and six supply chain phases. Data collection focused planning processes in relation to execution.

The paper has three authors. The two co-authors' role was large in research design, performing the analyses during the study project, and data collection. The paper was designed and written by the doctoral student and has been commented on by the two co-authors.

Paper 4: Selecting the right planning approach for a product

The next study concentrated on supply chain planning principles for highly innovative products. The project continued from the findings from the supply chain-visibility project, described in Paper 3, but focused on another business unit of the company. Planning experts from the company and two university researchers attended the project. The project focused on creating solutions to problems relating to demand planning for new products with short life cycles. The solutions aimed at utilising true demand information from the sales channel and points of sale to steer planning and support life-cycle planning. The case company had identified a need to differentiate planning to support different supply chains in the new business unit. The new unit had a wide range of diverse products and many alternative ways of sourcing them. The diversification of planning approaches became urgent, as the approaches utilized in established units with more stable product portfolios and supply networks could not produce satisfactory planning results for innovative new products with the available personnel.

The data collection in this study targeted identifying alternative planning approaches, and it was conducted in the form of a benchmark study. Reports on planning practices in companies that offer new innovative products with short life cycles were reviewed in several industry sectors. Further analysis focused on three innovative planning approaches for dealing with a diverse and changing product portfolio. Literature sources were also used to identify planning approaches.

The paper presents a framework for selecting a supply chain planning approach for product types, and therefore it answers research question 1. The goal was to establish a formal approach to selecting the supply chain planning method in the new business unit.

The framework provides a procedure that aimed at efficient planning resource usage and improved planning results. The procedure matches product features to the information and resource requirements of each planning approach. The procedure was tested for a group of products in the case company. When this study is compared with Mitroff et al.'s (1974) classification of research types, this model is classified as a conceptual model. According to the classification of research types (Table 5) an 'empirical descriptive' type is closest to this study.

The doctoral student was responsible for the benchmark study. The paper design was done by the doctoral student. Most parts of the paper (approximately 85%) were written by the doctoral student, while Dr Holmström's role was commenting and writing small inclusions to the paper.

Paper 5: Exploiting VMI to increase flexibility in package material supply

Increasing flexibility in upstream operations of a grocery supply chain was the issue of the next study. The study was based on two separate projects at a grocery manufacturer. The need for investigating upstream operations more thoroughly was noted during the time benefit studies discussed in Papers 1 and 2. The participants in the two projects were representatives from the manufacturing company and the supplier, and two researchers. These projects targeted increasing flexibility and reducing lead-time in packaging material supply. The packaging production environment was characterized by large production batches and high capacity usage requirements, which resulted in difficulties in matching supply to varying demand.

The first phase in both projects was a current state analysis, which was conducted in three supply chain echelons. The principal data-collection methods were interviews with key operational personnel and data collection from company databases to understand supply chain performance. Based on the results, key development areas were defined. Pilot projects were implemented to test the chosen development actions in practice.

During the studies, large data collection and analysis processes were implemented. Two researchers were responsible for this task. Planning and execution data was considered in three supply chain phases, and supply chain throughput times were considered in six phases. Much of the research effort was targeted towards operational data analyses and on the planning quality analyses. In addition, altogether over twenty key-person interviews in three supply chain phases were carried out to obtain a realistic picture on the operational model. The reliability of the analyses results was ensured in three ways. A simulation on operational results was carried out. Both qualitative and quantitative analyses results were validated in project group meetings and, furthermore, their reliability was tested in pilot projects.

This paper provides answers to research question 2, how the benefits of a coordination mechanism, in this case VMI, can be enhanced. The role of this study in the thesis is in treating the challenges concerning supply capabilities and constraints and providing understanding on the dual role of suppliers between requirements from downstream and constraints from second-tier suppliers.

This doctoral student was responsible for the both projects the paper is based on. Mr Kallionpää conducted most of the analyses during the latter project, and participated in the writing process by commenting the paper.

Paper 6: The effects of delivery speed on supply chain planning

The last study is a multiple case study on the state of supply chain planning in manufacturing companies. Paper 6 addresses the first research question. The aim was to investigate the use of different planning approaches in varying environments. The study aimed at discovering how manufacturing companies are defining their future volumes and which factors define the chosen planning approach. Furthermore, the state of planning integration with suppliers and customers was studied, together with the question of how planning results support company goals. The study was part of a larger project on the life-cycle logistics of products and services, funded by The National Funding Agency for Technology and Innovation and participating companies.

When studying planning approaches in different environments, a broad range of data on the phenomenon is required to cover the subject and to understand the situational factors. In this kind of situation, case-study research is the most productive way to collect and understand context data. The sample size was limited to six companies to allow deeper analyses of each case.

The main data-collection method involved structured interviews carried out in manufacturing companies. A questionnaire (Appendix 4) was used as the research instrument to collect both quantitative data and qualitative data from the six case companies. Two tests were carried out to ensure the questionnaire validity. First, it was checked and commented by the steering group. Second, the questionnaire was pre-tested with one company before going into interviews. Either one or two interviews were carried out in each company, with two to five respondents. Further inquiries were carried out after the interviews when needed. Written material from the companies and other literature sources were also used. The interviews were recorded and an interview memo was written. To ensure the accuracy, the respondents were asked to check the interview memos afterwards.

Analyses were carried inside each case and across cases. The data were collected into a spreadsheet according to the questionnaire themes for cross-case analyses. Analyses targeted on finding factors inside cases for the used planning approach, and in cross-case phase, to identify similarities and differences in planning approaches and find explanatory factors for these.

The study was defined and conducted by this doctoral student, and supported by a steering group. The paper was written by the doctoral student.

4 RESULTS

4.1 How to select a coordination mechanism

This section discusses answers to the question of how manufacturing companies can select operational coordination mechanisms that balance information flow and physical flow, and so improve supply chain performance. Therefore answers to research question 1 are given. The results are presented using the information abundance – execution flexibility - framework that was introduced in Chapter 2.6. First, different replenishment mechanisms are located into the framework from Papers 1 and 2. Then selection between order-based planning and forecast-based planning are discussed based on Paper 6. The final section of this chapter treats planning approaches for innovative products.

4.1.1 Selecting a replenishment mechanism

This section studies if VMI a suitable replenishment mechanism for a specific relationship.

This question is answered through locating different replenishment solutions in the information abundance – execution flexibility -framework. The suitability of each replenishment solution is based on time benefit analyses in Paper 1 and 2. The basic realization in the time benefit analyses is that, in VMI, the supplier has access to the demand information earlier than in an order-based replenishment model. The difference between the available reaction times in an order-based relationship compared to information sharing in VMI is *the time benefit for the supplier*, which is dependent on the level of order batching at the customer. Order-batching causes a delay in the information flow, and this delay is reduced in VMI. The time-benefit model can be used to calculate the suitability of VMI at product level in a specific customer-supplier relationship. The method was also used to compare frequent reorder-based replenishments with VMI. Next, the locations of optional replenishment mechanisms in the information abundance-execution flexibility matrix are explained based on Figure 8.

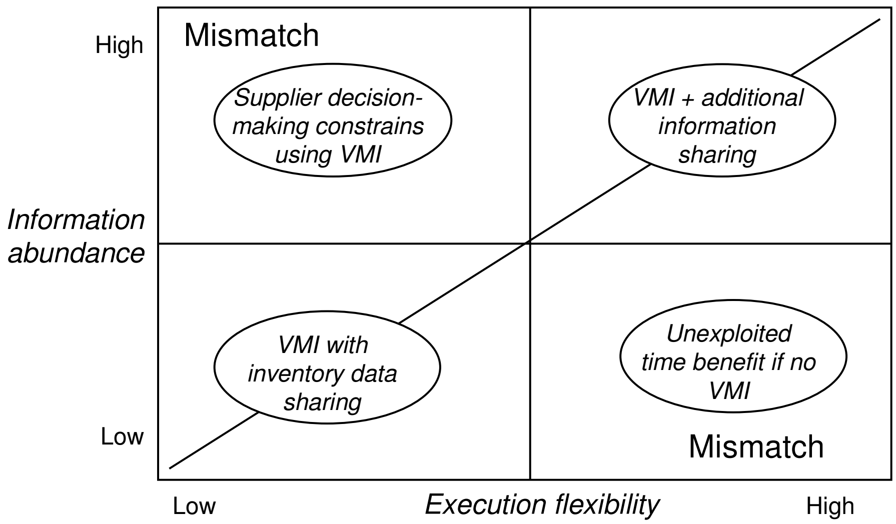

Figure 8. Time benefit results in material flow – information flow matrix.

The conventional VMI is located on the balance line in the lower left quadrant. In Paper 1, the time benefit method indicated that the potential time benefit in VMI is at its greatest with respect to low-volume products, which are ordered infrequently compared to consumption. Paper 2 revealed that the more distorted demand provided a greater time benefit for the supplier; thus suggesting that VMI is more beneficial when replenishment lot size, compared to demand variance, grows. Implementing VMI in grocery supply chain has been more common in downstream phases (Paper 2). This is because a more standardised replenishment system has been an attractive solution for a relatively constant demand in order to eliminate duplicate work and to lower inventory levels without risking availability. These results add to Waller et al.'s (1999) simulation study, where the results showed no difference in likely VMI benefits in relation to demand characteristics. They concluded that companies benefit to an equal degree as long as inventory levels were reviewed frequently.

The location of upper right quadrant was treated in Case 1 in Paper 2, where the operations between a grocery manufacturer and its subsidiary company were considered. This solution was a collaborative VMI. The replenishment solution was based on VMI and included daily inventory data sharing and daily deliveries from the manufacturer. In addition, the model included collaborative forecasting practices that targeted on improved response to assortment changes, promotions, and seasonal demand changes. As a result, the supply chain performance improved many ways. The workload at the manufacturer stabilised, because frequent replenishments allowed manufacturer operations to be matched more accurately with demand. This also concerned seasonal deliveries. Inventory levels dropped radically, and the customers were offered fresher products. This replenishment model is characterized with frequent information sharing practice to support both forecasting and replenishments, and frequent and quick deliveries with a speedy response time.

The comparison of VMI and frequent order-based replenishments model (these were called JIT-replenishments in Paper 1) in two cases in Paper 1, leads to the conclusion that visibility and frequent information exchange, as such, do not improve supply chain performance. Suppliers are not able to utilise the shared information if they are not offered responsibility for the replenishment. Therefore, replenishments with frequent information sharing, but no authority to schedule deliveries, are located in the mismatch location in the upper left quadrant of the framework. In addition, the situations where the supplier is obeying strict timetables or replenishment quantities are located here. In this kind of relationship, the supplier cannot benefit from VMI visibility, because it has limited freedom in its decision making. These kinds of situations are described in Paper 1 in case 1, and in Paper 5.

In the lower-right quadrant of the framework, which is a mismatch location, order-based operations are continued, although VMI would provide the supplier a significant time benefit (Paper 1). The supplier is not offered incremental visibility, and it is not able to benefit in its operations from shared downstream information. For example, the supplier may have to maintain inventories to be able to respond to orders. This quadrant-location suggests that the supply chain has unused flexibility; as was stated in Paper 2.

The results from time-benefit analyses are depicted in Table 7. The results indicate that VMI is an appropriate mechanism to serve both constant demand and variable demand. However, there is a need for different levels of shared information and collaboration. This is illustrated in Figure 8, where the VMI is located in the balance line.

Table 7. Results from the time benefit analyses from Papers 1 and 2.

Location in the framework	**Paper and case no**	**Conclusion**
VMI *Lower left quadrant* *Balance*	Paper 1 Paper 2	Time benefit analyses reveal if VMI is an advantageous replenishment mechanism. Time benefit and suppliers potential benefits grow when replenishment lot size is large compared to demand. Low volume products with high demand amplification benefit most from VMI. In stable demand conditions the benefits from VMI remain lower for the supplier, but can be realised in inventories or through simplified operations.
VMI + additional visibility + collaboration *Upper right quadrant* *Balance*	Paper 2, Case 1 Paper 5	When demand is variable or batch type, additional visibility from downstream for VMI supplier is needed. Further collaborative forms ensure improved supply chain performance.
Unused time benefit *Lower right quadrant* *Mismatch*	Paper 1, Case 1, situation 1 Paper 1, Case 2, before VMI Paper 2, Cases 1 and 2, before VMI	When time benefit exists, time is wasted in the relationship if VMI is not implemented.
Constrained supplier decision making *Upper left quadrant* *Mismatch*	Paper 1, Case 1, situation 2 Paper 2, Case 2 Paper 5	Supplier can not benefit from VMI visibility, if it does not have freedom in replenishment decision-making. Inflexible production system or long raw material lead times prohibit reacting to demand. Manufacturers lose reaction time in frequent order-based replenishments (in Paper 1 called JIT replenishments) compared to VMI.

4.1.2 Selecting between order-based and forecast-based planning

This section is based on Paper 6. First is identified, which factors explain the planning approach used in manufacturing companies. Second, explanation is given to how sources of flexibility are connected to the planning approaches.

Different supply chain planning approaches are located into the information flow – material flow framework in Figure 9. The speed of delivery was identified to be an important explanatory factor for the choice of planning approach. Customer delivery time, inventories or production were used as the main source of flexibility, which is a similar approach to Newman et al's (1993) and Pagell et al's (2000) studies. It was indicated that the planning approach is closely connected to the source of flexibility. In Figure 9, sources of flexibility are located on the x-axis to describe execution flexibility. On the y-axis is information abundance.

Order-based planning can be argued to be an appropriate coordination mechanism when there is a lengthy delivery time (Paper 6). Delivery time is the accepted or allowed delivery time from the customer's perspective. Forecast-focused planning, which was also known as 'proactive planning', was used when delivery time is short. These approaches require different levels of information sharing. Furthermore, high-levels of supplier and customer integration were needed in forecast-focused planning.

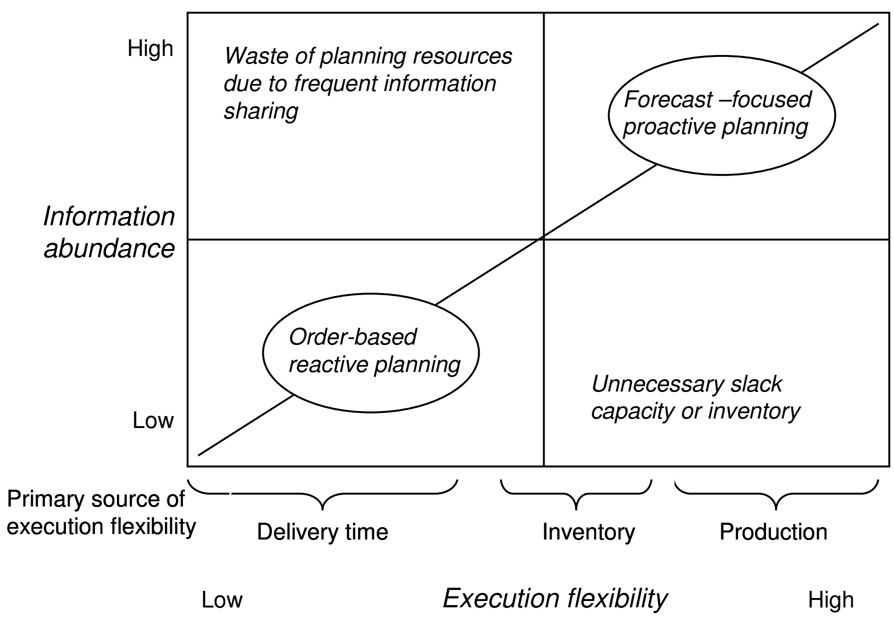

Figure 9. Selecting between order-based and forecast-focused planning.

The connection between sources of flexibility and planning is depicted in Figure 9. Delivery time, as a source of flexibility, indicates that customer waiting time is the main source of providing flexibility. Order-based planning is used in these cases. When flexibility is created by stocking finished goods (inventory as a source of flexibility), both order-based and forecast-based planning may be used. In these cases, the required delivery time and product features define the planning approach. Products with short shelf life or short life cycle need forecasting, because inventory risk grows. For some products, planning combines order-based and forecast-focused approach. This type of planning may be used in campaigns or new product introductions. It utilises early sales data in addition to historical data.

Forecast focused planning fits the situation where production is the main source of flexibility. This approach requires utilising multiple information sources and many types of information from the distribution channel.

In addition to the source of flexibility and delivery speed, product features were identified in Paper 6 to be factors that define the planning approach. The studied features were: change rate in the company product portfolio and the customization stage. Standard products with high change rates were supported with forecast-focused planning. Order-based planning was the appropriate solution for customized products.

4.1.3 Differentiating planning

In this section is studied how a manufacturing company should differentiate planning approaches according to product features.

The goal in differentiated planning, according to Paper 4, is to support the supply chain features required by the product. Another purpose is to improve the use of planning resources by automating planning when possible and by using scarce and expensive managerial or expert resources where most needed. Differentiated planning is needed for large product portfolios with different types of products. In Paper 6, it was also noted that differentiated planning was implemented in special demand situations, such as seasons or product introductions. The means to differentiate planning were selecting diverse planning frequency, product hierarchy level, planning horizon, and data used (Paper 6).

An example of differentiated planning is presented in Paper 4, where the goal was to support the selection of the appropriate planning approach for innovative products. In the case company, current uniform planning approach provided unsatisfactory results. Current planning was a forecast-based process, supported by extensive information on markets, products, supply chain features, distribution channel, and similar type of products in the market. Despite strong expert involvement and input, the process provided unsatisfactory planning results and did not support the matching of demand and supply for highly innovative products. A selection procedure was proposed to provide a better planning result and to rationalize the use of planning resources. Product groups are separated from the uniform planning process, so that more standardised planning can be implemented.

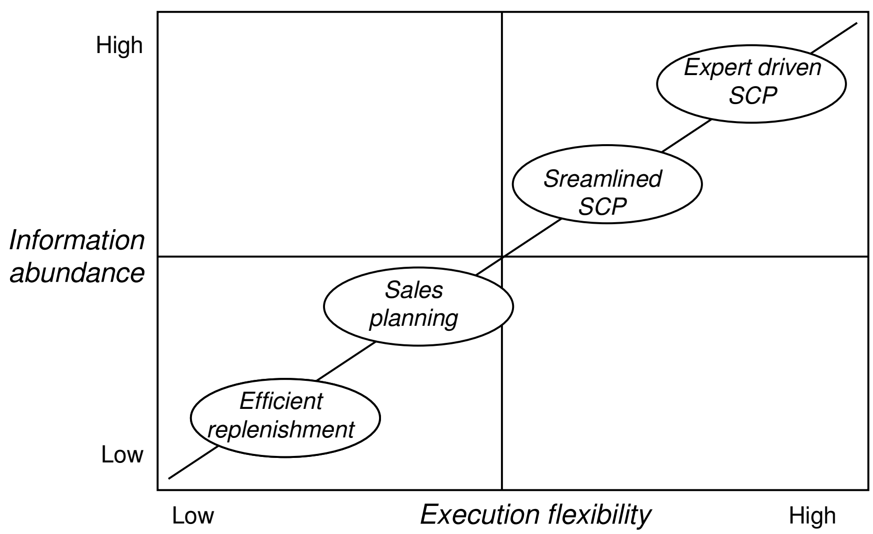

Figure 10. Differentiating supply chain planning (SCP) for innovative products.

The locations in the matrix distinguish the requirements concerning each approach, expressed as information needs and planning resource needs. Close to the lower-left quadrant, planning needs low levels of information and planning resources. The need for planning resources grows when the coordination mechanism moves towards the upper-right corner in the matrix. This principle obeys the coordination theory, stating that information processing capability need to be adjusted to the amount of information and to the uncertainty in the environment (Danese et al., 2004; Galbraith 1977, p. 35-57).

In Figure 10, a planning approach called 'efficient replenishment' is located close to the lower-left corner. This type of planning supports relatively stable and continuous demand. In this solution, the vendor replenishes, based on actual inventory data or forecasts, for example through a VMI mechanism. The required information for replenishment includes sales history for forecasting. The next approach, sales-based planning requires forming a collaborative sales plan that is matched with supply capabilities; and therefore availability can be guaranteed for the quantities in the confirmed plan. This approach requires an organisation to create the sales plan. In streamlined supply chain planning, purchases and assembly are based on downstream visibility rather than forward plans. This approach requires efficient sharing of downstream demand information, and can be used to support stable sales and continuous demand. Inventory buffers are needed to balance minor changes in demand and supply. In expert-driven planning a specialist group generates a volume estimate. This approach can be used to estimate variable or unpredictable demand, when historical sales data or other available data provides inadequate support for planning. Expert-driven planning requires a high planning effort to create a consensus forecast.

The planning approach for a product is determined by sequentially considering how the product fulfils the requirements for each planning approach. There are two basic criteria for selecting the mechanism: the first is the availability of planning resources and information needed and the second is the ease or difficulty with which the planning can be automated and whether there is the possibility of setting rules and procedures for performing the planning task. Efficient replenishment is considered first as it requires the least planning effort, whilst expert-driven demand-supply planning is considered last, as it requires the most planning resources.

In an ideal situation, these approaches are located along the diagonal in the matrix, as is shown in Figure 10. This suggests that information sharing practice and planning in each approach would support optimally the execution for each product group.

4.2 Reaching the balance between information flow and physical flow

In this section, the results from the Papers 3, 5 and 6 associated with the use of two supply chain management-mechanisms are combined. The section provides answers to research question 2. First, improving supply chain planning in manufacturing companies is discussed, followed by a discussion of VMI.

4.2.1 Balance between supply chain planning and execution

The suggested changes that companies should make in their planning are presented in Figure 11. Movements up and down take place by changing planning process, and left and right by changing physical process.

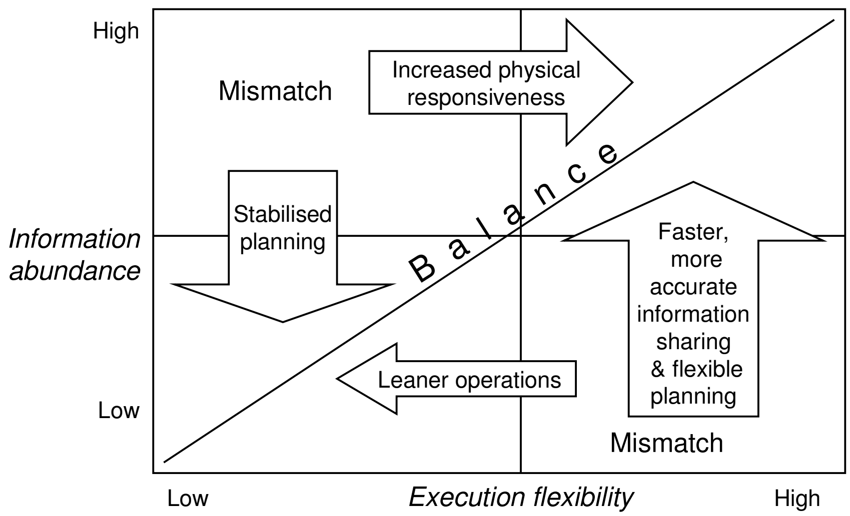

Figure 11. Movements in the information abundance - execution flexibility framework.

First is discussed the mismatch location in the upper left quadrant. Companies may finish up in this location for several reasons. Here the companies' planning system reacts fast to signals from the environment, for example demand signals. This may lead to the situation described in Paper 3, where suppliers' weekly volume changes were large. However if the companies' execution flexibility does not allow a quick response to these changes, this causes confusion. One reason for ending in this location was receiving demand information from several sources. The second problem was the nervousness of the shared data as was described in Papers 3 and 5.

In this location, companies should adopt more stable planning practices to avoid wasting planning resources; and thereby move down in the matrix. Several general principles that can be applied to improve planning processes are identified in Paper 3, and further in Kaipia and Hartiala (2006). One principle was planning simplification. This means reducing planning times, raising planning levels higher up the product hierarchy, or choosing the planning horizons adequate for each type of plan updates. This suggestion is similar to that from Disney et al. (2000), who present approaches to add stability to a production system. One aspect is to reduce the frequency the figures are altered, and weekly planning under stable conditions should be replaced with exception-based planning. The second improvement is to synchronize planning phases better. Time-related issues cause many problems in the supply chain. The differences in planning cycle length, data-processing phases, manual steps in the process, and synchronization problems cause delays in the process. The third improvement is stabilizing planning for example by avoiding major last-minute changes in plans.

The other direction is to move to the right, which means increased execution flexibility. This may take the forms of buffering or creating flexible production capacity for example by employing contract manufacturers. This was identified in Paper 6, where one company received frequent information from retailers, but its own planning process and execution capability were not able to utilise this information efficiently. Such frequent information sharing practice is not necessary, if current relative long customer lead-time is maintained. This furniture producing company could create a competitive advantage in a highly price competitive consumer product sector if it was able to shorten customer lead times radically.

The second mismatch location is in the lower-right quadrant. Here the companies are keeping *slack resources*, for example production capacity or inventories that are not required or utilised to satisfy customers. These companies can either adopt leaner physical operations or adopt more volatile and demand-responsive planning. The latter alternative requires capturing demand information closer to the end-customer and creating processes to align to those signals. This kind of movement is widely studied in literature on the value of information sharing (for example in Cachon and Fisher, 2002; Yu et al., 2001; Zhao et al., 2002). This direction also requires more integrated supply chain management and sharing of plans with suppliers and customers, as was found in Paper 6. This result supports the finding from Byrne and Heavey (2006) that suggest that to benefit from information sharing requires also further collaborative efforts.

The study on planning approaches in manufacturing companies (Paper 6) revealed that in special demand situations, such as campaigns and seasons, or in the product introduction phase, the companies are implementing differentiated planning. These situations concern mostly consumer product companies that are forecasting demand. Differentiated planning may be implemented for a customer or a group of customers. In addition, when the target is to gain access to demand data, such as customer plans, forecasts and weak signals from the market, the companies are adopting more collaborative forms of planning. This is important for manufacturers that are located far from end-customers in the supply chain, but need to obtain demand data to ensure responsiveness.

Planning differentiation involves creating a different planning organisation, and selecting the adequate planning frequency, planning level, planning horizon, and basing the plans on the best available data. In specific situations, more accurate data – for example, demand data closer to the end customer – needs to be obtained. In new product introductions, more frequent planning is to be employed and therefore moving towards the upper-right corner of the matrix. Similar situations are described in Holmström et al. (2006) and in Småros (2005, pp. 72-83). When differentiating planning, companies are taking several parallel positions in the information abundance – execution flexibility -matrix.

4.2.2 Balancing a VMI relationship

This section discusses two cases reported in Paper 3 and Paper 5, where is sought for balance between information sharing and flow coordination in a VMI relationship. In both cases, a weekly information sharing process is implemented to cover the information needs of the VMI supplier. It was discovered that the suppliers suffer from nervousness of the shared data. The reasons behind information quality problems in the VMI case in Paper 3 were concealed in inventory management logic, and in Paper 5 in production planning.

A VMI case from grocery products supply chain

In the VMI implementation case, the reason for planning nervousness originated from production planning, which provided the information for suppliers concerning package material and raw material needs. Long-term production plans were updated according to established demand and forecast updates and production requirements. A major forecast round was carried out monthly with minor changes in between. If forecasts were changed, production plans were automatically updated. In addition, when actual production came closer, the production planner took responsibility of the plans. It was recognised that the system parameters did not support the planners' ideas on batch sizes and production order, which resulted in large changes in the plan close to production moment. All these changes were updated in weekly visibility reports to suppliers.

In Figure 12, the information sharing mechanism is located in the upper-left quadrant of the information abundance – execution flexibility -matrix. The location signifies that downstream information sharing mechanism and the supplier's own capability to use the shared information in production planning, do not match. The supplier's planning horizon is long and the downstream information sharing mechanism provides information in such a frequency and extent that cannot be utilised by the supplier or responded to in supplier operations. The following sections explain the changes in supplier operations that increased flexibility and made the move illustrated in Figure 12 happen. These changes improved the balance in the relationship, yet some imbalance remained.

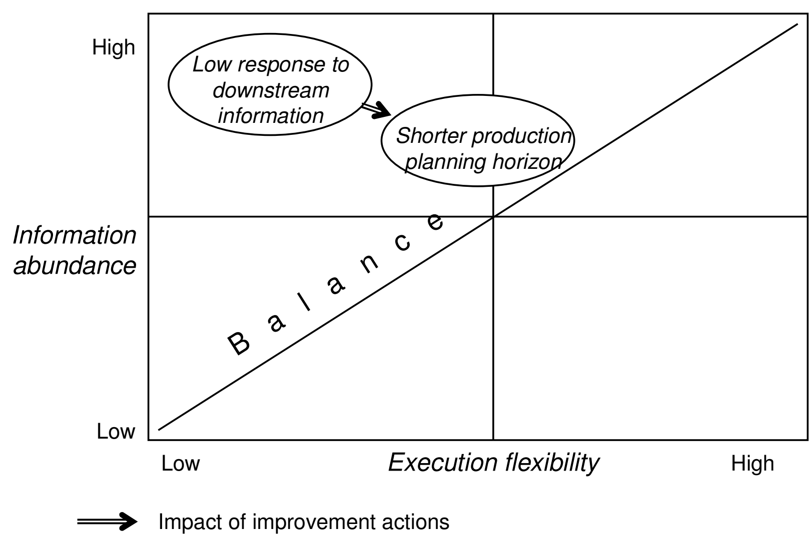

Figure 12. Changing a VMI relationship in the information abundance - execution flexibility matrix.

Two means to improve VMI information usage were suggested. A synchronized information sharing practice was established to support package material suppliers' production planning. In a weekly process, the planner was provided with a new production plan from downstream, and the freshest capacity usage situation from 2nd tier suppliers. This change reduced uncertainty and created a routine for decision-making. Second, production decisions concerning the share of variants in each production batch were delayed until very close to the beginning of production to benefit from the availability of a fresher and more accurate demand forecast.

An additional change, reducing supplier's production batch size, was identified and piloted as described in Paper 5. It was a very attractive way of reducing lead-time and shortening the planning horizon. Smaller production batches allow more frequent decisions concerning one product and improved match between supply and demand. However, current production machinery and the requirement for a high capacity utilisation rate do not support this change, and it resulted in problems in maintaining high quality standards.

The last change concerned stocking. To reduce the dependency on second-tier suppliers' timetables, it was proposed that buffering stage should be shifted upwards in the supply chain, before package production. This change would reduce total throughput time, and reduce uncertainty concerning raw material timetables and therefore shorten the planning horizon.

An interesting finding was that the information needs of VMI suppliers differ according to the type of demand. For VMI suppliers, who are serving variable demand, inventory movement alone is not adequate for production planning with a long planning horizon. This was first noticed in Papers 1 and 2 and it became more evident in Paper 5, where the suppliers are serving a batch production process. If solely inventory level information was shared, the supplier would only see batches diminish from the warehouse without being able to anticipate the demand. This result indicates that, if supplier's reaction time is less than the VMI supplier's production planning horizon added with the production throughput time, the supplier needs to acquire more information from downstream. This finding expands the usefulness of time benefit analyses (Paper 1 and 2). As time-benefit calculations are performed at product level, they can be used to reveal which products' management needs more downstream visibility, and where efforts to increase visibility should be targeted.

A VMI case from electronics supply chain

As reported in Paper 3, the VMI implementation in an electronic product supply chain used a specific inventory management logic, which caused large volume changes for the suppliers. The calculation model defined for each component minimum and maximum inventory levels and the suppliers were supposed to keep the inventory between those levels. The target inventory levels were updated weekly according to demand changes. The decision-making responsibility was shifted to the suppliers, but only little freedom was left for them. The suppliers were not able to benefit from the shared VMI information, nor the time benefit of VMI. In the case supply chain, the VMI information-sharing model did not smooth the workload experienced by the supplier. On the contrary, an additional decision-making step was realized and, furthermore, the calculation logic strengthened the swings in the information flow.

The supplier in the VMI case in Paper 3 was very flexible, but it had difficulties in adjusting its production according to the fluctuating target inventory levels. Therefore, changes in the data sharing mechanism as well as in the role of VMI inventory were suggested to level production quantities. These changes stabilised the information sharing practice and caused a move illustrated in Figure 13.

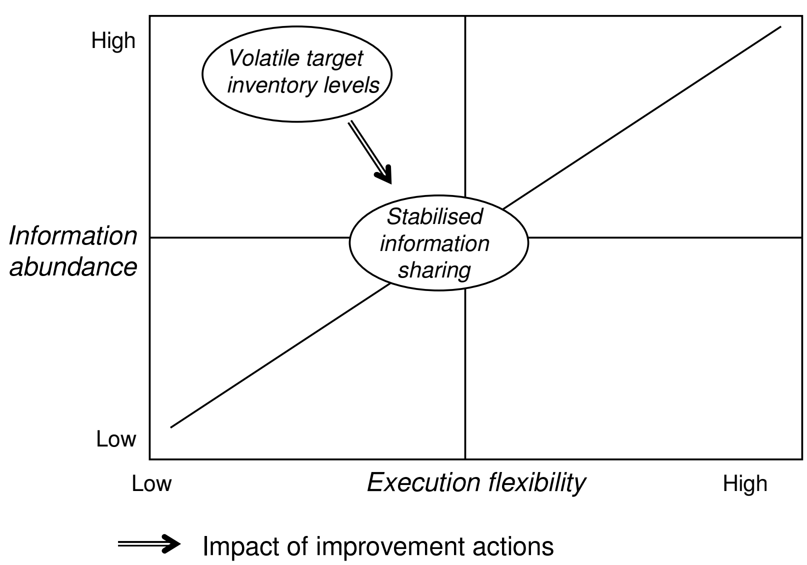

Figure 13. Change in VMI case from Paper 3.

The most important observation was the use of VMI inventory to balance demand fluctuations, enabling suppliers to level production quantities and, at the same time, maintain materials availability. In this way the inventory is used to level the demand, not to increase fluctuation of demand. In product introductions, setting the right target inventory level is especially important, because if a large inventory is required, the limited production capacity is used to fill up the inventory, not to respond to end-customer demand.

The second suggested improvement was to change the logic of the target inventory-level calculation. The target inventory level should not strictly obey the weekly delivery quantities, but it should be smoothed for example to correspond four weeks' average deliveries. This is an approach adopted from Disney et al. (2000), who argue that demand needs to be smoothed over a period in order to protect from excessive fluctuations in production rates.

5 CONCLUSIONS AND DISCUSSION

5.1 Conclusions

The conclusions concerning the first research question are presented next. The research question was:

How to select operational coordination mechanisms to match demand and supply in manufacturing companies?

This thesis presents a framework on selecting the supply chain coordination mechanism. According to the framework, the supply chain coordination mechanism should be selected according to the match between execution flexibility and information abundance. This approach combines execution capability to the information needs of the planning process. The main principle is that information sharing should target on providing accurate and good-quality information for the decision makers.

Papers 1 and 2 present how the selection between VMI and order-based replenishment should be completed according to the supplier's reaction time, which was measured as *time benefit* for the supplier. This time benefit is dependent on the information delay caused by order batching at the customer. In VMI this delay is reduced by information sharing, and thus it increases the supplier's reaction time. Therefore VMI is a profitable replenishment mechanism for the supplier when variance in orders is larger than variance of demand. In this situation, the supplier benefits from increased reaction time.

However, Paper 5 showed that the extent of shared VMI information should be selected along the suppliers planning horizon in relation to the demand variance. For products with constant demand replenishments can be based on shared inventory information. If the difference between variance in orders and variance in consumption is small, inventory level changes provide adequate information for replenishment decisions. When demand is variable and, especially, when the supplier's production planning horizon is long, additional information is needed for making efficient replenishment decisions. A prerequisite for suppliers with long planning horizon to benefit from a VMI relationship is information sharing concerning downstream production plans or demand forecasts.

Paper 6 showed that supply chain speed requirements from customers called for companies to create flexible production modes and adaptive planning modes. This presumes acquiring accurate demand information and integrating suppliers into the planning process. The speed requirement was caused by two factors: rapid market changes or product features. This situation needs volatile planning and frequent information sharing to support flexible production and supply chain execution. In this thesis, such planning is referred to as *proactive planning*. Planning takes place before actual demand is realised. In the case of flexible and lengthy customer delivery time, *reactive planning* based on actual orders should be employed.

To improve planning and the use of planning resources, differentiated planning modes should be selected (Papers 4 and 6). A high-level of execution flexibility is required in special demand situations, new product introductions or products with volatile demand. In a product's maturity phase, or for products with stable demand, the demand can be satisfied with a lower level of flexibility. According to the information abundance – execution flexibility framework, each level of execution flexibility should be supported with different levels of information sharing, different planning frequency, and correct planning level.

The conclusions concerning the second research question are presented next. The research question was:

How to reach the balance between information flow and material flow?

The framework on selecting the supply chain coordination mechanism was used to identify the actions companies should take to achieve balance between information flow and execution. Results from Papers 3 and 6 indicated that current planning is not always capable of supporting the material flow efficiently. Currently supply chain planning may suffer from lack of information, overabundance of information or poor information quality.

Two main reasons for imbalance between information abundance and execution flexibility were identified. In Paper 3, frequent plan updates according to demand changes caused planning nervousness. Other reasons to the phenomenon were varying planning processes, delays in information flow, multiple decision-making phases, unsynchronized planning calendars, and long planning horizons. This phenomenon caused bullwhip and large volume changes at the supplier. The other reason was lack of planning capability or inadequate information. In Papers 1 and 2, it was identified that unused execution flexibility in replenishments could be released with VMI. Lack of planning capability was also the case in Paper 6, where MTO-manufacturers had difficulties in keeping customer service level high despite of relatively long and flexible delivery time.

The VMI supplier is not able to benefit from shared information if its decision-making is constrained. Low production planning frequency is an important factor that limits benefiting from shared information. However, two other factors affecting the VMI benefits in the upstream phases of the supply chain were identified. Paper 5 showed that inflexible production environment with long planning horizon limited the ability to benefit from shared information. Planning horizon has an impact on VMI benefits, because replenishment decision has to be made under greater level of uncertainty. Production capacity features, or long raw material lead times, as identified in Paper 5 may cause long planning horizon. This factor is related to production planning frequency because often, but not always, infrequent planning means also long planning horizon. Too accurate a response to varying downstream demand limited VMI benefits, as was found in Papers 3 and 5. In these cases the supplier had no possibility to use flexibility in timing replenishments.

Planning nervousness can be reduced with stabilising planning and synchronising information sharing with upstream and downstream players to ensure that decisions are based on the freshest available data. As shown in Paper 6, the faster delivery speed in the supply chain, the more integrated planning with frequent information sharing is required.

Improving a replenishment relationship takes place by shifting flexibilities and uncertainties between supply chain members. In Paper 1 and 2 was discussed the impacts of VMI, where the supplier takes the authority of replenishments and the uncertainty is shifted to them. Improving the quality of shared VMI information takes place by offering the right information and improving downstream planning. Furthermore, it was noted that to realise the full potential of the shared VMI information further collaboration practices need to be implemented.

An increase in execution flexibility was achieved by locating the buffering stage accurately in the supply chain. VMI inventory should be exploited to balance demand fluctuations. Locating buffering further upstream was proved to reduce lead times and increase flexibility in VMI suppliers' operations when dependency on 2^{nd} tier suppliers was high. A supplier also benefits if production decisions can be delayed, when more accurate forecasts can be used. Reducing production batch sizes improves significantly possibilities to match production to downstream demand, but is challenged by the capacity usage requirements.

5.2 Discussion

This section provides the theoretical and practical implications of the research. The results of this thesis are presented from the viewpoint of supply chain coordination literature, supply chain planning, VMI, and information quality literature.

5.2.1 Supply chain coordination

This thesis provides a framework for selecting coordination mechanisms according to physical flow and information flow characteristics. These flows are described with information abundance and execution flexibility. This framework is a contribution to the growing stream of literature attempting to better understand the value of information sharing in managing physical flows in the supply chain. Previous literature does not offer solutions for systematically organising these efforts, as was pointed out by Sahin and Robinson (2002; 2005). The framework presented in this thesis offers a novel solution for combining these diverse efforts.

Spekman et al. (1998) presents the transition phases from negotiation-based supplier relationships to a collaborative relationship. Each stage requires different levels of information sharing to enable the relationship. This study supports the principle that supply chain integration can be implemented in different wideness and the goal of the relationship is not close collaboration with all partners. Collaboration is an investment in the relationship, and not all suppliers and customers warrant such an investment. The approach used in this thesis aligns with that of Hines et al. (2000) and Bacon et al. (2002), as they too consider the integration process as a continuum.

A slightly different approach is taken by Lee (2000) who states that "with shared information and knowledge in place, the supply chain partners are ... ready to start coordinating their efforts by exchanging decision rights, work, and resources." When we consider this statement in the light of the framework for integrating the physical flow and information flow presented in this thesis, it can be concluded that sharing information and knowledge without considering physical flow capabilities at the same time potentially leads to a mismatch situation.

This study considers the use and need of planning resources for coordination, which has not been widely studied. One study, however, has addressed the costs of coordination (Xu and Beamon, 2006). In selecting a coordination mechanism, the trade-off is between the cost of the coordination process and the increase in the quality of actions generated by coordination. In most companies, resources for development are limited, so managers must choose which development actions to take each year, and with whom. The presented framework may offer a new way of thinking when considering development actions and help targeting monetary and other resources efficiently. On the other hand, the need for increased planning capacity and capability can be identified by using the framework in companies. The solution may be to employ information technology to automate the solving of standard problems, and to hire planning experts to act as liaisons in the organisation for non-standard problem solving.

Incorporating an adequate level of information sharing into the coordination mechanism is the central idea of this thesis. In most companies, a common practice is to widely adopt information-sharing practices and employ IT systems to support these practices. Real-time information sharing has become available and feasible. To justify these investments, the profitability of the investment should be ensured by selecting such a level of information sharing that improved decision-making and supply chain performance is realised. Traditionally, lack of information has been the problem. Today, the problem may also be information overabundance. For example, there is little use in sharing weekly plans with varying contents to a supplier who reacts three times a year in its own production planning. In Paper 3 was described a situation where frequent plan updates are the cause for extensive volume changes at the supplier. This is a serious shortcoming that may take place due to frequent re-planning in supply chains.

On the other hand, the results of this thesis can increase our understanding of the need for a certain type of capacity in companies. According to Olhager and Selldin (2004), the main objectives of supply chain design are still cost minimisation and capacity usage. Flexibility issues seem not to be as important as cost-related factors. The framework suggests that volatile production capacity is needed in uncertain environments and should be targeted towards those products that require most flexibility. For example, the clothing company Zara, which renews its products at a high speed, relies on proximate production capacity: its own production capacity is extended with small local sewing shops that offer flexibility for the most labour-intensive production phases. This solution is contrary to the industry trend of producing in distant low-cost countries. Zara's solution is connected to an active and rapid capturing of demand trends, and fast reactions to the identified changes.

5.2.2 Supply chain planning

The framework presented in this thesis suggests that planning capabilities and resources should be adapted to the features and requirements of the information flow and the material flow. Earlier studies have aimed at matching product features to supply chain characteristics. These studies started with Fishers study (1997) on matching product features to supply chain characteristics, which is further developed in many papers to better align supply chains with products (Li and O'Brian, 2001; Lee, 2002; Collin, 2003; De Treville et al., 2004). Additionally, demand and product variety have been used as selection criteria (Childerhouse et al., 2002) added with profit (Wong et al., 2006), as well as customization and supplier lead times (Hvolby and Trienekens, 2002).

This thesis provides a new insight from that of extant literature by focusing on supply chain planning approach selection. The availability of data and planning resources are used as selection criteria, in addition to customization stage and demand features. This approach takes into account the limited planning resources of companies, and limited availability or usability of existing data. It also points out where planning resources are wasted in frequent re-planning or information exchange practice.

5.2.3 VMI operations model

Knowledge on the VMI operations model was enhanced in this thesis in two ways: first, concerning the suitability of a VMI system, and second, with respect to the question of how to make the use of an existing VMI system more efficient. The time benefit tool was useful in identifying the benefits of VMI and the need for further stages of integration.

This study contributes to VMI literature by showing that VMI is more beneficial for suppliers concerned with low volume products with infrequent ordering practice and for products with variable demand. This study also identifies the need to share information beyond VMI inventory if production-planning horizon is long. Earlier VMI studies have indicated the benefits of VMI as reduced inventories, fewer stockouts, and improved customer service (Småros et al., 2003; Waller et al., 1999; Blatherwick, 1998), while the benefits in production planning have been unclear (Vergin and Barr, 1999; Kauremaa, 2006).

It was also observed that suppliers' long production planning horizon and infrequent production makes benefiting from VMI more challenging for manufacturers. This result supports the finding from Småros' (2005) study, which proved that demand information visibility is more valuable when connected to short planning cycles. A similar idea is expressed in flexibility literature, where is stated that infrequent production limits timing flexibility (Bertrand, 2003). In organizational research, the same idea is treated as the level of coordination that is to be justified according to the uncertainty (Table 2). Therefore, a useful finding for companies is that flexibility in a VMI operations mode can be increased by implementing changes that shorten planning horizon in production planning, and improve the synchronization between information sharing and decision-making.

5.2.4 Information sharing and information quality

In this thesis, information abundance was selected as an important factor to define the right planning approach. The attributes that were identified to define information abundance are existence, availability, and usability of data. For example, new products do not have historical sales data, but in some cases, the demand data of similar products can be used as a substitute. Even though the best possible data for a certain decision-making situation exist, they may not be available. Either supply chain partners are not willing or capable of sharing end-customer demand data, or it is received after such a delay that the decision has already been made. However, not all data is usable, because it may be in the wrong form, inadequate for making the decision or suffering from redundancy. In information-sharing literature, information is assumed to be of high quality (for example, Lee et al., 2000; Gavirneni et al., 1999; Yu et al., 2001). In reality, information quality is not, however, perfect. For example, availability and accuracy, which have an effect on supply chain performance, may be inadequate (Petersen, 1999).

The effect of poor information quality can be dampened by targeting information sharing resources towards those situations and products that require them most. This result concurs with Simchi-Levi et al.'s (2003) statement that, management should be concerned about what data should be transferred and analysed, and what part of the data can be ignored. Information sharing was noticed to be more valuable when demand variance grows. In the information sharing literature, this has already been proved by Gavirneni et al. (1999) and Lee et al. (2000).

The study revealed that planning nervousness was one source of confusion in the information abundance-execution flexibility matrix. This mismatch situation is a result of the increased speed of change in the markets that require collaborative practices across the supply chain and more efficient information sharing between supply chain members. Supply chains are formed of companies that come from different types of industries with different clock-speeds (Fine, 1998). When such companies share information, the differences in clock-speeds may cause this mismatch. Capacity-intensive industries are not capable of responding to the requirements of, for example, consumer product producers.

Several industry sectors face requirements for flexibility that are hardening to such an extent that they cannot be met with the current inflexible machinery.

This research suggests that planning processes are one source of uncertainty for suppliers. In Paper 3, the manner in which planning accuracy fluctuates as the planning process proceeds across the supply chain is studied. Additionally, in Paper 5, this phenomenon was one factor, which prohibited the suppliers from benefiting from visibility. This issue is widely discussed in the bullwhip literature. As a solution, it is proposed that information sharing from further downstream, in a VMI operations mode, for example, would dampen the bullwhip effect (Disney and Towill, 2003a). In contradiction to some previous literature (for example Chen et al., 2000), this study emphasises that, in many cases, suppliers who are independent decision makers are not able to benefit from downstream demand data, but need accurate information from the supply chain phase they are serving. In the VMI studies in Paper 1, 2 and 5, were identified situations where additional demand information was required.

5.3 Limitations of this research

This section discusses the strengths and weaknesses of the research. The subject of the thesis is supply chain coordination mechanisms, their selection, and usage in order to improve supply chain performance. Following the literature review, it was found to be an under-researched topic, and therefore suitable for empirical research (Swamidass, 1991).

Coordination theory is applied in this thesis to recapitulate the results from Papers 1-6. Coordination theory proposes that characterizing different kinds of dependencies can be used to identify coordination processes to manage these dependencies. This approach brought new insights into the results from Papers 1-6 and helped in identifying and classifying them. The use of coordination theory was the key to forming the framework on the balance between information flow and physical flow. Therefore, two metaphors concerning theories can be underlined. First, coordination theory acted as a lens (Amundson, 1998) through which the results were observed. Second, coordination theory was a very practical tool in building the framework, and therefore the remark by Van de

Ven (1989), originally from Lewin (1945), that "Nothing is quite so practical as a good theory" was felicitous.

However, this thesis has several limitations. Case-study research was widely applied in the studies. Case research is best suited for theory building (Eisenhardt 1989), but have been criticized for difficulties in generalizing the results and for providing too simple theories. The studies in this thesis include one in-depth single case study, one two-case study and one multiple case study. This follows the suggestion by Handfield and Melnyk (1998), who stated that the alternative case study research strategies, few focused case studies, in depth case studies, multi-site case studies or best-in-class case studies, should be selected according to the stage of theory development.

Furthermore, in this thesis, empirical case studies alternated with modelling studies. The benefit of model-based studies concerning the ability to study a phenomenon 'out there' was valuable. Providing predictions was more evident in model-based studies, as was the case in the time-benefit studies in Papers 1 and 2, and in forming the framework for the planning approach selection in Paper 4. However, the comprehension of the overall research issue would not have been possible without using both empirical and modelling studies. The use of complementary research approaches clearly adds to the richness and depth of understanding the research area. Therefore, both empirical studies and modelling studies have been valuable in the theory-building process in this thesis.

One way to ensure reliability of the single studies was publishing the research results in an early research stage. The journal blind-review processes have brought valuable feedback for all the papers and offered the researcher the opportunity to improve the papers and bring them into a more focused form. Publishing offers a way for the academic community to evaluate the research. Feedback from the research community of the early papers, especially Paper 1 has already been received. Several researchers have critically evaluated the model (Papers 1 and 2), and it has been positively commented upon. This paper has also been cited by authors' in several publications.

Altogether fourteen companies were investigated in the studies as a whole. Nonetheless, two companies were more dominant than the others, both being present in four papers. These two companies have had more impact on the results than the rest of the participating companies. Yet, these companies are leading companies in their industry sectors, and have therefore offered an excellent environment for case studies. Both these companies participated in the multiple case study in Paper 6; hence, the sample is clearly biased towards the best-performing companies.

The model in Paper 4 was developed for the needs of the case company, and tested with a group of products. The planning experts of the case company – a leading-edge company in the industry – considered the model practical, useful, and even 'splendid'. However, testing and validation of the model is limited to the experiences from the case company.

5.4 Further research

The topic of supply chain uncertainties was disregarded from this compendium, although the issue is closely related to the adoption of coordination mechanisms. Uncertainties are present in every supply chain, they are related to decision-making situations, and have an affect on supply chain performance (Van der Vorst and Beulens, 2002; Gupta and Maranas, 2003). In this research, the uncertainties concerned information flow in the senses of information availability and quality. However, uncertainties may concern lead times, process variability or environmental contingencies and they may be predictable (classifiable) or unpredictable. In future research, the connection between different types of uncertainties to supply chain coordination mechanisms needs to be addressed. This research might, arguably, follow the principles of Grandori and Soda's research (2006), which considers coordination mechanisms and their ability to solve coordination problems, which they describe as interdependencies or uncertainties between activities. This is also an evident direction to further develop the framework presented in this thesis: to consider supply chain uncertainties and identify which mechanisms are adequate to manage them.

The lack of an end-to-end view of supply chains in the literature is pointed out by several researchers. For example, Erengüç et al. (1999) classified research on supply chain planning into three classes based on the respective supply chain stage: supplier stage, plant stage and distribution stage. They state that analytical or simulation models that integrate the three major stages are still lacking. Furthermore, in information-sharing research, the end-to-end view is not common – most studies concentrate on one-stage information sharing and often with only one collaborative partner. Therefore, studies to find synchronised solutions to combining material flow - production and stocking phases – and the information flow are needed. This kind of model is too complex to be easily implemented to cover the whole supply chain, and probably will suffer from serious deficiencies. Therefore, partial simulation studies from, for example, three upstream echelons would be attainable and productive.

Coordination theory is not widely applied in supply chain management research and in empirical research on supply chains even less. Even though incentives and collective learning, which are the organisational coordination linkages (Table 1), were ignored, coordination theory proved to be a working approach in this thesis. It could offer a novel and productive way to analyse and understand supply chains. Further investigations into the redeployment of resources, decision-making authority, time, and information to the best-positioned supply chain partner may take the form of case studies to identify good practices. In addition, a more constructive approach may be fruitful to study the determinants for implementing coordination in different supply chain settings.

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Appendix 1: Coordination literature

Studies on supply chain coordination 1/2

Author(s)	***Nr of sc echelons***	***Method***	***Target/Studied coordination mechanism***	***Decision making situation***
Albino, Pontrandolfo and Scozzi, 2002	1, production process	Analysis of information flows	To define a methodology for describing the coordination needs	A production process
Cachon and Zipkin, 1999	2, supplier - retailer	Analytical model	Cooperative and cooperative inventory policies	Inventory level
Cachon, 1999	2, one supplier and N retailers	Analytical model	A fixed batch size in a scheduled ordering policy	Balanced orders vs. synchronized orders and their impact on inventories and system costs.
Chen, Chen and Chen, 2004	2, manufacturer and retailer	Analytical model	Risk sharing contract	Production quantity, with long lead time and demand information updating
Danese, Romano and Vinelli, 2004	4-5, supplier, production, distribution centre, sales companies, customers	A three case study	Use of liaison devises in CPFR implementation	CPFR implementation
Gupta and Weerawat, 2006	2, a make-to-order manufacturer and a component supplier	Analytical model	Specifying component inventory level, 2 types of revenue sharing	Component inventory
Lewis and Talalayewski, 2004	Number of nodes, connections and transactions in different physical and informational structures	Transaction cost analyses	To show that IT-enabled information structure is more efficient than hierarchical distribution structure	Supply chain structural alternatives
Patnayakuni, Rai and Seth, 2006	Focal firms and its partners	Survey	The impact of asset specificity, long term orientation and control variables on sc coordination	
Piplani and Fu, 2004	3, a multi-agent system	A framework and a single case study	A coordination framework to align inventory decisions	Inventory decisions in decentralized supply chains

Studies on supply chain coordination 2/2

Author(s)	***Nr of sc echelons***	***Method***	***Target/Studied coordination mechanism***	***Decision making situation***
Romano, 2003	In two cases 5, in one case 4	Multiple case study	Use of coordination mechanisms in three supply networks	
Sahin and Robinson, 2005	2, vendor and a manufacturer	Analytical model	Five supply chain strategies on different levels of information sharing and coordination	Replenishment in MTO supply chain
Schneeweiss and Zimmer, 2004	2, a producer and a supplier	Analytical model	Hierarchical coordination mechanisms with private information	Capacity, order quantity, inventory
Simatupang, Sandroto and Lubis, 2004	1, a fashion company	A case study	How coordination mechanisms are carried out in practice and comparison to theory	Production quantity, with long lead time, demand uncertainty and a short selling season
Stank, Crum and Arango, 1999	1, interfirm collaboration	Survey, 47 respondents	The relation of communication, information exchange, partnering and performance monitoring to logistics performance	
Zimmer, 2001	2, a producer and a supplier	Analytical model	To find a coordination mechanism performing as well as a centralized one	Order quantity and excess capacity in just-in-time (JIT) environment
Xu and Beamon, 2006	1, job order within a job shop	Attribute based approach	Develop a process for selecting coordination mechanisms in a supply chain, selection between 4 mechanisms	Identifies relationships between information systems, coordination mechanisms and technologies

Literature reviews on supply chain coordination

Author	**Target**	**Result**	**Classification principle**	**Finding**
Li and Wang, 2006	Review of coordination mechanisms of supply chain systems	Coordination models	Nature of demand, centralized vs. decentralized	
Sahin and Robinson, 2002	Consolidate research efforts on the value of information sharing and physical flow coordination	Over 100 articles classified	Informational sharing, physical flow coordination	Several research suggestions
Sarmah, Acharya and Goyal, 2005	Supply chain coordination models with quantity discounts	Buyer-vendor coordination models	Number of players, two stages	The literature describes supply chain in a highly aggregated level and considers only two decision makers
Simatupang, Wright and Sridharan 2002	Literature survey on coordination	Taxonomy of coordination modes	Mutuality, focus of coordination	
Whang, 1995	Literature survey on coordination in different systems	A taxonomy of coordination in operations	Coordination within operations, cross-functional coordination, inter-organizational coordination	

Appendix 2: Supply chain flexibility types

Classification	***Type of flexibility***	***Author(s)***	***Ability needed***
Input flexibility	Supplier flexibility	Sawhney 2006	The responsiveness enjoyed by the firm to the desired changes in its raw material supply involving mix, volume, delivery time and new product/modifications
Process flexibility	Labor flexibility	Upton 1994, Sawhney 2006	The ability of the workers to handle a range of tasks
	Changeover flexibility	Pagell and Krause 2004	The ability of a manufacturing system to handle additions or subtractions to the product mix
	Modification or design change flexibility	Pagell and Krause 2004, Upton 1994	The ability of a manufacturing system to implement minor changes in current products
	Product flexibility	Vickery et al. 1999, Upton 1994	The ability to produce customised products
	Equipment or machine flexibility	Upton 1994, Sawhney 2006	The ability of equipment to handle a wide range of operations
	Material-handling flexibility	Sawhney 2006	The ability to accommodate changes and efficiently link different machine centers in the production system
	Input quality flexibility	Sawhney 2006	The ability of the production system to accommodate a range of input variations and conform a range of tolerances
	Expansion flexibility	Upton 1994, Sawhney 2006	The ability to increase the capacity of the production system within the company's minimum planning period
Output flexibility	Distribution or access flexibility	Vickery et al. 1999	The ability to spread products to the market
	Responsiveness to the market	Vickery et al. 1999	The ability to meet or exceed customer requirements
	Volume flexibility	Pagell and Krause 2004, Vickery et al (1999), Upton 1994	The ability to increase and decrease production in response to customer demand within the minimum planning period
	Mix flexibility	Sawhney 2006, Uoton 1994, Pagell and Krause 2004	The ability to produce a wide range of product lines within the minimum planning period
	New product flexibility	Vickery et al. 1999, Sawhney 2006	The ability to introduce many new products and product varieties within the minimum planning period
	Delivery flexibility	Pagell and Krause 2004	The ability to shorten or lengthen delivery time

Appendix 3. Research cooperation

Six studies are included in this thesis. Five of the papers are contributed by other researchers or logistics experts from companies. The share of the authors' contribution to the papers in each research phase is depicted in Table below.

Table. Each author's contribution in different research phases to the six papers.

Paper	Authors	Research design	Data collection	Data analyses	Drawing conclusions	Paper design	Paper finishing
1	Kaipia	50	100	90	80	60	80
	Holmström	50	0	10	20	20	10
	Tanskanen	0	0	0	0	20	10
2	Kaipia	60	50	50	40	80	80
	Holmström	20	0	0	30	10	20
	Hellström	20	50	50	30	10	0
3	Kaipia	20	20	20	40	80	80
	Korhonen	60	40	40	30	10	10
	Hartiala	20	40	40	30	10	10
4	Kaipia	60	100	90	80	80	85
	Holmström	40	0	10	20	20	15
5	Kaipia	80	60	60	80	90	95
	Kallionpää	20	40	40	20	10	5
6	Kaipia	100	100	100	100	100	100

In the first study the doctoral student worked together with Dr Holmström and professor Tanskanen from Helsinki University of Technology. The research design in the first paper was conducted by the author of this thesis, the doctoral student, and Dr Holmström. The doctoral student was responsible for data collection and most parts of the analyses and conclusions. The third author, professor Tanskanen took part in paper design and in finishing the paper.

The study reported in the second paper was based on co-operation with Mr Hellström, who worked in the case company, and Dr Holmström as in Paper 1. All the three authors of Paper 2 attended the research design, however the role of the doctoral student was strongest. The paper includes two cases, of which one was conducted by Mr Hellström and one by the doctoral student. The workload in data collection and data analyses phases was therefore divided even between these authors. The doctoral student was responsible for paper design and finishing the paper, and the other authors' role was to comment on the manuscript.

Paper 3 reported a single case study on planning processes in a global company, where both co-authors worked at the time the research was conducted. The study was based on a large project implemented in the company. The research design for this specific paper was conducted collaboratively by the three authors, however Mrs Korhonens role was large based on the work she performed in the project. In data collection and analyses phases Mrs Hartiala shared the most work load with Mrs Korhonen. The doctoral student's role grew when conclusions were drawn, and especially in designing the paper and finalizing it.

In Paper 4 the author worked together with Dr. Holmström, whose role was strong in designing the research with the doctoral student. Data collection and analyses was conducted by the doctoral student. Dr. Holmström assisted in designing the paper and he wrote one chapter in the paper.

In Paper 5 a study on supply chain upstream operations was reported based on two cases. The co-author, Mr. Kallionpää, who worked at the Helsinki University of Technology at the time, attended strongly in the latter case. However the author of this thesis was responsible for the research design and finishing the paper.

The study reported in Paper 6 was designed and conducted by this doctoral student, and supported by a steering group. The paper was designed and written by the doctoral student.

Appendix 4: Questionnaire used in Paper 6

1. Company information

1.1 Company and respondents
Company name:
Respondents: name, current position
The part of the company the responses concern:

1.2 Which role the company is keeping in the supply chain? *Please share 100% between the alternatives. (e.g. 30%wholesaler, 70% retailer)*		
Raw material producer	___	%
Component manufacturer / subcontractor	___	%
Package material producer	___	%
Producer of end products (OEM)	___	%
Wholesaler	___	%
Retailer	___	%
Service provider (e.g. maintenance, assembly, logistics, consulting)	___	%

1.3 Which part of your production takes place according to the following principles? *Please share 100% between the alternatives*		
Make to stock (MTS)	___	%
Assemble to order (ATO)	___	%
Make to order (MTO)	___	%
Engineer or design to order (ETO/DTO)	___	%
Sum	100	%
Which part of your production takes place by subcontractors?	___	%

2. Products and demand characteristics

2.1	Products	
2.1.1	How many active SKUs your company has?	______
2.1.2	How many product groups your company has ?	______
2.1.3	How big share of your products are tailored according to the customer ?	____ %
2.1.4	What is the typical product life cycle duration and life cycle range ? ____	____
2.1.5	How often your company presents a new product to the market? ____	____
2.1.6	What is your company profit margin ? ____	____
2.1.7	Is there any specific seasonal products in the product assortment ?	____
2.1.8	Is there any one-time products, which are produced and sold only under one season or one specific occasion ?	____
2.1.9	Number of competing products in the market ?	____
2.1.10	How often new products are introduced to the market by the competitors ?	____

2.2	Demand characteristics	
2.2.1	How big share of your sales is even throughout the year ?	_______ %
2.2.2	How big share of your sales is seasonal ?	_______ %
2.2.3	Which are the most important sale seasons ?	____
2.2.4	How big share of your demand varies unexpectedly (not acc. to the seasons) ?	____

3. Supply chain structure and operative models

3.1	Customer relationships	
3.1.1	How many customers your company has on the average under one year ?	____
3.1.2	How many customers respond 80% of sales ?	____
3.1.3	How big share of your present customers were customers 3 years ago ?	____ %
3.1.4	Which part of your customers are company customers ?	____ %
3.1.5	Are there any customer segments ? Segmenting principles:	____
3.1.6	Do you own your customer or do you belong to the same group of companies ?	____

3.2	Supplier relationships	
3.2.1	How many suppliers your company has annually on the average ?	____
3.2.2	How many suppliers respond 80% of your purchasing volume ?	____
3.2.3	How big share of your present suppliers were your suppliers 3 years ago ?	____ %
3.2.4	How big share of your suppliers are small or middle sized companies ?	____ %
3.2.5	Do you own your suppliers or belong to the same group of companies ?	____

3.3	Demand chain structure (from the company to customers)	
3.3.1	How many levels there are in your delivery process before the final customer ?	_______
3.3.2	How many players there are at each level ? ____________________	_______
3.3.3	What are the delivery times between the levels ? ____________________	____
3.3.4	What is the service level between the levels ? ____________________	____

3.4	Supply chain structure (from the suppliers to the company)	
3.4.1	How many levels there is in your supply chain ?	_______
3.4.2	How many parties there are on each level ? ____________________	_______
3.4.3	What are the delivery times between the levels ? Longest - shortest ?	____ - ____
3.4.4	What is the service level between the levels ?	____ - ____

4. Planning approach and description of the planning processes

4.1	Planning process
4.1.1	How often different plans are created ? ____
4.1.2	What is the planning horizon ? ____
4.1.3	How much planning effort is required, e.g. in days ? ____
4.1.4	Is the plan changed outside the planning rounds ? ____
4.1.5	Which phases there are in the process ? ____
4.1.6	What decision phases does the process include ? ____
4.1.7	Which are the target functions of the plans ? ____
4.1.8	How and in which phase are the demand requirements and supply restrictions balanced ? ____

4.2	Used technology
4.2.1	What is the main planning tool ? ____
4.2.2	What other tools there are in use ? ____
4.2.3	Are any analytical tools used e.g. decision support systems ? ____

4.3	Planning information
4.3.1	What kind of data do you receive from your customers or your distribution channel regularly? ___
4.3.2	What information does your planning process use ? ____
4.3.3	How frequently the newest information is in use ? ____
4.3.4	How big delay there is in receiving the data ? ____
4.3.5	What information do you receive from your suppliers or from the supply chain regularly ?_____
4.3.6	What information does the planning process use ? ____
4.3.7	How big delay there is in receiving the data ? ____

5 Planning collaboration

5.1.	Does your company collaborate with your customers in the following planning and management operations? *Please mark with x the alternatives where collaboration is implemented. Estimate also how common the practice is for example by marking how many customers collaborate or how big share of sales is affected.*		
		Collaboration	Wideness
5.1.1	Demand forecasting	_	_____
5.1.2	Production planning	_	_____
5.1.3	Inventory planning	_	_____
5.1.4	Replenishment planning, e.g. VMI	_	_____
5.1.5	Planning seasonal demand	_	_____
5.1.6	Campaign planning	_	_____
5.1.7	Sales planning	_	_____
5.1.8	New products demand planning	_	_____

5.2.	Does your company collaborate with your suppliers in the following planning and management operations? *Please mark with x the alternatives where collaboration is implemented. Estimate also how common the partice is for example by marking how many suppliers collaborate or how big share of purchases is affected.*		
		Collaboration	Wideness
5.2.1	Demand forecasting	_	_____
5.2.2	**Production planning**	_	_____
5.2.3	Inventory planning	_	_____
5.2.4	Replenishment planning, e.g VMI	_	_____
5.2.5	Procurement planning	_	_____
5.2.6	Ensuring availablity	_	_____
5.2.7	Seasonal planning	_	_____
5.2.8	Campaign planning	_	_____
5.2.9	Sales planning	_	_____
5.2.10	New products demand planning	_	_____

6 Planning result and planning quality

6.1	Planning result		
6.1.1	What plan is the main result of the planning process ? ____		
6.1.2	To which parties is the plan divided and how frequently?		
6.1.3	Is there any delays in delivering the plan ? ____		

6.2.	Planning quality *Please estimate the importance of the following operative goals in your company. Mark the alternative with numbers 1-10, 1= the most important goal, 10=least important. Estimate in the second column how well your planning process supports the goals. Please use numbers 1 to 5, so that 1=planning process supports well reaching the goal, 5=planning process does not support reaching the goal.*		
		Importance	Success
6.2.1	Service level to customers	_	_
6.2.2	Capacity utilization level	_	_
6.2.3	Shortening delivery times to customers	_	_
6.2.4	Fast reactions to demand changes	_	_
6.2.5	Finished goods inventory level and turns	_	_
6.2.6	Reducing costs	_	_
6.2.7	Suppliers' service level	_	_
6.2.8	Reducing the raw material and component delivery times	_	_
6.2.9	Supply chain flexibility	_	_
6.2.10	Minimizing lost sales	_	_
6.2.11	Other, please name _____	_	_

6.3	Please estimate how well the following goals of your planning process are implemented in your company. Use range 1 to 5, 1=the goal is reached, 5=the goal is not reached.	
6.1.1	The planning targets are well known by different parties (departments) ?	___
6.1.2	Planning targets are the same for all parties ?	___
6.1.3	Planning result is one set of numbers ?	___

7 Planning differentiation

7.1	Does your company use different planning approaches in different situations? What kind of approaches and in which situation ? ___

7.2	What factors affect the choice of a different planning approach?	
7.2.1	Customer	______
7.2.2	Demand characteristics (e.g. seasonal product, one-time product, unpredictable demand, product's demand depends on other products demand)	______
7.2.3	The ability to respond quickly to customer requirements	______
7.2.4	Production process	______
7.2.5	Product characteristics (e.g. profit)	______
7.2.6	Life cycle phase	______
7.2.7	Product's shelf life	______
7.2.8	Restrictions due to the Supplier operations (lead time, availability)	______
7.2.9	Supply chain transparency, demand data availability	______
7.2.10	Competitive situation of the industry	______

7.3	Does your company use the following planning methods or guiding principles: MRP, JIT, CPFR, VMI, any others? ___

Papers

In the following pages the articles included in this thesis are presented.

Paper 1

Kaipia, R., Holmström, J., Tanskanen, K. (2002), "VMI: What are you losing if you let your customer place orders?", *Production Planning & Control*, Vol. 13, Iss. 1, pp. 17-25.

Paper 2

Kaipia, R., Holmström, J., Hellström M. (2007), "Measuring the benefit of changing the value offering in grocery supply chains", *Production Planning & Control*, Vol. 18, Iss. 2, pp. 131-141.

Paper 3

Kaipia, R., Korhonen, H., Hartiala, H. (2006), "Planning nervousness in a demand supply network: an empirical study", *The International Journal of Logistics Management*, Vol. 17, Iss. 1, pp. 95-113.

Paper 4

Kaipia, R., Holmström, J. (2007), "Selecting the right planning approach for a product", *Supply Chain Management – An International Journal*, Vol.12, Iss. 3, pp. 3-13.

Paper 5

Kaipia, R., Kallionpää S. (2007), "Exploiting VMI to increase flexibility in package material supply".

Paper 6

Kaipia, R. (2007) "The effects of delivery speed on supply chain planning" forthcoming in the *International Journal of Logistics: Research & Applications*.