THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Materials Supply and Production Outsourcing

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Abstract

Supplier and customer markets have become more global and have forced companies to consider restructuring their supply chains to take advantage of opportunities in terms of costs, competence, etc. at different locations. One way to take advantage of opportunities in other locations is to outsource parts of the production to suppliers. Production outsourcing implies change from in-house material supply to purchasing materials from a supplier; therefore, production outsourcing can affect material supply in terms of delivery reliability, lead times, and product quality. The focus of this thesis is how the production outsourcing transition from making to buying a product affects material supply. The overall purpose of the thesis is to understand how to ensure reliable and efficient material supply during the whole outsourcing process. With the whole outsourcing process is included from before physical transfer where the decision to outsource is made until a steady state is reached with a continuous supply from the new source. The thesis is answering three research questions using the results of six appended papers. The six papers are based on five studies, i.e., two single case studies, two multiple case studies, and one simulation study. Empirical data in the case studies were mainly collected through interviews with staff working in the outsourcing companies.

The first research question identifies what logistics considerations are necessary for each of the phases of a general outsourcing process, in order to accomplish a well functioning supply chain during production transfer and start-up and steady state after physical transfer. The second research question provides a framework for the evaluation of the consequences of outsourcing and the impact on tied-up capital, product quality, customer service, and delivery flexibility of sourcing from a specific supplier. Further, the simulation study showed that supply chain performance can be improved through how the different parts of the supply chain are utilised, which can be accomplished through a sourcing strategy of sourcing stable demand globally and handle uncertainty locally. The third research question describes the material planning environment during production transfer and start-up and shows how the choice and application of the material planning process during production transfer and start-up affects supply chain performance.

In the discussion, the results from the research questions were combined and a framework how to ensure material supply during the whole outsourcing process was outlined. The thesis contribute to the material supply research area by identifying how existing processes and methods within the material supply area must be adapted to fit the specific conditions of outsourcing. Contributions to the outsourcing research area are made by showing that to ensure materials supply, the whole outsourcing process has to be in focus i.e., from before physical transfer where the decision to outsource is made until a steady state is reached with a continuous supply from the new source.

Keywords: materials supply, outsourcing, outsourcing process, supply chain performance, materials planning, supply chain uncertainty

List of appended papers

This thesis is based on the work contained in six papers. The papers are appended in full, and will be referred to in the text by Roman numerals:

Paper I
Fredriksson, A. and Johansson, E. (2009), "Integrating logistics into the outsourcing process," *International Journal of Logistics - Research and Application*, Vol. 12, No. 4, pp. 281-298.

Paper II
Fredriksson, A. and Jonsson, P. (2009), "Assessing consequences of low cost sourcing in China," *International Journal of Physical Distribution and Logistics Management*, Vol. 39, No. 3, pp. 227-249.

Paper III
Fredriksson, A., Jonsson, P. and Medbo, P. (2010), "Utilizing the potential of combining local and global supply chains," *International Journal of Logistics - Research and Application*, Vol. 13, No. 4, pp. 313-326.

Paper IV
Fredriksson, A., Wänström, C. and Medbo, L. (2011), "The impact of outsourcing on materials planning"

An earlier version of this paper was published in the proceedings of EurOMA, Porto, Portugal, 2010.

(Submitted to Production Planning and Control)

Paper V
Fredriksson, A. (2011), "Materials availability during production transfer and start-up".

(Submitted to International Journal of Production Research)

Paper VI
Fredriksson, A. (2011), "Materials planning environments during production transfer and start-up"

Contributions to the appended papers

Paper I
Main author. Collected data. Shared planning, analysis and writing procedure.

Paper II
Main author. Shared data collection, planning, analysis and writing procedure.

Paper III
Main author. Shared data collection, planning, analysis and writing procedure.

Paper IV
Main author. Collected data. Shared planning, analysis and writing procedure.

Paper V
Single author.

Paper VI
Single author.

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Andreas, my wonderful and supportive husband my warmest thanks to you, for being you and always taking care of me. You have made me understand that there is no meaning running through life and you make me see the joy in everyday events. I love you. Kerstin, I know you are disappointed that your mum has not been writing about Bamse and I am truly sorry about that. I would like to thank you for all the joy and love you bring to my life. I love you too.

Last but not least I would like to dedicate this thesis to my wonderful sister Malin, who passed away just as this work started. Malin, I know that you would have liked to write your own thesis and I am so sorry that you never had the chance to do this and all the other things that you planned for in life. I will always miss you and love you. You were the best sister one could ever wish for and I feel so lonely without you.

Anna Fredriksson
Mölndal, May 2011

Table of Contents

1 Introduction

This thesis concerns materials supply when outsourcing production. The focus is on how to ensure efficient and reliable materials supply throughout the whole outsourcing process, from before physical transfer where the decision to outsource is made until after steady state is reached with continuous supply from the new source.

1.1 Background

During the past decades the conditions for the production industry have changed considerably; the external business environment has become more global as international trade has increased massively (Kleinert, 2003; Feenstra, 1998). Globalisation has opened up new markets for companies both to sell their products in and to identify new suppliers from. Developments in information and communication technologies have facilitated the ability of organisations to globalise production and access new markets (McIvor, 2006). The globalisation of markets and improved communication technologies together increasingly bring about a redesign of the value adding chain (Feldmann et al., 1996). One way to take advantage of opportunities in other locations is to redesign the value adding chain by outsourcing parts of the production to suppliers. In a questionnaire study of the Swedish production industry it was shown that outsourcing is a common response to globalisation (Bengtsson et al., 2005). Approximately 50 percent of the responding 241 companies had outsourced part of their manufacturing between 2001 and 2004, of which 37 percent outsourced to low-cost countries.

In many cases, outsourcing is seen as an opportunity for organisations to achieve cost reduction and strategic goals (Fill and Visser, 2000; Kremic et al., 2006; Bengtsson et al., 2005; Elmuti and Kathawala, 2000; Monczka and Trent, 1991). A significant strategic goal of outsourcing is to allow companies to refocus their resources on core business (Prahalad and Hamel, 1990; Lankford and Parsa, 1999) and one important approach to reach cost reduction goals is to produce in low-cost countries, thus decreasing labour costs by utilising the low wages in these areas (Kotabe and Murray, 2004; Markides and Berg, 1988; McIvor, 2006). Reaching these cost and strategic goals is the motivation behind outsourcing. Although there are benefits to outsourcing, several risks need to be handled to ensure that the expected benefits can materialise. According to Nordigården (2007), there are three types of risks: 1) the risk of only looking at cost reduction potential and not sufficiently understanding the implications of outsourcing for the company as a whole, 2) the risk of outsourcing critical activities, and 3) supplier related risks. Supplier-related risks of outsourcing relate to the risk of increased dependency on the supply of materials from a source outside the company (Nordigården, 2007). Thereby, supplier-related risks result in a risk of not receiving ordered materials on time leading to materials shortages. Materials availability and thus materials supply is for a producing company an important issue as lack of materials can lead to delayed deliveries to customers and/or extra costs. The outcome of supplier-related risks can be an inability to meet customer requirements (Zsidisin, 2003).

In most cases, outsourcing includes both a change of location and an organisational change in terms of ownership and control of the production task or product that

increases the number of organisations in the supply chain (Rudberg and Olhager, 2003). Most of the definitions of outsourcing imply that activities and products previously made in-house are now performed by an external source (Brannemo, 2006). Outsourcing makes companies less self-supporting with materials, since the responsibility of materials supply moves from in-house to purchasing from a supplier (Fraering and Prasad, 1999; Mattsson, 2002; Zeng and Rossetti, 2003; Wild, 1998). Figure 1.1 shows how the transitions from making to buying a product, taking place during an outsourcing process, affect materials supply. The materials supply system changes from only covering the production cycle within the focal company to covering the procurement cycle and the production cycle and thereby including suppliers, transports and the focal company. The change takes place as the physical transfer starts. The materials supply system includes the activities of materials feeding, handling, storage, transportation, packaging and manufacturing planning and control (Johansson, 2006).

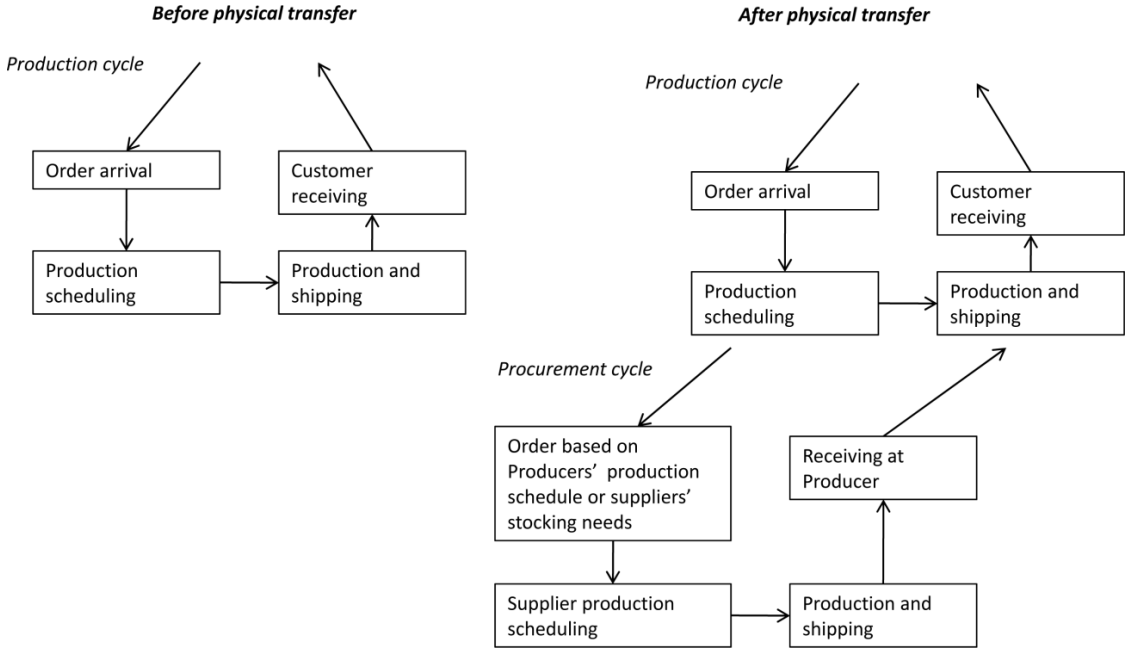

Figure 1.1: Outsourcing of production implies a shift in materials supply of the outsourced item from only including the production cycle to including both the production cycle and the procurement cycle. The picture is adapted from Chopra and Meindl (2004) p. 13-14.

The outsourcing process can be divided into three stages: decision making before the physical transfer, realisation of the decision (the physical transfer and production start-up) and steady state with continuous supply from the new source. In order to illustrate the relationship between the outsourcing process and the three stages, Figure 1.2 shows how an outsourcing framework is presented.

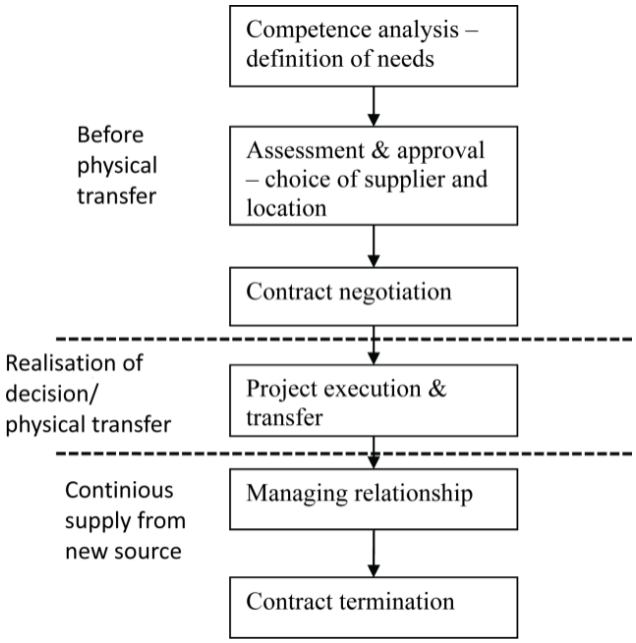

Figure 1.2: The outsourcing process (adapted from Momme and Hvolby, 2002, p. 193). The three stages—before physical transfer, realisation of decision/physical transfer, and continuous supply from new source—have been added to the original process.

1.2 Problem area – the effect on materials supply of outsourcing

In most cases, it is necessary to involve several organisations in the value creation process, which are dependent upon each other to supply the final customer. Each company in the value creation process has a structure of suppliers, which in turn has suppliers. In this structure the supplier provides the customer with materials. The supply structure is either called "supply chain" or "supply network" (e.g. Christopher, 1998; Lambert et al., 1998). A supply chain consists of all parties involved, directly or indirectly, in fulfilling a customer request and is the sequence of processes and flows that take place within and between the different parties to fill a customer need for a product (Chopra and Meindl, 2004). The term "supply network" may be used instead of "supply chain" as it is in most cases multiple suppliers, and suppliers to suppliers as well as multiple customers and customers' customers in the total system (Christopher, 1998). In this thesis the term "supply chain" will be used even though sometimes a supply structure of multiple suppliers is studied.

Outsourcing changes the supply structure of a company, in most cases extending it by one or several links of suppliers, i.e., stretching the supply chain (Nordigården, 2007). This affects how the flow and storage of goods and information exchange should be managed. The management of a supply chain is concerned with coordination between the companies in the supply chain (Feldmann et al., 2009). Outsourcing increases the amount of uncertainty that needs to be managed while at the same time decreasing management control over the supply chain (Fawcett, 1992), because the coordination problem is no longer an internal problem and becomes harder because it requires efforts and resources from more than one organisation. The company becomes more dependent on the performance of others; for example, manufacturers suffering from disturbances in inbound flows from suppliers also may have disturbances in outbound flows to customers (Svensson, 2001). Several materials supply-related risks arise when outsourcing because of the inability of organisations to understand that managing

suppliers requires different competencies than managing an internal process (McIvor, 2006). It is necessary, when making outsourcing decisions, to weigh possible cost reductions of outsourcing against changes in the ability to deliver on time and the flexibility to respond to changes in customer demands (Bengtsson and Dabhilkar, 2009).

1.2.1 *The effect of supply structure on materials supply*

Outsourcing means going from in-house production with distances counted in minutes to use of a supplier which, in most cases, is further away. Outsourcing and specifically offshore outsourcing may create geographically spread supply chains (Fraering and Prasad, 1999; Mattsson, 2002; Zeng and Rossetti, 2003). Because of the greater distances with longer transports and suppliers and manufacturers separated by different currencies, payment systems and cultures (Zeng and Rossetti, 2003; Mattsson, 2002; Fraering and Prasad, 1999) is outsourcing, in nearly all cases, accompanied by more complex supply chains (Bengtsson and Dabhilkar, 2009). Results of these more complex supply chains include increased lead times and decreased delivery accuracy (Bengtsson and Dabhilkar, 2009). Long lead times may cause effects such as increased costs in terms of expedited freight, extra inventory and managerial time spent "fire-fighting" (Levy, 1995). Due to longer transports across borders, outsourcing also brings inflexible schedules, customs and document requirements, and shipping irregularities and damage (Fawcett and Birou, 1992). Zeng (2003), based on a case study, estimated the total logistics costs when outsourcing globally at as much as 29 percent of the value of the final part.

Furthermore, the context of the supplier and buyer, such as legal, political, financial and cultural differences, creates challenges (Fawcett and Birou, 1992). Differences in cultures, languages, practices and time-zones also diminish the effectiveness of business processes such as demand forecasting and materials planning (Mattsson, 2002; Levy, 1995). For example, the communication change from the same language into English or another language (in most cases, none of the parties' mother tongue) and different cultural settings affect the interpretation of the messages. Overcoming these challenges requires communication and logistics capabilities within the supply chain (Fawcett and Birou, 1992).

1.2.2 *The effect of physical transfer and supplier start-up on materials supply*

It is not only the characteristics of the new supply chain that affect material supply uncertainty during the outsourcing process. The realisation of outsourcing decisions involves the physical transfer of production, where the supplier's production starts and the company's own production is phased out. The supplier production start-up is the period during which a production process makes the transition from the set-up of the production process, where no products are produced, to full-scale production (Terwiesch et al., 1999). The steady-state phase begins when capacity and quality targets of the new supply chain are attained (Almgren, 1999b). From the start of transfer until a steady state is reached is denoted here as production transfer and start-up. It is hard to say that an outsourcing process always reaches a steady state as there is a continuing work with improving the supply chain. Though, in this thesis steady state is used to denote the situation after the end of the production start-up, i.e., the reach of the materials supply working as planned for before the start of the physical transfer and no

extraordinary means are necessary to ensure materials supply due to the supplier not having reached its expected levels of quality and capacity.

The production start-up is a complex event (Zhu et al., 2001). Several companies that have been through the process have seen that reaching a steady state usually takes longer than expected (Madsen, 2009; Galbraith, 1990). The troubles of reaching expected gains are traced to a multitude of unforeseen circumstances. During the start-up period the output is low due to low production rates and yields because the production process is still poorly understood and inevitably, much of what is made does not work properly the first time (Terwiesch and Bohn, 2001). This leads to decreased delivery reliability and decreased quality levels, further increasing the uncertainty of materials supply during production transfer and start-up.

The increased supply chain uncertainty during production transfer and start-up is something of which most customers of the outsourcing company are aware. Further, in several cases outsourcing is accompanied by an engineering change that means it is a question of a last-time buy for some products (Terwiesch et al., 1999; Terwiesch et al., 2005). Increased supply chain uncertainty leads to increased customer demand for the company outsourcing in order for the customers to ensure their supply (Vollmann et al., 2005), and a last-time buy increases demand volumes to ensure supply of the product until a replacement has been identified and approved. This behaviour among customers faced with the supplier outsourcing part of their production increases demand uncertainty for the outsourcing company.

1.2.3 *Materials supply in existing outsourcing processes*

As has been seen in preceding sections, materials supply is affected by outsourcing. To be successful with outsourcing it is necessary to prepare for the physical transfer, the supplier production start-up and the characteristics of the new supply chain. When the materials supply system required to coordinate global operations is not given adequate consideration in the initial design of a supply chain, the effectiveness of the supply chain performance is reduced (Fawcett, 1992). Wasner (1999) argues that previous research within outsourcing has mainly focused on the strategic considerations of outsourcing (i.e., what and why), although the process of carrying out the transfer (i.e., to whom and how) is equally difficult because of interdependency on an operational level. Boulaksil and Fransoo (2010) agree and conclude that there is a need for more research considering the operational effects of outsourcing.

There exist several outsourcing frameworks in the literature (e.g. Cánez et al., 2000; Franceschini et al., 2003; McIvor, 2000; Momme, 2002; Platts et al., 2000; Probert, 1996; Zeng, 2003; Moses, 2009). The frameworks consist of factors to consider and processes, including phases in which activities are to be executed. When preparing the decision, the whole outsourcing process is gone through phase by phase to try to foresee the effects of each phase on the company. The activities within the phases aim at helping the company establish and manage the outsourcing process on the basis of criteria such as quality consciousness, cost potential, reliability of delivery, innovativeness and geographic location (Momme, 2002; Momme and Hvolby, 2002). Even though several frameworks exist, Kremic et al. (2006) conclude from a literature review that although possible benefits, risks and strategic issues of outsourcing were abundantly discussed, additional work designing tools and guidelines in terms of decision support are needed, especially based on empirical work. Further, outsourcing

frameworks of today do not include standardised processes to ensure materials supply. Today, materials supply aspects such as on-time delivery are considered first when the actual supply begins (Kumar et al., 2010). The lack of materials supply aspects and a heavy focus on core competences when formulating outsourcing strategies—as is the case with present outsourcing frameworks—make decision makers risk forgetting that components are still vulnerable to supply failure (Nordigården, 2007).

1.3 Purpose

To summarise, outsourcing affects materials supply; first through the new supply chain created by outsourcing that in most cases increases lead times and materials supply uncertainty and decreases coordination possibilities and oversight. Second, materials supply is affected by the production transfer and start-up, during which supplier output is uncertain and demand uncertainty increases. There is an association between outsourcing internal activities and disturbances in the inbound logistics flows (Svensson, 2001). For an organisation to gain all the possible benefits from outsourcing, it is essential to have an efficient and reliable materials supply system so the right item arrives at the right time at the right cost. To achieve this, it is important to be able to highlight materials supply during the whole outsourcing process, both before physical transfer and during and after physical transfer. There are several frameworks describing how to make outsourcing decisions, although there are fewer that include materials supply aspects systematically. Some factors addressing materials supply are included in some of the existing frameworks but they are seldom the focus; instead, materials supply is discussed in general terms. This can be seen as natural, since it is not possible to go into detail in a framework with the large areas they cover. However, it is not possible, based on the existing outsourcing frameworks, to plan and prepare for how to ensure materials supply during the whole outsourcing process. Therefore, there is a need to increase the understanding of how to ensure materials supply during the whole outsourcing process.

The overall purpose of the thesis is to understand how to ensure reliable and efficient materials supply during the whole outsourcing process.

1.4 Scope

This section describes the scope of the thesis. The purpose of this thesis is to understand how to ensure reliable and efficient materials supply during the whole outsourcing process. How to ensure materials supply is the focus of this thesis. During the whole outsourcing process is the setting in which materials supply should be ensured. Thereby, where this thesis aim to contribute is firstly the materials supply area and secondly the outsourcing area. The whole outsourcing process includes decision making before physical transfer, the physical transfer and start-up of production and continuous supply during steady state after physical transfer.

How to ensure materials supply during the whole outsourcing process is studied from the perspective of the focal company and the focal company in this thesis is the outsourcing company, sometimes referred to as the buying, sourcing or sending company. Thus, the materials supply studied is the materials supply of the outsourced item from the supplier to the outsourcing company. The research has only covered items to be used in the outsourcing company's production or final products. Johansson (2006) describes the materials supply system as being made up of six entities: materials

feeding, handling, storage, transportation, packaging and manufacturing planning and control. Within these entities are the activities to ensure materials supply studied in this thesis to be found.

No specific industry or production system was the focus of this research, though all studies include Swedish production companies. All the studied companies have been engaged in business-to-business sales and no consumer products have been studied. Further, outsourcing decisions are not confined to products and production activities alone. However, this thesis has not included any non-production activities, such as support services, e.g., cleaning, catering, etc.

Outsourcing to low-cost countries is not the specific focus, although these countries play an important role in outsourcing today since many companies see outsourcing as an opportunity to lower costs. Supplier location implies a difference in the structure and management of the supply chain and therefore it is necessary to differentiate between outsourcing locations. The research in this thesis covers outsourcing within the same country as well as nearshore outsourcing and offshore outsourcing. The thesis refers to both outsourcing and sourcing. From a decision point of view, and because of the effect of the decision on materials supply, there is a difference between outsourcing and sourcing. Outsourcing is a more widespread decision than sourcing because it implies a transition from making to buying, whereas a sourcing decision is a decision about where to buy.

1.5 Outline of the thesis

Chapter 1 (Introduction) introduces and describes the background of the research and the problem area. It presents the purpose of the research and the scope of the study.

Chapter 2 (Theoretical background) reviews previous research on materials supply and outsourcing and presents three research questions. To start with, outsourcing is defined and by what outsourcing and production transfer are characterised is introduced. Next, how materials supply can be viewed is presented; thereafter supply chain performance is described. Then outsourcing processes and logistics are presented as a basis for the first research question. In addition, research on factors affecting the design and management of supply chains is reviewed, and the second research question is derived. Finally, this chapter presents production transfer and start-up, the materials planning process and how the areas are related as a foundation for the third research question.

Chapter 3 (Research methodology) presents the research process and the methodology used in the research. Each included study is introduced and validity and reliability of the research is discussed.

Chapter 4 (Results) presents the results of the thesis. The chapter sets out to answer the research questions put forward in Chapter 2. The research questions are answered based on the results of the appended papers. Each of the research questions is answered in two parts—first a theoretical framework is developed and then it is applied to the studies included in this thesis.

Chapter 5 (Discussion and further research) discusses the theoretical and practical contributions of each research question. The results from the research questions are compiled and how they combine to answer the purpose is discussed. Based on the

combination of the results from the research questions, this chapter outlines a framework of how to ensure materials supply during the outsourcing process. The generalisation of the research is discussed and the reader is provided with issues for further research.

Chapter 6 (Conclusions) presents the conclusions of the thesis.

2 Theoretical background

This chapter presents the theoretical background of the thesis and sets out the research questions. First, the introduction to the chapter discusses how the outsourcing process, depending on how materials supply is affected, can be divided into different stages. This division of the outsourcing process is used as a platform for deriving the research questions, because depending on what stage of the outsourcing process is viewed, different theoretical starting points are relevant to understand how to ensure materials supply. However, before the research questions are derived the chapter introduces outsourcing and production transfer, materials supply, and supply chain performance. The purpose of introducing outsourcing and production transfer is to develop a common ground based on which the cases studied can be described and to define what outsourcing is. Materials supply is introduced in order to describe what is included in the term "materials supply" in this thesis. Supply chain performance is introduced to describe what reliable and efficient materials supply means. To have an understanding of these three areas is necessary deriving the research questions and interpreting the studies. Thus the outline of this chapter after the introduction is as follows: first, outsourcing and production transfer, materials supply, and supply chain performance are introduced, and second, the specific theoretical background for each research question is presented and the research questions are derived.

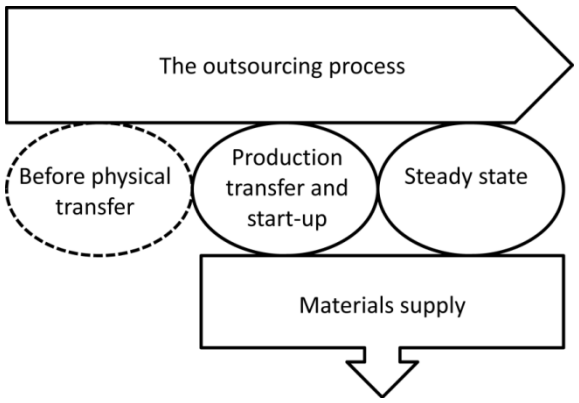

Figure 2.1: Overview of the theoretical background (The stage marked with a dotted line is included in the outsourcing process as a whole and is not treated as a separate area.)

The purpose of this thesis is to understand how to ensure reliable and efficient materials supply during the whole outsourcing process. In section 1.1 it was seen that the outsourcing process can be divided into three stages. These three stages affect materials supply in different ways and thereby is it necessary to approach the question of how to ensure materials supply differently depending on which stage of the outsourcing process is viewed. Each of the three research questions are related to one of the stages of the outsourcing process. Figure 2.1 illustrates the division of the outsourcing process. Below it is discussed how the stages of the outsourcing process are related to materials supply.

Before the physical transfer, the outsourcing process includes the decision making process. The decisions made here include what product or production process to

consider for outsourcing based on the company's core competences, which supplier should be selected, what governance structure should be used and how to design the cooperation between supplier and buyer, etc. (Momme and Hvolby, 2002). Part of decision making is to review the effects of different decision alternatives. The outsourcing process before physical transfer helps to review the effects of different decision alternatives by picturing the possible effects of a decision alternative in the later stages of the outsourcing process. From a materials supply point of view, this is done by considering what the different decision alternatives imply for materials supply during and after physical transfer. To understand how materials supply is dealt with in existing outsourcing processes and how these investigate the effects of a decision alternative, a first step is to investigate what characterise the existing outsourcing processes and how they deal with materials supply issues.

The actual physical effects for materials supply are first seen when the physical transfer of equipment and materials start; the production transfer and start-up stage in Figure 2.1. Before the start of the physical transfer, materials supply is not affected, as materials are still supplied through in-house production. However, with the start of the physical transfer, the responsibility for materials supply moves from in-house production to procurement from a supplier. How materials supply is affected depends on the supply chain performance of the new supply chain formed. Supply chain performance is affected by the supply uncertainty of the supply chain. As steady state is reached, the uncertainty is related to the more complex supply chains brought about by outsourcing (Bengtsson and Dabhilkar, 2009). However, during production transfer and start-up there is an extra dimension of uncertainty for materials supply related to the progress of technology and knowledge transfer and supplier start-up. During production start-up there are capacity and quality losses (Almgren, 1999b). How these capacity and quality losses show up is hard to foresee, which increases the uncertainty of materials supply during production transfer and start-up. The difference in uncertainty of materials supply between steady state and production transfer and start-up allows the outsourcing process with the start of the physical transfer to be divided into two stages— steady state and the production transfer and start-up (see Figure 2.1). How to ensure materials supply demand different answers in relation to these stages and therefore are these two stages dealt with in two research questions.

The research questions are developed in relation to the whole outsourcing process, the steady state and the production transfer and start-up. By viewing the outsourcing process as a whole, how to ensure materials supply before physical transfer will be covered (see Figure 2.1). Further, how to ensure materials supply after the physical transfer is studied by, first, viewing how the design of the new supply chain during steady state affects materials supply and, second, viewing how the physical transfer and start-up affect materials supply. Combining these three areas ensuring materials supply during the whole outsourcing process is studied.

2.1 Outsourcing and production transfer

This section sets out to describe outsourcing and production transfer. Outsourcing can be studied from several perspectives and depending on the perspective outsourcing can be defined differently. The purpose of describing outsourcing and production transfer is to define outsourcing as it is used in this thesis and to develop a common ground based on which the cases studied can be described. The section starts by defining outsourcing, and thereafter is the basis for how supply chain collaborations are organised described,

and finally, is what characterises production start-up and technology and knowledge transfer presented. The section ends with summarising the main aspects brought up regarding what characterises outsourcing and production transfer. The characterisation of outsourcing and production transfer is in Section 3.3 used to describe the cases studied. This will increase the understanding of what the studies have covered regarding outsourcing and production transfer.

2.1.1 *Defining outsourcing*

Outsourcing production has a long history and a variety of names are present. Outsourcing, subcontracting and make-or-buy all belong to the same family of activities and the differences between them are the drivers, demand on cooperation between involved parties and independence of the supplier (Wasner, 1999). There are several definitions of outsourcing in the literature. For instance, do Bengtsson et al. (2005) define outsourcing as "when a company hires a supplier to conduct an activity that was earlier performed by the company" and McIvor (2006) defines it as "the sourcing of goods and services previously produced internally within the sourcing organisation from external suppliers". It is seen that outsourcing definitions imply that the product or activity to be outsourced has to have been performed in-house before, i.e., it cannot be a new activity (Moses, 2009). Greaver (1999) has a definition that focuses on recurring activities: "outsourcing is the act of transferring some of an organisation's recurring internal activities and decision rights to outside providers, as set forth in a contract". Further, it is not only the activities that are transferred, but also the decision rights and the resources that make the activities occur, which can include people, facilities, equipment, technology, and other assets (Greaver, 1999). Nordigården (2007) is similar to Greaver (1999) and defines outsourcing as "transferring an activity from internal governance to external control". Wasner (1999) summarises what constitutes outsourcing; it is a make-or-buy decision and a transfer. These two issues also make outsourcing into a process as they have to be carried out over time (Wasner, 1999). When discussing outsourcing definitions, in the context of how to ensure materials supply during the outsourcing process, it is not the exact wording in the definition of outsourcing that is most important. Instead, it is that outsourcing implies a transfer of activities, resources and decision rights from internal to external control and in the case of production outsourcing, it is the question of a physical transfer followed by a start-up of the production in the new place.

Outsourcing types are differentiated depending on the location of the receiving supplier. First of all, outsourcing types are divided between within the same country and international outsourcing to a supplier in another country (Bengtsson et al., 2005). Further, international outsourcing is divided, depending on the physical distance to the supplier, between outsourcing to a supplier situated in neighbouring countries, nearshore outsourcing and to suppliers situated in countries further away, offshore outsourcing (Schniederjans et al., 2005). Offshore outsourcing and offshoring also have different meanings. Offshoring is moving an activity to a wholly owned company or an independent supplier in another country (usually a low-cost country) (Lewin and Peeters, 2006). The difference between offshore outsourcing and offshoring is that offshoring does not necessarily mean loss of control as it can be a transfer to a wholly owned company. In this thesis all studied cases have been outsourcing, though it has covered offshore outsourcing, nearshore outsourcing and outsourcing within the same country.

2.1.2 *Collaboration within supply chains*

Outsourcing has been approached either from transaction cost theory and resource-based theory or a combination of both (Fransson, 2005). Both these streams of theory deal with the question of how to draw the boundaries of the firm. Outsourcing changes the boundaries of the firm and a new supply chain is created. The collaboration within the supply chain created can be structured in many ways; it can be based on ownership, but also on more complex structures such as partnerships, joint ventures, and licensing agreements (Rudberg and West, 2008; McIvor, 2006). Depending on how the collaboration is structured this will affect the interdependence and the relationship between the partners of the supply chain (Schniederjans et al., 2005). But, how the collaboration within the supply chain is structured is dependent on different issues depending on which theoretical viewpoint is studied. The transaction cost theory and the resource based theory are briefly described below since it is important to have a basic knowledge of both to be able to evaluate the cases studied in this thesis.

The transaction cost theory considers on the basis of cost efficiency how the firm should define its boundaries, i.e., make or buy certain activities or products. According to the transaction cost theory there are three ways by which transactions can be organised, called governance structures: markets, hierarchies and hybrids (Williamson, 1979). The governance structure is dependent on the transaction frequency and the investment characteristics; the latter being labelled asset specificity and transactions with recurrent frequency and high asset specificity should have a high degree of governance (Williamson, 1979). Further, the more unique the product or production process the higher asset specificity. Gereffi et al. (2005) have further developed Williamson's (1979) three governance structures into five depending on the complexity of transactions, the ability to codify transactions, and the capabilities in the supply-base. The five governance structures are:

- *Markets* where the cost of switching to a new partner are low for both parties.
- *Modular value chains* where suppliers make products to a customer's specifications, which may be more or less detailed.
- *Relational value chains* where there are complex interactions between buyers and sellers, which often create mutual dependence and high levels of asset specificity.
- *Captive value chains* where smaller suppliers are transactionally dependent on larger buyers and suppliers face high switching costs. These supply chains are characterised by a high degree of monitoring and control by lead firms.
- *Hierarchy,* where the governance form is characterised by vertical integration.

The governance structure describes the relationship between the focal company outsourcing and the supplier. Depending on governance structure the power in the supply chain will differ as well as the control the focal company's outsourcing has over the supplier.

From a resource-based perspective, it is more meaningful to define a firm in terms of its resources than in terms of its products (Fransson, 2005; Wernerfelt, 1984). Resource-based theory advocates that certain resources are attractive and are used as barriers towards competitors (Wernerfelt, 1984). Core competence is another name for these attractive resources (Prahalad and Hamel, 1990). It is argued that only activities, products and services that are regarded as core competencies should be produced

internally (Arnold, 2000; Quinn and Hilmer, 1994). The more attractive the resources outsourced are the closer collaboration there should be.

2.1.3 *Production start-up and technology and knowledge transfer*

In section 2.1.1 it was seen that an important aspect of outsourcing is the transfer of activities and resources to outside control, which for production outsourcing implies a physical transfer followed by a start-up in the new place. Production transfer is the transfer of production technology and the knowledge necessary to efficiently use the production technology. Production start-up and technology and knowledge transfer are two different theoretical streams. Below are the main points from earlier studies within production start-up and technology and knowledge transfer introduced in order to provide an understanding of the complexity of the physical transfer and start-up when outsourcing production.

Production start-up

Production transfer and start-up cover from the initiation of the physical transfer until a steady state is reached. It is hard to say that a change of a supply chain reaches a steady state as there is a continuous work going on to improve and adapt the supply chain. However, steady state is in this thesis defined as outgoing from the production start-up literature and this literature considers a steady state as when activity to be started has reached the intended levels of output. Terwiesch et al. (1999) define production start-up/ramp-up as the period during which a production process makes the transition from zero to full-scale production at targeted levels of cost and quality. During this period the production rate is stepwise or gradually increased (Fjällström, 2007). During production start-up there are capacity and quality losses that increase the cost of production. Increased costs are the results of extra production time to make up for lost capacity, and extra resources for inspection and correction (Almgren, 1999b). Lost production volume (capacity loss) is related to three causes: (i) machinery and equipment; (ii) personnel; and (iii) materials supply. Quality losses is divided into three areas: (i) incoming material; (ii) operator competence; and (iii) product design (Almgren, 1999b). The physical transfer can be fast with a steep start-up or slower with a stepwise start-up (Madsen, 2009; Terwiesch and Bohn, 2001).

Technology and knowledge transfer

Technology and knowledge transfer is to shift production technologies between production facilities (Galbraith, 1990). The technology and knowledge transfer depends on the absorptive capacity of the receiving supplier, i.e., the supplier's ability to learn (Lyles and Salk, 1996; Szulanski, 1996; Ferdows, 2006). The absorptive capacity depends on the recipient's knowledge prior to transfer, i.e., its capability (Szulanski, 1996; Galbraith, 1990; Ferdows, 2006) and the experience of transfers on the part of both the sender and recipient (van Wijk et al., 2008; Szulanski, 2000; Ferdows, 2006). Creating instructions is important for the technology and knowledge transfer (e.g. Galbraith, 1990) and adapting the production process to the new environment (e.g. Grant and Gregory, 1997a). Complex production technologies in early stages of development will take longer to implement (Galbraith, 1990; Salomon and Martin, 2008). However, an established production technology also implies increased levels of tacit knowledge, which is more difficult to transfer than explicit knowledge detailed in manuals (Grant and Gregory, 1997b). Knowledge transfer depends on a close relationship, including trust and frequent contact between the sender and receiver (Szulanski, 1996; van Wijk et al., 2008). Long distances increase the length of

communication lines and cultural distance and misunderstandings hamper knowledge transfer (van Wijk et al., 2008; Salomon and Martin, 2008; Terwiesch et al., 2001).

2.1.4 *Outsourcing and production transfer characteristics*

From sections 2.1.1 to 2.1.3 it is seen that outsourcing and production transfers are characterised through several issues and it is thereby important to be able to describe what issues of outsourcing and production transfer the research presented in this thesis have covered. Therefore, this section aims, based on what has been presented in sections 2.1.1 to 2.1.3, to identify characteristics based on which the studied cases in section 3.3 shall be described. Describing the cases studied in this thesis based on the characteristics identified in this section will increase the understanding of what the studies have covered regarding outsourcing and production transfer and thereby help to identify where this thesis contributes.

In section 2.1.1 it is seen that an important aspect of outsourcing is the transfer of control and physical assets. Section 2.1.2 describes how collaboration within supply chains could be organised and it is seen that the focal company control over the supply chain is dependent on the governance structure, i.e., where on the scale between market and hierarchy the relationship is. Further, the governance structure also affects the power relationship in the supply chain. What governance structure is possible is dependent on the uniqueness of the product or the production process, i.e., the asset specificity of the relationship. Outsourcing can also be differentiated based on where the product or production is transferred; if it is outsourcing within the same country or if it is offshore outsourcing. Thus outsourcing is characterised based on the following aspects:

- Governance structure (market-hierarchy)
- Focal company control of the supply chain
- Focal company power in the supply chain
- Uniqueness of product and production process
- Local or offshore outsourcing

Section 2.1.3 described technology and knowledge transfer and production start-up. The absorptive capacity of the supplier affects the ability to learn and the absorptive capacity increases with earlier experience of the production process and of receiving outsourced products or production processes. The pace and the size of the transfer, the level of tacitness of the transferred knowledge and the need for adaptation of the production process to the new environment also affects the time to reach steady state. The product or production process in itself also affects the time to transfer depending on its complexity. Finally, if existing first tier suppliers remain as second tier suppliers after the transfer or if new second tier suppliers are to be identified affect the time to reach steady state. Because incoming materials affect quality levels during production start-up and it can take time before new suppliers reaches the quality and delivery reliability of existing suppliers. Thereby the source of incoming materials to the receiving supplier does make a different for the production start-up. Thus production transfer is characterised based on the following aspects:

- Supplier capability and absorptive capacity
- Pace of the transfer
- Size of the transfer
- Tacit or explicit knowledge

- Need for adaptation of the production process or product to the new context
- Technology complexity
- Source of incoming materials to receiving supplier

2.2 Materials supply

Materials supply can have different meanings depending on who is dealing with the question. Materials supply is here introduced in order to describe what is meant by the term "materials supply" in this thesis. This is done by presenting how materials supply can be viewed and what the implications are of the different views. In this thesis materials supply is seen as a part of logistics. Logistics provides a fundamental mechanism for linking the firms of diverse supply chains in a coordinated manner in order to ensure materials supply (Fawcett, 1992). Johansson (2006) defines the materials supply system as the system that supplies materials from suppliers through the focal company's production system to industrial buyers. The materials supply system thus comprises materials flows between as well as within plants and includes both physical flows and their planning and control (Johansson, 2006). The aim of the logistics system is to supply customers efficiently with their required products and the purpose of the materials supply system is to supply production with materials and items (Jonsson, 2008).

Materials supply can be viewed in four ways (Jonsson, 2008), either with a function or process focus, or as a structure or control decision (See Figure 2.2). These four ways of viewing materials supply are complementary and it is necessary to consider all four views in order to ensure efficient and reliable materials supply during the whole outsourcing process. Because depending on what phase of the outsourcing process that are studied are the alternative views more or less relevant. The alternative views to consider are in Figure 2.2 illustrated as questions. Below, the four ways of viewing materials supply are introduced.

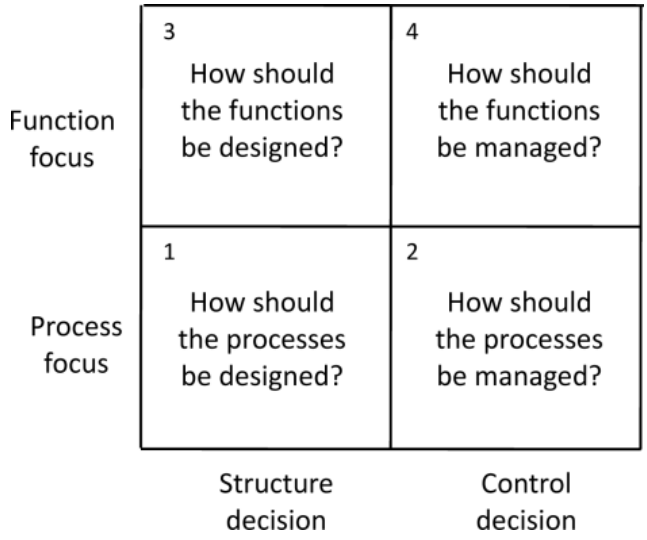

Figure 2.2: The relationship between the four different ways of viewing logistics and materials supply, structure/control decision and function/process focus.

First, materials supply is viewed either as a structural decision or as a control decision of planning and implementing efficient flows of materials. Structural decisions

(sometimes referred to as configuration) are related to how systems for products, distribution, production and supply of materials should be designed for specific conditions (Rudberg and Olhager, 2003). Control decisions (sometimes referred to as coordination) are related to planning and implementing efficient flows of materials starting with existing structures, i.e., the management of existing structures (Rudberg and Olhager, 2003; Jonsson, 2008).

Second, materials supply is viewed either from a process or function focus. A logistics and materials supply system can be described as a set of processes which transform materials into products for distribution to customers as well as in terms of its main functions, i.e., the primary output function of each subsystem (Jonsson, 2008). When the materials supply system is described as a set of processes, the different processes constitute the system. Chopra and Meindl (2004) divide the supply chain process into four cycles: the customer order cycle, the replenishment cycle, the production cycle and the procurement cycle. In addition, when the materials supply system is described in terms of it mains functions, the different functions constitute the system. These functions are also responsible for carrying out the processes. Johansson (2006) includes six functions in the material supply system: materials feeding, handling, storage, transportation, packaging and manufacturing planning and control.

- Materials' feeding mainly concerns what principle to use for feeding the materials to a work station or plant (Johansson, 2006).
- Handling includes movements within facilities, where lifting and putting down as well as packaging the material is included (Johansson, 2006).
- Storage is the storage of raw materials and items at or near a manufacturing or assembly process, partially completed products along a production line as well as finished products (Johansson, 2006).
- Transportation refers to the movement of a product from one location to another as it makes its way through the supply chain; there are several transport modes by which the movement can take place, such as air, truck, rail, water and pipeline (Chopra and Meindl, 2004).
- Packaging has many functions. To enable efficient handling and storage, to protect the materials and environment during handling, and to identify the material in question, it is generally enclosed in some sort of packaging or put into a load carrier (Jonsson, 2008).
- The manufacturing planning and control system is defined by its task – to manage the flow of material, the utilisation of people and equipment, and to respond to customers' requirements in order to meet their demands but also to provide planning information upon which the planning staff can make accurate decisions (Gustavsson, 2008). The manufacturing planning and control system make decisions that differ with regard to precision and time-horizon, which is handled by planning materials flows and production successively in a hierarchical structure of planning levels (Jonsson and Mattsson, 2009).

Figure 2.2 depicts how the four ways of viewing materials supply are related to each other. Depending on what stage in the outsourcing process is dealt with, the materials supply issues treated in this thesis will cover different combinations of the four quadrants in Figure 2.2. Depending on what part of the supply chain and on what level of detail it is viewed, different processes and functions will be in focus. Thereby, the questions of what to take into consideration when designing them and managing them will vary. For example, the focus can be the whole supply chain and then it is a question

of how to design the supply chain from supplier to customer including all the functions and processes introduced above. However, it can also only be the manufacturing planning and control system in focus and then it is a question of how to design manufacturing planning and control function and the processes carried out by that function.

2.3 Supply chain performance

To decide what actions to take to ensure materials supply, it is necessary to measure supply chain performance. Reliable and efficient materials supply is to have the right items, in the right quantity available at the right place at the right time at the expected cost (Jonsson, 2008). When outsourcing, it is important that the measures of supply chain performance cover the supply chain of materials from one organisation to another, i.e., measures related to the suppliers' performance and the performance of the physical supply chain. This section presents what supply chain performance measures used in this thesis.

There are many authors who suggest what supply chain performance measures to use and how they should be organised. One frequently cited model is the SCOR model (Supply Chain Council, 2006; Stewart, 1997), which includes metrics focusing on reliability, responsiveness, flexibility, cost and assets within the supply chain processes of plan, source, make, deliver and return. Gunaskeran et al. (2004), following the supply chain processes of the SCOR model, suggest that supply chain performance should be measured at strategic, tactical and operational levels. Also following the supply chain processes of the SCOR model, Shepherd and Günter (2006) categorised supply chain performance measures into cost, time, quality, flexibility and innovativeness, and whether they are quantitative or qualitative. According to Shepherd and Günter (2006) measures of time and quality reflect the ability of a supply chain to deliver high customer service, while flexibility and innovativeness indicate the ability to cope with rapid changes in demand or supply. Beamon (1999) said that the use of resources, desired output and flexibility (how well the system reacts to uncertainty) should be used as a basis for deriving supply chain performance measures. According to Beamon (1999) resource measures are usually measured in terms of the minimum requirements, and output measures include: customer responsiveness, product quality and the quantity of final products produced (capacity). Flexibility measures a system's ability to accommodate volume and schedule fluctuations from suppliers, manufacturers and customers.

The question to start with when developing performance measures is, "Who are the stakeholders and what do they want and need?" (Neely et al., 2001). Measuring the supply chain performance from the viewpoint of the focal company is the purpose of the supply chain performance measures used in this thesis. The purchasing department of the focal company will have a relationship and exchange information with the supplier, and the operations department of the focal company depends on the suppliers' performance in the form of product quality, delivery reliability, delivery flexibility and lead times (Slack et al., 2007). Therefore are the stakeholders when outsourcing the operations and purchasing departments within the buying company, i.e., the focal company. The supply chain performance measures used in this thesis should capture the efficiency and reliability of materials supply from the supplier to the arrival at the operational department within the focal company. Several authors suggest that performance measures should cover issues related to reliability, time, cost, flexibility

and quality see Table 2.1. The performance measures used in this thesis will be found among these performance measures, as these measures capture the effect on the operations and the relationship of the physical and information exchange between the supplier and the focal company. However, exactly what performance measures are used depends on the focus of the study and are presented in relation to the results of each research question in Chapter 4.

Table 2.1: Performance measures

Performance measures	Examples of what to measure
Reliability	Order fulfilment (Supply Chain Council, 2006), mean time between failures, on-time delivery (Beamon, 1999), lateness complaints and schedule adherence (Slack et al., 2007)
Time	Lead times (Beamon, 1999), and purchase order cycle time (Shepherd and Günter, 2006)
Quality	Percentage of defects per unit (Gunasekaran et al., 2004), level of customer complaints and scrap level (Slack et al., 2007)
Cost	Cost of tied-up capital (Beamon, 1999), transportation cost, administration costs and risk and damage costs (Zeng, 2003)
Flexibility	Delivery flexibility, i.e., the ability to change planned or assumed delivery dates (Slack, 2005)

2.4 The outsourcing process

In this section the first research question is derived; it is related to logistics and materials supply in outsourcing processes (see Figure 2.3).

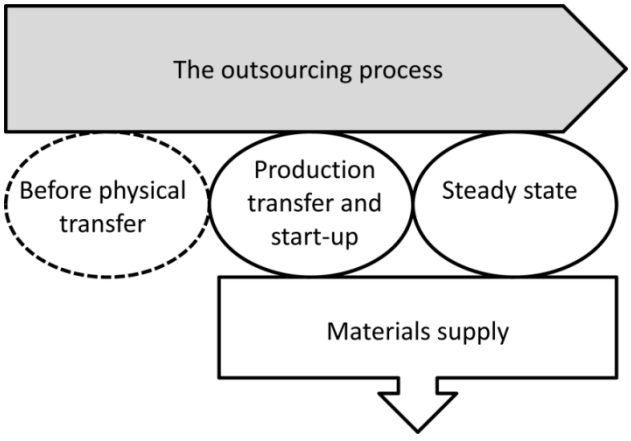

Figure 2.3: The focus of the present section is outsourcing processes (marked in grey).

2.4.1 *Outsourcing frameworks*

Before physical transfer, the focus of the outsourcing process is on decision making. Decision making is about weighing all possible pros and cons and displaying scenarios of what effects a certain decision alternative will bring. The purpose of using an outsourcing process is to make the most advantageous decision for the company as a whole. A process also provides a structure for the decision making and the carrying out of the decision. By having a structured approach the decision makers get helped by the

activities included in the process to take a cross-functional view on the outsourcing decision (Moses, 2009). Through the cross-functional view the decision makers can evaluate the effects of a decision alternative for different parts of the company. A decision process can be defined as a flow of actions to transform input into a decision (Moses, 2009). However, the existing literature about outsourcing decision making has not only focused on decision processes; in some cases other forms of structures for decision making have been developed. Therefore, the term "outsourcing framework" used in this thesis denotes any kind of structure that supports outsourcing decisions and outsourcing projects and the term "outsourcing process" is used to denote an outsourcing framework consisting of specific phases and specific activities in order to make outsourcing decisions. This section introduces a variety of outsourcing frameworks and processes to show their differences, similarities and content.

It can be distinguished between frameworks, focusing on developing strategies prescribing a comprehensive top-down analysis of production activities or products in order to identify those most suitable for outsourcing, and frameworks with an operational approach where a suitable production activity or product has already been identified (De Boer et al., 2006; Wasner, 1999). In the frameworks presented below it is seen that the first phases of the existing frameworks aim to prepare the decision making by analysing the present situation based on the company's overall or production strategies. Thereafter, in most cases, cost calculations follow where some frameworks end their processes (e.g. Platts et al., 2000; Probert, 1996; McIvor, 2000). Other frameworks go further and include supplier evaluations to identify suitable suppliers, contract negotiations, physical transfer and relationship management after physical transfer (e.g. Momme and Hvolby, 2002; Zeng, 2003; Franceschini et al., 2003). The frameworks that end before physical transfer are not suitable from a perspective of how to ensure materials supply as these do not include the physical transfer and steady state where actual materials supply takes place. These frameworks have a strategic focus, whereas the framework that also includes the physical transfer and the steady state focuses on both the strategic aspects as well as the operational aspects of carrying out the decision. Thereby are the frameworks that also include the physical transfer and the steady state in their outsourcing processes of more interest in this thesis. However, the frameworks with a focus on strategies do through the factors they include provide input to the decision making stage before physical transfer.

Platts et al. (2000) have developed an outsourcing framework that start in the production strategy of the company. The aim of their framework is to create a holistic understanding of the outsourcing process. An outsourcing decision process is triggered by things such as cost reduction, lack of capacity, and investments. The make-or-buy process is performed in three steps: 1) the preparation phase, where a project team is selected and the items or processes to be outsourced are identified; 2) the data collection phase, where data needed for the decision is specified and gathered; and 3) the analysis and result phase, where weightings and ratings are combined to give a single figure that indicates the merits of the options. Platts et al. (2000) mention four areas that should be compared and evaluated during the outsourcing process. They are: technology and production process, cost, supply chain management and logistics and support systems.

Probert (1996) describes a framework for developing a make-or-buy strategy from six cases. The framework is based on an analysis of the production technologies and the product architecture used by the company, the competitiveness with which they are

used, and their importance for the success of the business. The ideal "greenfield" business scenario is a guiding picture of how the business would be organised if it were started today. The model starts with the company defining their long-term vision and strategic goals. Then, the product structure and production technology of today are defined and the relationship between the technology and the products is established. This leads to an assessment to determine if there are any go/no go conditions depending on the technologies, subsystems and part families. The evaluation considers the importance, competitiveness, and impact on measures, products/processes and strategic issues of technology, subsystems or part families.

The McIvor (2000) framework aims at including a value chain perspective, core competence thinking, supply base influences and a transaction cost view into the outsourcing decision. It is based on interviews with senior managers in 12 companies and a literature review. McIvor's (2000) framework starts with the company defining their core activities, since customers consider this as adding value and therefore it is a major determinant of competitive advantage. The next step is to evaluate relevant value chain activities by benchmarking each selected core activity against the capabilities of potential external providers and identifying the costs associated, either by retaining the activity in-house or by outsourcing it. After the evaluation, a total cost analysis of the core activities should be done; it should encompass all costs associated with the acquisition of the activity throughout the supply chain. The final step is to do a relationship analysis.

The Zeng (2003) framework aims to combine global sourcing processes with logistics and is based on literature studies and a case study. The Zeng (2003) framework includes the whole outsourcing process from identification of core activities to after transfer. It has five steps:

1. Investigation and tendering
    a. Core activities
    b. Analysis of company, customer and competitors
    c. Sourcing strategy
2. Evaluation
    a. Selection criteria
    b. Pre-screening
    c. Estimate of economic and operating benefits
3. Supplier selection and development
    a. Negotiation
    b. Technical assessment
    c. Savings identification
    d. Implementation schedule
4. Implementation
    a. Team, strategy and schedule
    b. Agreement on supply and logistics terms
    c. Measurement of actual performance
    d. Progress report
5. Performance measurement and continuous improvements
    a. Monitoring of suppliers' performance
    b. Relationship analysis
    c. Continuous improvement opportunities
    d. Maintaining a dynamic and flexible procurement process.

Franceschini et al. (2003) present a framework that aims at developing a generic outsourcing framework in accordance with total quality management principles; it is based on literature studies and a case study. The framework consists of four steps. The first step, internal benchmarking, helps the outsourcing company evaluate its processes, analyse their efficiency and evaluate what to outsource. A company-specific core competence definition is made, possible relationships with suppliers are identified, and finally, a stratification of activities is created. Steps two through four consist of an external benchmarking with the aim of supplier selection, followed by contract negotiations and finally managing the outsourcing process.

The framework by Momme and Hvolby (2002) aims at linking operational and tactical considerations to strategic planning by combining core competence thinking with an outsourcing process. The framework was developed from a case study of a strategic outsourcing programme used by Aalborg Industries. Momme and Hvolby (2002) introduce an outsourcing decision process in six phases and include activities to be executed during the phases:

1. Competence analysis
    a. Strategic analysis
    b. SWOT analysis
    c. Core/non-core competence mapping
2. Assessment and approval
    a. Defining critical assessment criteria
    b. Supplier assessment
3. Contract negotiation
4. Project execution and transfer
    a. Establishing basis for supplier integration
    b. Defining workflow interfaces
    c. Adapting organisation to supplier performance
5. Managing relationship
    a. Establishing communication, information and monitoring systems
6. Contract termination

2.4.2 *Outsourcing decision factors*

Outsourcing decision factors are criteria considered in an outsourcing framework to help the decision makers judge whether to outsource as well as know how a possible outsourcing should be conducted. When viewing the whole outsourcing process it is important to lift the view and not only consider the materials supply system but the whole logistics area. Therefore, the outsourcing decision factors described in this section are related to logistics and not only materials supply. There is a wide range of decision factors for outsourcing and several groupings of decision factors are present in the literature. Decision factors can be obligatory, quantitative, qualitative or connected to the implementation of the decision (Momme and Hvolby, 2002; Schniederjans and Zuckweiler, 2004). Decision factors should be considered in a structured manner and identified based on the specific context and scope of the company outsourcing (Momme and Hvolby, 2002). What decision factors to consider varies depending on the nature or type of business of the outsourcing company. The factors also may depend on the geographic region in which the location and supplier is being considered (MacCarthy and Atthirawong, 2003). Brannemo (2006) identifies, in an evaluation of three outsourcing frameworks, seven types of decision factors included in the outsourcing

process: cost calculations, qualitative criteria, quantitative criteria, core competence evaluation, strategy, logistics and benchmarking. However, it is not obvious how these categories of decision factors are related to logistics and what is meant by the logistics type of decision factor. To describe the relationship between the decision factors and the effects of outsourcing on logistics would give an answer to what decision factors are relevant to logistics.

2.4.3 *Summary*

Outsourcing decisions contain four questions: why, what, to whom and how. The first question asks for the drivers for outsourcing; the second question examines what is possible or profitable to outsource; the third question leads to who is most suitable to take over the responsibility and become a supplier; and the fourth and final question covers how the structure and coordination between the outsourcing company and the supplier should be established and managed. Some factors considering logistics are included in a few of the existing frameworks but they are seldom the focus. Outsourcing of production affects logistics and an efficient and reliable materials supply has a significant effect on the result of the outsourcing of production. Therefore, logistics should be part of outsourcing processes or there is a risk of neglecting logistics issues. Making logistics an active part of the outsourcing process would improve the process and enhance the quality of the decision. The phrase "integrating logistics" means to make logistics a part of the answer to the four questions of outsourcing. Therefore, Research Question 1 is to identify how logistics can be integrated in the outsourcing process (see Figure 2.4).

Research Question 1: How can logistics be integrated into the outsourcing process?

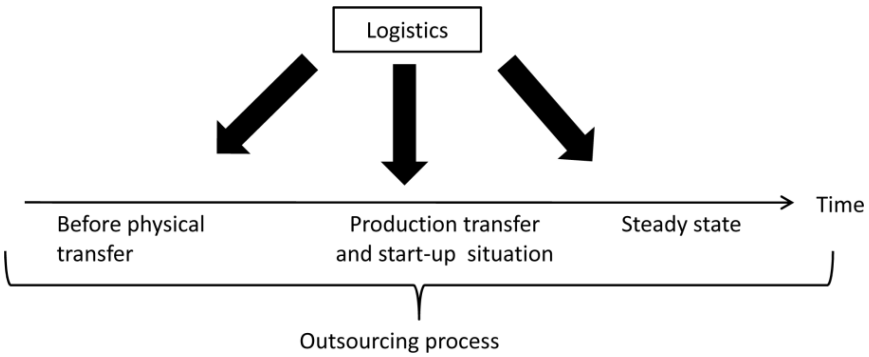

Figure 2.4: Focus of Research Question 1.

2.5 Steady state – sourcing characteristics

This section focuses on the steady state stage of the outsourcing process (Figure 2.5). Production transfer and start-up cover from the initiation of the physical transfer to when a steady state is reached. Steady state is in this thesis defined as outgoing from the production start-up literature and this literature considers a steady state as when activity to be started has reached the intended levels of output in the form of quantity and quality (Almgren, 1999b). That steady state is in focus, meaning that the supply chain studied here is already designed and a normal purchasing situation exists. Thereby, how outsourcing affects materials supply in the steady state stage of the outsourcing process depends on the supply chain performance of the supply chain formed through

outsourcing. Below, research on how to evaluate existing supply chain designs is presented to identify the research gap leading to Research Question 2.

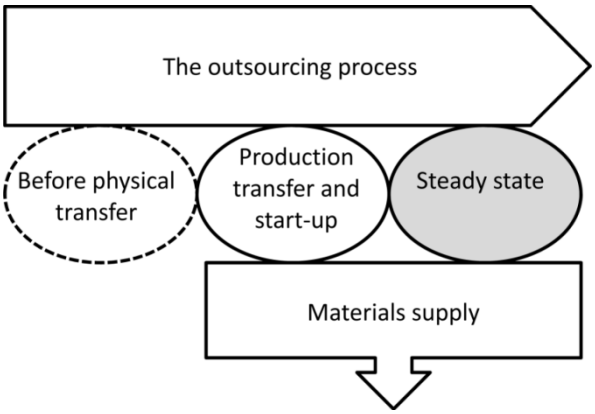

Figure 2.5: The steady state within the outsourcing process (marked in grey) is the focus of the present section.

There exist several frameworks for evaluating the effects of supply chain designs. Fill and Visser (2000) introduce two groups of characteristics—strategic and structural aspects associated with an organisation's decision to reconfigure, and costs. Strategic and structural aspects associated with an organisation's decision to reconfigure help the outsourcing company identify how integrated the company should be based on the characteristics of production and the production process in relation to the supply chain structure (i.e., the geographic distances between the outsourcing company, its market and the supplier). Costs describe what is most favourable based on comparing the internal cost of producing the product with the transaction costs of purchasing the product. Graf and Mudambi (2005) classify characteristics into firm-specific and situation-specific factors. Firm-specific factors include the drivers for outsourcing such as cost, capability and process improvements, and situation-specific factors describe the strategic importance of the process and customer expectations for interaction. This affects what possible locations to select depending on how the location affects these factors (Graf and Mudambi, 2005). Levy (1995) analyses sourcing decisions via location-specific factors and relational factors. Considered in isolation from the rest of the supply chain, location-specific factors determine the optimal location for each activity in the supply chain. Relational factors address the relationship between the activity being sourced and other activities within the value chain. According to Fraering and Pasad (1999), by studying how product, organisation and country factors affect sourcing location, supplier communication, logistics and delivery reliability, it is possible to determine how materials management is affected by a sourcing location and how this affects financial performance. Product factors cover asset specificity and materials costs, organisation factors cover operations cost, innovation and R&D, and country factors cover exchange rate volatility, tariffs and infrastructure.

Even though the outsourcing process has reached a steady state it is necessary to understand what the new supply chain signifies in the form of supply chain performance and how it should be managed. It can sometimes be necessary to redesign the existing supply chain to improve supply chain performance. Earlier research presents factors for evaluating how supplier locations affect the supply chain and how the internal organisation of the outsourcing company fits with different supply chain structures and

supplier locations. However, the existing frameworks cover only parts of how the design and management of the supply chain affect materials supply. In spite of the fact that there are several frameworks for evaluating the effects of supply chain design and management, it is necessary to combine the areas these existing frameworks cover. Here, the term "sourcing characteristics" is used to denote the outsourcing decision factors by which decision makers evaluate the effects of outsourcing on the supply chain. Below it is elaborated on which categories of characteristics are necessary to include in order to determine how materials supply is affected by supply chain design and management.

The structure or configuration of the supply chain or how the supply chain is controlled or coordinated affects how flow and the storage of goods and information exchange should be managed. Competitive advantage may be gained both from superior supply chain structure and superior supply chain relationships and co-ordination (Colotla et al., 2003); there is a need to analyse supply chain organisation by its effect on configuration and coordination. Therefore, factors for analysing the organisation of supply chains are divided into two categories of characteristics: the supply chain structure (Harrison and van Hoek, 2002) and the supply chain relationships (Gadde and Håkansson, 2001). To create stable and cost efficient supply chains, it is important to match the right product with the right supplier at the right location (Fisher, 1997). For example, a low-cost country implies certain characteristics of the supplier and its location, and sourcing from these countries requires that companies are aware of these (Kumar et al., 2010). How the characteristics of the supplier location affect the supply chain will be analysed via one category of characteristics, sourcing country characteristics.

Three categories of characteristics are identified to describe the sourcing characteristics of a supply chain: supply chain structure, supply chain relationships and sourcing country characteristics. Outsourcing of production affects materials supply through the characteristics of the supply chain, since the characteristics of the supply chain set how it should be managed. The issue for many companies is to understand how to make the best out of supply chains. To analyse this, it is important to know how the characteristics of a supply chain affect supply chain performance. Therefore, Research Question 2 describes how supply chain structure, supply chain relationships and sourcing country characteristics affect supply chain performance. Figure 2.6 presents the analytical structure of Research Question 2.

Research Question 2: How do supply chain structure, supply chain relationships and sourcing country characteristics affect supply chain performance?

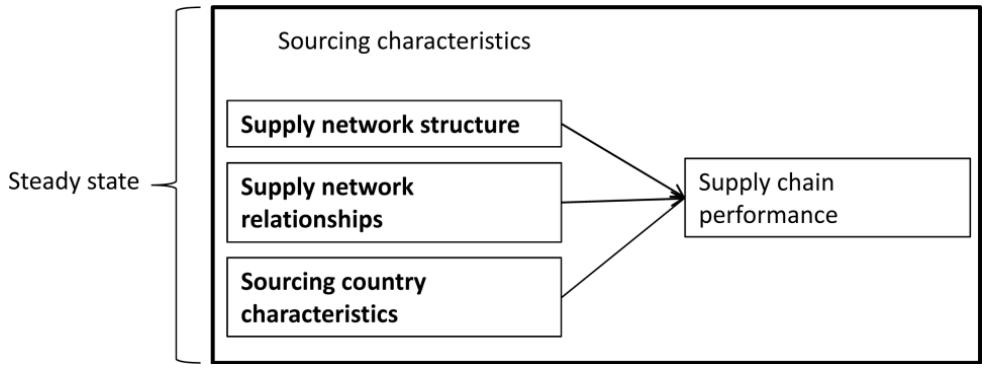

Figure 2.6: Analytical structure of Research Question 2

2.6 Production transfer and start-up

The production transfer and start-up stage is the focus of this section (see Figure 2.7).

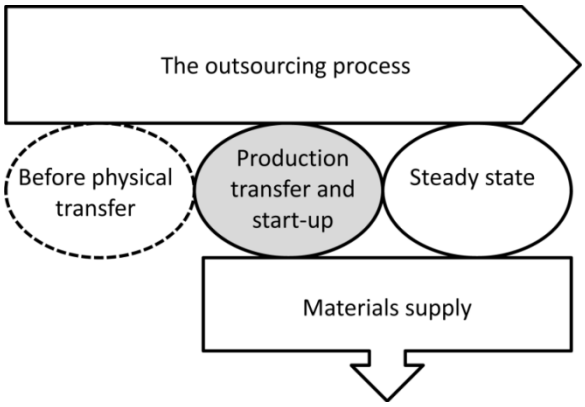

Figure 2.7: The production transfer and start-up situation are the focus of the present section (marked in grey).

The production transfer and start-up stage is where the supply chain design, decided upon by the decision to outsource, is implemented. Supply chain uncertainty increases during production transfer and start-up. Supply chain uncertainty originates from deviations – from the predicted or required performance – that are unknown to the decision maker in the decision making situation. Supply chain uncertainty exist in terms of variations in lead time, product quality and quantity (van der Vorst and Beulens, 2002). The deviations cause disturbances for the production system in the form of delays, rush orders, quality problems, and unavailable materials (Vieira et al., 2003). The materials planning process is vulnerable to supply chain uncertainty, because deviations upset the plans made to ensure material availability and the plans have to be revised. To ensure materials supply during production transfer and start-up it is important to understand what the production transfer and start-up imply for the materials planning process. Below, materials' planning during production transfer and start-up is examined and the third research question is developed.

2.6.1 *Materials planning during production transfer and start-up*

The materials planning process refers to planning, control and follow-up of materials flows from suppliers to customers, e.g., decisions about what and when to produce, deliver and replenish stocks (Jonsson and Mattsson, 2009). The result of the materials planning process is materials plans, i.e., production and purchase orders for the items to secure the materials supply (Wänström, 2006). The materials planning process before physical transfer generates manufacturing orders which are executed in the workshop of the focal company. Whereas after physical transfer the materials planning process generate manufacturing orders for the main product, which the outsourced item is part of, and procurement orders to the supplier of the outsourced item. Generating the procurement orders is part of the materials procurement process and this process interacts with the supplier´s order-to-delivery-process (Jonsson and Mattsson, 2009); see Figure 2.8.

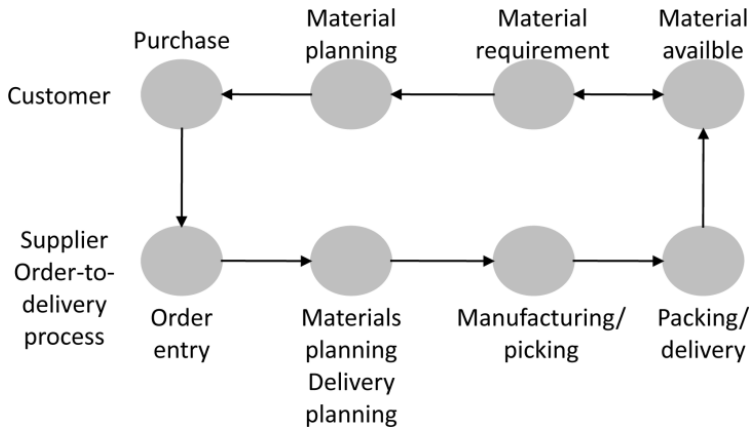

Figure 2.8: The customers' materials planning and materials procurement process interact with each other and with the order-to-delivery process of the supplier (Jonsson and Mattsson, 2009, p. 383).

There are different materials planning methods of synchronising the flows of materials. The applicability of different materials planning methods depends on the materials planning environment (e.g. Berry and Hill, 1992; Howard et al., 2002; Jonsson and Mattsson, 2003; Wänström and Jonsson, 2006). The materials planning environment describes the current circumstances, i.e., the reality within which the materials planning process has to be carried out (Olhager and Wikner, 2000). Thereby the materials planning environment constitutes the prerequisites for the materials planning process that has to be taken into consideration, as decisions about what to produce and when, and when to deliver and replenish stocks are made. What separates the materials planning environment during production transfer and start-up from the materials planning environment during steady state is the increased supply chain uncertainty, as evolving supply chains cause uncertainties for companies regarding yield, process reliability and lead time (Lee, 2002). The materials planning environment can be characterised by the production process, product and demand (Berry and Hill, 1992). Wänström and Jonsson (2006) add the category of materials supply to describe the materials planning environment during engineering change. These four cornerstones of characteristics, based on which the materials planning environment can be described, are in this thesis denoted "production transfer and start-up characteristics."

Production transfer and start-up can roughly be divided into three main phases: 1) preparations prior to the transfer, 2) the physical transfer of equipment, and 3) the start-up in the new location (Madsen, 2009). The actual physical transfer, which takes only a short time—the time required to move the necessary equipment, materials and other resources from location A to location B (Madsen, 2009)—will not be the focus of this research question. Instead, the research question focuses on the preparations before the physical transfer and the start-up after the physical transfer.

The output of the materials planning process depends on the specific activities carried out (van der Vaart et al., 1996). The materials planning activities before and during production transfer and start-up deal with all the questions that have to be answered and updates that have to be made because of the transfer of materials supply from in-house production to purchasing. Thereby, the materials planning activities before and during production transfer and start-up cover the actions and choices made in the materials planning process necessary to ensure materials availability during production transfer

and start-up. Before the physical transfer, the outsourcing company prepares for production transfer and start-up by building up safety stock and upgrading documentation, equipment, control systems, etc. (Madsen, 2009). Preventive actions can, except for building safety stocks in raw materials and finished goods inventories, also be safety capacity, safety lead times and overplanning (Forslund and Jonsson, 2007). The materials planning activities prior to the physical transfer thus cover preparations and preventive actions to ensure materials supply. An engineering change situation resembles a production transfer and start-up because it incorporates a phase-in and a phase-out of products or production. Thus, it can be assumed that the preparations for an engineering change show similarities to those of production transfer and start-up. materials planning activities in an engineering change situation are company specific depending on the specific situation (Wänström, 2006). Wänström (2006) exemplifies the activities as follows: establishing and adjusting master schedules and effective dates, deciding lot-size and lot-sizing methods, the extent of tooling changes, coordinating production control and determining gross requirements. However, in order to estimate gross requirements during the production transfer and start-up, it is necessary to estimate the time to reach steady state.

After the transfer during start-up, corrective actions may be necessary depending on the progress of the start-up of the new supply chain. Corrective actions are for example subcontracting, expediting, part delivery, rescheduling, reservation breaking, overtime and express transport (Forslund and Jonsson, 2007). Implementation always involves unexpected events and to avoid surprises, the fulfilment of purchase orders is usually tracked (van der Vaart et al., 1996), and tracking purchase orders during production transfer and start-up implies monitoring the progress of the supplier start-up. Also, during production transfer and start-up the materials planning process has to adapt forecasting and materials handling to purchasing instead of an in-house supply (van der Vaart et al., 1996; Boulaksil and Fransoo, 2010) and dealing with the new supply chain including nodes situated in a different context (Manuj and Mentzer, 2008).

Furthermore, the materials planning process also include different materials planning methods and techniques to synchronize the flows of materials and the goal for all these methods and techniques is to generate the flows as efficiently as possible. The materials planning methods and techniques use a number of planning parameters and materials planning data of different types as inputs. Some of these planning parameters and the materials planning data are necessary to change or update in order to ensure materials availability during production transfer and start-up. During production transfer and start-up it is important how the materials planning process deals with changes to handle the disturbances caused by variations in lead time, quality and quantity. Parameters such as planning frequency (Wänström and Jonsson, 2006), time fences (e.g., release time fence and planning time fence) (Jonsson and Mattsson, 2009) and planning periods (Vollman et al., 2005) affect the ability to make changes. Further, outsourcing in most cases increases lead times. The planning horizon must, as a minimum, equal the longest accumulated time for production and purchasing of all items included in the end product. If the longest accumulated lead time is changed, it is necessary to adjust the planning horizon (Jonsson and Mattsson, 2009).

Materials planning data quality, data that is complete, concise, reliable, timely, valid, accessible, of an appropriate amount, credible, relevant and understandable is critical for the materials planning process (Gustavsson and Wänström, 2009). Materials planning

data is defined as fundamental information about the conditions and circumstances of a company´s products and its manufacture of those products. The main types are: item data, bill-of-material data, routing data and work centre data (Jonsson and Mattsson, 2009). Item data contain basic data, price and cost data, forecasting data, sales data, planning data and inventory data (Jonsson and Mattsson, 2009). For example, forecast data are used as input when taking preventive actions and the quality of the preventive actions are dependent on forecast data accuracy (Verganti, 1997).

2.6.2 *Summary*

The main task for the materials planners during production transfer and start-up is to ensure the materials supply to maintain customer service levels by avoiding production stops at a reasonable cost. The materials planning process during production transfer and start-up is described via the activities that have to be carried out and the planning parameters and materials planning data quality that set the prerequisites for the activities. Further, the materials planning environment during production transfer and start-up can be described via four categories of characteristics (the production transfer and start-up characteristics): production process, product, demand and materials supply. The majority of earlier studies of the materials planning environment described static planning situations, meaning that the situation does not change over time (e.g. Berry and Hill, 1992; Jonsson and Mattsson, 2003). However, during production transfer and start-up the materials planning environment will be different depending on progress of the production start-up and the technology and knowledge transfer. Therefore, to understand how the materials planning process during production transfer and start-up should be managed it is necessary to understand how production transfer and start-up affect the supply chain uncertainty of the materials planning environment. By describing the supply chain uncertainty of the materials planning environment, the impact of production transfer and start-up on the materials planning process is operationalised. Figure 2.9 show the relationship between the materials planning environment, supply chain uncertainty, the materials planning process and supply chain performance.

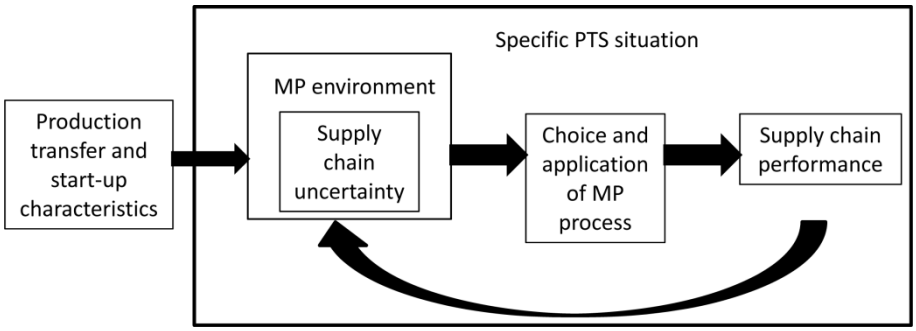

Figure 2.9: The analytical structure for Research Question 3. The materials planning environment equals the value of all production transfer and start-up characteristics during specific production transfer and start-up.

Research Question 3a asks how the production transfer and start-up affect the supply chain uncertainty of the materials planning environment and Research Question 3b

seeks to describe how the choice and application of the materials planning process during production transfer and start-up affects supply chain performance.

Research Question 3a: How do the production transfer and start-up affect the materials planning environment supply chain uncertainty?

Research Question 3b: How does the choice and application of the materials planning process affect supply chain performance during production transfer and start-up?

3 Research methodology

This chapter presents and discusses the methodology used in this thesis. The chapter starts with a brief description of the research process, followed by a description of the research strategy and the studies conducted. Finally, validity and reliability are discussed.

3.1 Research process

The six papers appended to this thesis are based on five studies with different characteristics. The studies are described in more detail in Section 3.3 and are enumerated in chronological order. Figure 3.1 summons the research process. During the research process there was an interaction between the theory and empirical data; therefore the theory does not necessarily precede the empirical data or vice versa. By going back and forth between different types of research activities it is possible for the researcher to expand understanding of the theory and empirical phenomenon (Dubois and Gadde, 2002). It allows researchers to make new insights about existing phenomena by examining these from a new perspective (Kovács and Spens, 2005).

The research process started in November 2005. The first part of the research process was to participate in the PROLOG research project, a joint project between the Division of Logistics and Transportation at Chalmers University of Technology, Swerea IVF AB and ALMI Företagspartner Jönköping AB. The aim of the project was to develop tools and guidelines to improve decision making within localisation decisions. Eight Swedish production companies participated in the project. The companies' wish to participate was rooted in considering the subject to be important and problematic. Four studies were carried out by the author together with other researchers in the PROLOG project (the pre-study, Study 1, Study 2 and Study 3). The result of the project was four papers, three of them included in this thesis (Paper I, Paper II and Paper III) and the licentiate thesis "Integrating logistics in outsourcing decisions" (Fredriksson, 2008).

The first step in the PROLOG project was the pre-study. In the early stages of many research processes, exploration is needed to develop research ideas and questions (Voss et al., 2002). The pre-study set out to identify what problems related to outsourcing and logistics were the most troublesome among the companies participating in the PROLOG project. Based on the pre-study, the three other studies conducted within the PROLOG project were identified. In parallel with the pre-study, a literature study covering outsourcing drivers, decision factors and processes was performed. The problems identified in the pre-study and the literature review of outsourcing processes and outsourcing decision factors resulted in Study 1 and Study 2. Study 2 showed many practical problems in the case related to how to utilise the supply chain. Conceptual ideas existed in the literature, upon which such allocations in supply chains could be made (e.g. Fisher, 1997; Christopher and Towill, 2001). However, the conceptual ideas were not utilised and this led to the start of Study 3, a simulation study, set out to test some of the presented conceptual ideas of how to use supply chains with nodes in different contexts. The PROLOG project was finalized by the presentation of the licentiate thesis (Fredriksson, 2008).

The second part of the research process started in mid-2009 after the author returned from maternity leave. In this part of the research process, five companies participated. However, the studies included in this thesis cover only four of the companies. The study

of the fifth company focused on in-sourcing, which is outside the scope of this thesis. A final conclusion from the PROLOG project was that it was necessary to focus on the parts of the outsourcing process where actual materials supply started to really grasp how outsourcing and materials supply were linked. In all the studies in the PROLOG project, the companies experienced trouble achieving their goals of outsourcing because it was much more complicated than thought when making the decision to outsource to reach steady state. The second part of the research process used the results of the PROLOG project as a starting point and focused on materials planning and production transfer and start-up. A literature study was conducted that focused on production ramp-up and materials planning. The result of this literature study was that there was a lack of literature that addressed outsourcing and how to carry out the transfer and ensure materials supply until a steady state was reached. Study 4 was conducted to get an understanding of production transfer and start-up and how it affects materials supply. After Study 4 was carried out, the literature study was extended to also cover technology and knowledge transfer. For Study 5, a multiple case study was carried out to complement the results of Study 4 by diversifying the contexts studied. The result of this part of the research process was three papers (Paper IV, Paper V and Paper VI).

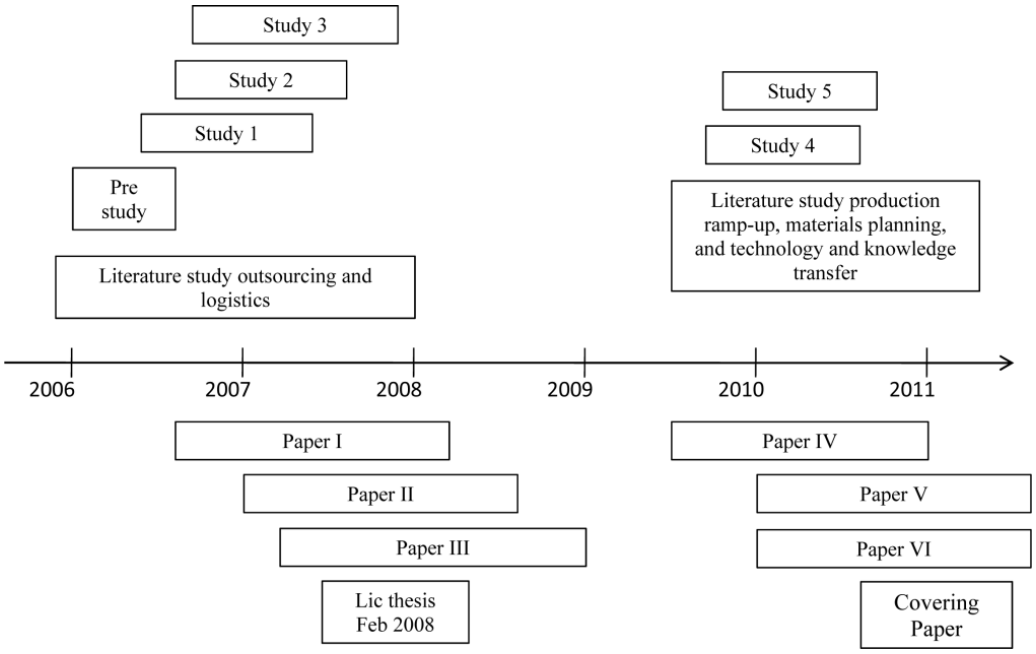

Figure 3.1: The research process

3.2 Research strategy

This section describes the research strategies used within this thesis. A research strategy represents a way of collecting and analysing empirical data (Yin, 2002). Depending on the form of the research question, it requires different control of behavioural events and a focus on contemporary events; different research strategies have advantages and disadvantages (Yin, 2002). Case studies are suitable when a "how" or "why" question is being asked about a contemporary set of events over which the investigator has little or no control (Yin, 2002). A case is a detailed description of an organisation, incident or phenomenon (Simon, 2009). The case study research strategy focuses on understanding the dynamics present in a single setting (Eisenhardt, 1989).

The research in this thesis tries to understand the dynamics of how to ensure materials supply in the setting of the outsourcing process. The research questions are "how" questions. The research analysed contemporary events over which the researcher had no control. The research in this thesis attempts to capture a rather wide and to some extent new problem area; the research process has been a process where the research questions have evolved as the researcher has gained deeper knowledge of the phenomenon studied. Furthermore, there was seldom one person that could provide the researcher with the necessary information. To be able to understand the dynamics and create a detailed description of the phenomenon studied, information had to be collected from several different people and sources. Therefore, the case study was the most suitable way to get the knowledge needed to answer the research questions put forward in this thesis.

A primary distinction in designing case studies is between single and multiple case design (Yin, 2002). The single case study design is justifiable when the case represents a critical test of existing theories, a rare or unique circumstance, or a representative or typical case serving as revelatory or for longitudinal purposes (Yin, 2002). If the research problem is directed toward analysing a number of interdependent variables in complex structures, it is natural to go deeper into one case (Dubois and Gadde, 2002). Using a multiple case study design, the cases may be chosen to replicate previous cases or extend emergent theory, or they may be chosen to fill theoretical categories and provide examples of polar types (Eisenhardt, 1989). If the research problem is focused on a comparison of a few specific variables, the natural choice would be to increase the number of observations to compare through a multiple case study (Dubois and Gadde, 2002).

The studies in this thesis represent both single and multiple case studies. Study 2 and Study 4 were single case studies. Study 2 represented a rare opportunity of studying three echelons of a supply chain from China to Sweden. Study 4 was a single case study because it served as revelatory to describe the production transfer and start-up situation and its relation to materials planning. Study 1 and Study 5 are multiple case studies. Study 1 uses replication logic to study the outsourcing process in different companies and Study 5 also uses replication logic to see how production transfer and start-up is related to the materials planning environment and the materials planning process in different contexts.

According to Yin (2002), research strategies can be exploratory, descriptive and explanatory. An explorative study has the goal of reaching a more specific problem description (Hellevik, 1984). When the problem is specific, it is possible to do a more systematic and profound study, a descriptive study (Hellevik, 1984). In an explanatory study, the researcher tries to prove causes of underlying characteristics found in the study (Hellevik, 1984). Normative studies answer how things should be and how they can be justified (Badersten, 2006). The research conducted in this thesis was exploratory, descriptive, explanatory, and normative (Table 3.1).

Table 3.1: Characteristics of the studies

Study	Exploratory	Descriptive	Explanatory	Normative
Pre-study	X			
1		X		X
2	X	X		
3		X	X	X
4		X		X
5	X	X		

3.3 The studies

The following text describes the studies, the selection of the cases and data collection techniques used in the studies. To provide an overview of what has been studied Table 3.2 presents the relationship between the research questions, the studies and the papers.

Table 3.2: The connection between research questions, studies and papers

Research question		Study	Paper	Purpose of paper	Analysis of data set
Research Question 1: How can logistics be integrated in the outsourcing process?		Study 1	Paper I	*To derive a general outsourcing process and relate logistics to this process*	Which of the phases in the general process were included in the studied companies' outsourcing projects was analysed. Logistics-related problems and issues considered or experienced by the companies during the outsourcing projects were identified.
Research Question 2: How do supply chain structures, supply chain relationships and sourcing country characteristics affect supply chain performance?		Study 2	Paper II	*To develop a framework for low-cost sourcing assessment and to explore the consequences of low-cost sourcing in China for a European manufacturers*	A theoretical framework describing the sourcing characteristics was developed. It was applied to the case and it analysed which consequences were related to each dimension of the sourcing characteristics and their perceived performance effects.
		Study 2 and Study 3	Paper III	*To explain the performance effect of various strategies of combining in-house manufacturing and outsourced manufacturing*	The strategies were tested via a simulation study and compared based on their effects on inventory levels.
Research question 3a: How do the production transfer and start-up affect the materials planning environment supply chain uncertainty? **Research question 3b:** How does the choice and application of the materials planning process affect supply chain performance during production transfer and start-up?	RQ 3a and RQ3b	Study 4	Paper IV	*To develop the understanding of in what ways an materials planning process during production transfer and start-up impacts supply chain performance*	A conceptual framework describing the materials planning process in the production transfer and start-up situation and the production transfer and start-up characteristics was developed. The production transfer and start-up characteristics were used to describe the context in the case. Further, problems in the materials planning activities, materials planning parameters and materials planning data quality during production transfer and start-up and ways in which these affected the supply chain performance were identified.
	RQ 3b	Study 5	Paper V	*To describe how the choices made during an materials planning process and their implementation before and during production transfer and start-up affect materials availability of an outsourced item*	A cross case analysis was performed in two parts: 1) What in the materials planning process during the preparations before the physical transfer impacted materials availability during production transfer and start-up; ; and 2) What in the materials planning process during production start-up after physical transfer impacted materials availability during production transfer and start-up.
	RQ 3a		Paper VI	*To describe the materials planning environment supply chain uncertainty during production transfer and start-up*	The purpose was answered by discussing insights of how the production transfer and start-up characteristics in the cases affected supply chain uncertainty and how the production transfer and start-up characteristics could be used to describe the materials planning environment in the specific case.

3.3.1 *Selection of the cases*

This section describes how the cases were selected and what they have covered in terms of outsourcing and production transfer. The selection of cases is important. The

selection of an appropriate population controls extraneous variation and helps to define the limits for generalising the findings (Eisenhardt, 1989). The way boundaries are expanded is of major importance because it determines what will be found (Dubois and Gadde, 2002). In one way, the extension of the boundary is seen as the sampling problem in case studies (Dubois and Gadde, 2002). When selecting cases, it is important to consider the parameters and factors that define the population and that are to be held constant across the sample (Voss et al., 2002). Furthermore, studies covering processes have to come to an end, while the processes in the real world continue and the researcher has to make a choice of how far back in time he/she wants to trace the process in question (Dubois and Gadde, 2002).

All eight companies studied (only four were part of the PROLOG project) are Swedish manufacturing companies working in business-to-business markets. All cases focused on one specific outsourcing project though different stages of the outsourcing process. Empirical data in Study 1 was collected using a multiple case study consisting of three cases, Companies A, B and C. Study 1 was conducted in 2006. In the selection of cases for Study 1, all eight companies participating in the PROLOG project were asked to present cases from the field of logistics and outsourcing of production that they considered interesting. The three cases included were selected based on their relevance from a logistics point of view and access to people involved at the companies. Each of the three cases covered the whole outsourcing process from initiation, where the question of whether to outsource was raised, to after the transfer to the supplier and the relationship with the supplier during steady state. All three cases were historical cases that took place from six months to several years ago.

Study 2 and Study 3 (Study 3 is further described in section 3.3.3) focused on the steady state and were based on the same single case study conducted to obtain deep insight into and explore the effects of a European manufacturer when conducting low-cost sourcing in China. The supply chain studied included Company D, Company J and Chinese suppliers of casting goods. The data collection in Study 2 and Study 3 took place during 2006 and 2007. The case was selected based on the opportunity it provided to study a low-cost casting goods supply chain from Chinese manufacturers through a Chinese intermediary company to a European equipment manufacturer. Casting goods are quite standardised and mature items, physically non-sensitive to transport, and with a low value. However, casting goods put some very specific requirements on the supply chain, depending on their physical characteristics and how they are produced.

Study 4 and Study 5 focused on the production transfer and start-up stage. Data collection took place during 2009 and 2010. Study 4 was a single case study conducted at Company E in order to obtain deep insight into and describe how the materials planning process in the production transfer and start-up situation affected supply chain performance. The case was selected based on the opportunity it provided to study an ongoing production transfer and start-up of EMS production from Sweden to China. In Study 5 a multiple case study approach was selected based on the assumption that different companies manage production transfers and start-up situations differently. The use of a multiple case study makes it possible to study different production transfers and start-ups and how they were approached. Empirical data in Study 5 was collected from four Swedish production companies, E, F, G and H. The companies were selected with the purpose of representing different materials planning environments on an all company level. Jonsson and Mattsson (2003) identified four main types of planning

environments on a company level based on product, demand and production processes to compare companies with different planning environments (Table 3.3). The four selected companies can each be related to one of these groups. Company F is a Type 1 company, Company E is a Type 2, Company G is a Type 4 and Company H is a Type 3.

Table 3.3: Classification of planning environments for the whole company (Jonsson and Mattsson, 2003)

	Planning environments			
	Type 1 – Complex customer products	Type 2 – Configure to order products	Type 3 – Batch production of standardised products	Type 4 – Repetitive mass production
Product characteristics				
BOM complexity	High	Medium	Medium	Low
Degree of value added at order entry	ETO	ATO/MTO	MTS	MTS/ATO
Demand characteristics				
Order volume/frequency	Few/small	Many/medium	Many/large	Call-offs
Production process characteristics				
Production process	One-off		Batch	Mass
Shop floor layout	Functional	Cellular/line	Cellular/functional	Mass
Batch sizes	Small	Small	Medium/large	
Through-put times	Long	Short	Medium	Short

Outsourcing is a wide ranging subject and it is not obvious what has been studied by just saying that an outsourcing process or project has been studied. To understand what has been studied it is important to describe the cases based on the same terms. Thus, section 2.3 summarised the characteristics based on which the cases could be described (see below). These characteristics have been used to illustrate the commonalities and differences between the studied cases. An overview of how the cases relate to the characteristics below is presented in Table 3.4, Figure 3.2, Table 3.5 and Figure 3.3. The overview shows the settings of where the results of this thesis are valid. To develop Figure 3.2 and Figure 3.3 it was necessary to illustrate the variance within each of the characteristics presented below. Some characteristics had a discrete number of alternatives and each alternative was given a number. Some characteristics could be described based on the spectrum between low and high and here the numbers are relative based on a comparison between the cases. The number used to construct Figures 3.2 and 3.3 were set based on the authors' judgement and Figures 3.2 and 3.3 should only be seen as illustrations of Tables 3.4 and 3.5.

Outsourcing

- Governance structure (in Figure 3.2, market=1, hybrid (modular value chains =2, relational value chains=3, captive value chains=4), or hierarchy=5)
- Focal company control of the supply chain (in Figure 3.2 low=1 to high=5)
- Focal company power in the supply chain (in Figure 3.2 low=1 to high=5)
- Uniqueness of product and production process (in Figure 3.2 low=1 to high=5)
- Local, nearshore or offshore outsourcing (in Figure 3.2 local=1, nearshore=3 and offshore=5)

Production transfer

- Supplier capability and absorptive capacity (in Figure 3.3 low=1 to high=5)
- Pace of the transfer (in Figure 3.3 fast (clear cut)=5 to slow (parallel production)=1)
- Size of the transfer (in Figure 3.3 small=1 to large=5)
- Tacit knowledge (in Figure 3.3 predominant=4 or not predominant=2)
- Explicit knowledge (in Figure 3.3 predominant=4 or not predominant=2)
- Need for adaptation of the production process or product to the new context (in Figure 3.3 low=1 to high=5)
- Technology complexity (in Figure 3.3 low=1 to high=5)
- Source of incoming materials (in Figure 3.3 new=5 or remaining=1)

Table 3.4: Characteristics of the studied outsourcing projects

	Cases/companies							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Industry	Mobile applications for vehicles	Productivity equipment	Low voltage power products	Pumps	Electronic critical communi-cation	Power generation	Sub-supplier automotive industry	Sub-supplier automotive industry
Location of the outs. receiver	Local outsourcing in Sweden	Nearshore outsourcing to Estonia	Nearshore outsourcing to Romania	Offshore outsourcing to China	Offshore outsourcing to China	Nearshore outsourcing to Hungary	Nearshore outsourcing to Romania	Nearshore outsourcing to Lithuania
Gover-nance structure, focal company control and power	The receiving company is a known supplier over which company A has little control. Company A has some power in the supply chain. The governance structure is a relational value chain.	The receiving company is a known supplier over which company B has little control. Company B has limited power in the supply chain. The governance structure is a relational value chain.	The receiving company is a known supplier over which company C has little control. Company C has some power in the supply chain. The governance structure is relational value chain.	The receiving company is a sister company within in the same group over which company D has some control. Company D has some power in the supply chain which is seen as a relational value chain.	The receiving company is a known supplier over which company E has little control. Company E has limited power in the supply chain. The governance structure is modular value chain.	The receiving company is a sister company within the same group over which company F has little control. Company F has some power in the supply chain. The governance structure is relational value chain.	The receiving company is a sister company within in the same group over which company G has some control. Company G has some power in the supply chain which is seen as a captive value chain.	The receiving company is a known supplier over which company H has some control. Company G has some power in the supply chain which is seen as a captive value chain.
Uniqeness of product and prod. process	Machining of castings was outsourced. The production process was not unique. The products specific for the company.	Assembly of electric motors was outsourced; the production process was not unique with a high level of manual production. The products were unique.	Assembly of coils as coils. Neither the coils nor the production process were unique.	Foundry and machining of castings. The production process was not unique, though the products were specific for the company.	Assembly of base station outsourced. The production process was not unique, though the products were unique.	Machining of compressor blades was outsourced. The production process was not unique though with tight tolerances, the products were company specific.	Assembly of high tech products containing hazardous materials. The production process was not unique, though complicated by the hazardous material. The product was unique.	Stamping and assembly of metal parts was outsourced. Neither the production process nor the products were unique.

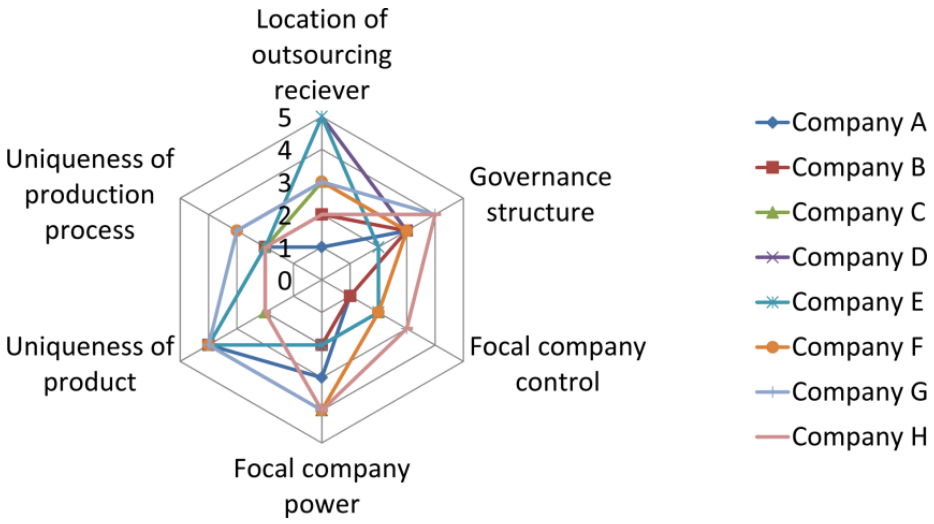

Figure 3.2: Overview of the characteristics of the studied outsourcing projects

Table 3.5: Characteristics of the production transfers within the studied outsourcing projects

	Cases/companies							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
The size and pace of the transfer	Relatively large and a clear cut transfer	Relatively large and a clear cut transfer	Relatively large and parallel production	Relatively small (only products) and parallel production	Relatively large and a clear cut transfer	Relatively large and parallel production	Relatively large and parallel production	Relatively small (only products) and parallel production
Supplier experience	Experienced with similar products	A new product to the company	Experienced with similar products	To start with a newly established supplier with limited experience	Experienced with similar products	Experienced with similar products	A newly established supplier with no experience	To start with a newly established supplier with limited experience
Tacit and explicit knowl. and complexity of prod. process	Predominant tacit knowledge and complex production process	Predominant explicit knowledge and relatively uncomplex production process	Predominant explicit knowledge and relatively uncomplex production process	Predominant tacit knowledge and complex production process	Predominant explicit knowledge and complex production process	Predominant tacit knowledge and complex production process	Predominant explicit knowledge and complex production process	Predominant explicit knowledge and relatively uncomplex production process
Adaption of prod. process and source of incoming materials to first tier suppliers	No need for adaption of production process, 2nd tier suppliers remained	Need for adaption of production process and 2nd tier suppliers remained	Need for adaption of production process and new 2nd tier suppliers	Need for adaption of production process and new 2nd tier suppliers	No need for adaption of production process, 2nd tier suppliers remained	Need for adaption of production process and 2nd tier suppliers remained	No need for adaption of production process and 2nd tier suppliers remained	Need for adaption of production process and 2nd tier suppliers remained

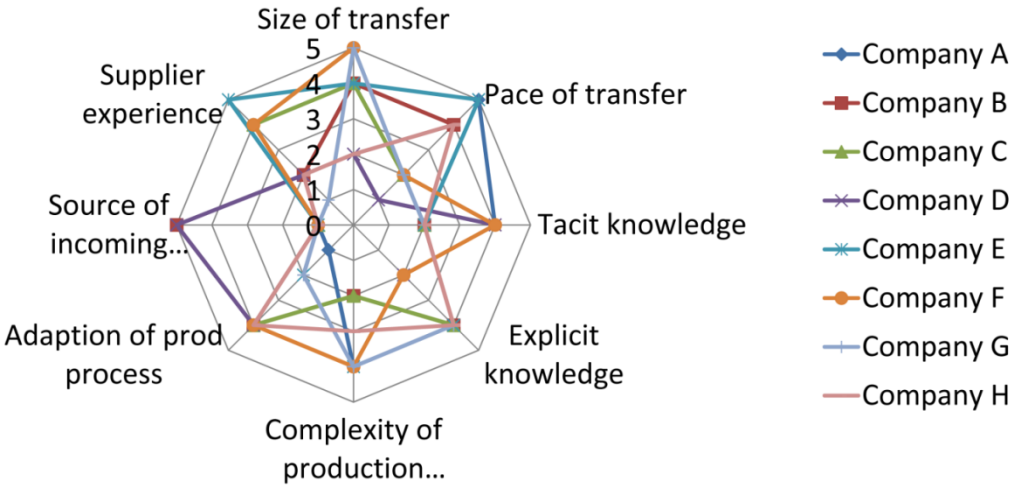

Figure 3.3: Overview of the characteristics of the production transfers within the studied outsourcing projects

To clarify the semantics used to denote studies and companies in the papers and the thesis, respectively, the following notations are made (Table 3.6). Companies A, B and C are denoted the same in Paper I. In Paper II and Paper III, Company D is referred to as "The European Manufacturer (EM)." In Paper II and Paper III, Company J is referred to as "The Chinese Manufacturer (CM)." Company E, in Paper IV, is referred to as "The Company" and Company B in Papers V and VI. Company F, G and H are called Company A, C and D in Paper V and Paper VI.

Table 3.6: Case study denotations in papers and the thesis

Study	Paper	Companies	Previously denoted in the papers
1	I	A, B, C	A, B, C
2	II	D, J	EM and CM
3	III	D, J	EM and CM
4	IV	E	The Company
5	V, VI	E, F, G and H	B, A, C and D

3.3.2 *Literature studies*

The results of each research question are answered in two parts. First, a theoretical framework is developed and thereafter the theoretical framework is applied to one or several cases depending on the study. Thereafter the frameworks are updated based on insight from the cases. Therefore, it becomes important to account for how the literature, upon which the theoretical frameworks are based, has been identified; that is what this section presents.

Through the literature studies, the author, started to build a knowledge base on the subject, by reading textbooks and theses in appropriate areas. The author has participated in PhD courses focusing on reading and discussing literature in the areas of supply chain management and production strategy, which also helped to identify relevant areas of literature. Also, searches were conducted in databases such as Emerald, Google Scholar and Science Direct to identify relevant papers. The search was

not limited to logistics, purchasing, supply chain management and operations management-related journals because the areas covered are diverse, and relevant papers were found in journals of a diverse nature. To ensure comprehensiveness of references, an ancestry approach of looking into the reference list was also performed and other papers were identified. The collected literature was discussed with other researchers at the department and at international conferences and additional literature was added.

To achieve the objective of Study 1, a general outsourcing process was derived from the literature. The general outsourcing process was based mainly on four theoretical frameworks that were identified on the basis of frequency of citation and integration of logistics. Most frameworks follow a similar structure, so the derived general outsourcing process includes common parts from frameworks in the literature reviewed with the addition of a number of more specific parts from individual frameworks. In Study 2 a theoretical framework describing the sourcing characteristics was developed. The theoretical framework was based on theory within outsourcing and sourcing decision factors, materials supply, supply chain design and production strategy.

In Study 4 a conceptual framework was developed to describe the materials planning process during production transfer and start-up and the materials planning environment during production transfer and start-up. The framework developed was used to construct the research protocol, from which the interview questions were taken. The studied literature covered production ramp-up, materials planning during product/production phase-in and phase-out situations and technology and knowledge transfer.

3.3.3 *Data collection techniques*

This section describes the data collection techniques used. Further, it describes what data have been collected in each case, summarised in Table 3.8. Finally, the simulation study, Study 3, is presented.

There are two main groups of data collection techniques (Arbnor and Bjerke, 1994)—the use of already collected data (secondary data) and new data (primary data). According to Arbnor and Bjerke (1994) new data can be collected in three ways: observations, interviews and experiments. Case studies usually combine several data collection techniques such as archival documents, interviews, questionnaires, and observations (Eisenhardt, 1989). In the research presented in this thesis, interviews, documents, and observations have been used as data collection techniques in all five studies.

Table 3.7 summarizes the data collection made in each study.

Table 3.7: Summary of the data collection within the companies studied

Study	**Study 1**			**Study 2**	**Study 5**			
					Study 4			
Company	**A**	**B***	**C***	**D**	**E**	**F**	**G**	**H**
No. of visits	3	7	3	8	4	4	4	2
No. of interviews	4	8	4	10	7	8	6	4
Interviewees' positions within the company	Sourcing manager, strategic purchaser, quality responsible	Plant manager, production manager, purchasing manager, outsourcing team leader, production leader, technician, assembler	Production development manager, design engineer and cost accountant, purchasing manager	Purchasing manager, logistics, inventory management production planning, production technology	Outsourcing project leader, plant manager and supply chain manger, logistics manager, purchaser, production planner	Purchasing manager, outsourcing project leader, project leader part project, purchasers, operative purchasers, material coordinator	Purchasing manager, logistics manager, quality manager Romania, plant manager Romania production technology, product developer	Plant manager, purchaser, outsourcing project leader, logistics coordinator
Supplier interviewed		X		X#			X	
Examples of documents taken part of	Outsourcing process descriptions and supplier evaluations	Outsourcing process descriptions and supplier evaluations	Outsourcing process descriptions and supplier evaluations	Order statistics, internal costs and quality levels	Project plans, cost calculations, progress descriptions	Project plans, project evaluations	Internal outsourcing process, cost calculations	Production instructions and cost calculation

***** The empirical data were collected by the author of the thesis with assistance from four authors of related projects (Arumeel and Bergman, 2006; Jiménez and Tsukrejeva, 2006).
Company J in China was visited once and included tours of the production facilities to get a view of the production but also to better understand the supply chain. A follow up interview with the CEO of Company J was conducted during a meeting in Europe. The Chinese supplier was visited only by the second author of Paper II. The quantitative data regarding the Chinese part were estimated by a responsible manager and validated by the European CEO of the Chinese intermediary.

Interviews

In order to find the right information it is important to prepare the interviews and to interview the right people. There are many ways in which an interview can be conducted. Interviews can be unstructured, focused with more structure or highly structured resembling a questionnaire (Voss et al., 2002). When conducting interviews, a research protocol or a guideline including themes or questions to be asked should be used as a starting point for the interviews (Halvorsen, 1992). A research protocol or a guideline should also be used as a follow-up to check that all areas of interest have been brought up for discussion during the interview (Eisenhardt, 1989; Voss et al., 2002).

Semi-structured interviews were used as the main data collection technique in the studies and a guideline including what themes the interview should include was used during the interviews. It was not uncommon to find differing and incomplete views in the interview answers. In such cases it is important to revisit the issue and seek other sources of data to clarify the information (Voss et al., 2002). One way to deal with this is to conduct the interviews over a period of time (Voss et al., 2002). In the cases included, the companies were visited several times for interviews and more than one person was interviewed (see Table 3.7). Notes were taken during all the interviews and transcribed to an electronic document as soon as possible after returning from the visit

at the company. The interviews were not recorded because of the delicate nature of the outsourcing subject. To have recorded the interviews would have hampered the answers and discussions.

Observations
Passive data is what the researcher set out to find, whereas active data is associated with discovery (Dubois and Gadde, 2002). Typically, observations lead to the findings of active data (Dubois and Gadde, 2002). Observations were done by visiting the Swedish production sites of the companies studied and the relevant products and production processes were demonstrated. Furthermore, in Company E it was possible to participate in phone meetings with the supplier and in Companies E, F, G and H it was possible to study the materials planners at work. In Companies B and D the supplier was also visited.

Documents
For case studies, documents are used to corroborate and augment evidence from other sources (Yin, 2002). Documents used in the studies were internal process descriptions, calculations preceding decisions, supplier evaluations and ERP records.

Simulation
Study 3 was a simulation study where the simulation model was based on the case study in Study 2. The aim of Study 3 was to test two strategies of combining in-house production and outsourced production. The strategies were compared based on their effects on inventory levels. The simulation study follows the methodology proposed by Banks et al. (2001), including the following steps: problem formulation, setting of objectives and overall project plan, model conceptualisation, data collection, model translation, model verification, model validation, experimental design, runs and analysis, and documentation and reporting.

The conceptualisation of the simulation model was translated into a computerized model using the simulation software Simul8 (2002). To ensure that the results from the simulation study were accurate, the simulation model needs to be verified and validated (Banks et al., 2001). There are several techniques that could be used in the process of verifying a simulation model. Banks et al. (2001) proposes a list that includes eight techniques from which two have been used in this study: 1) the computerized representation (the Simul8 model) was checked by one of the authors of Paper III, who was not its developer, and 2) an extensive analysis of the reasonability of the model output under varying input conditions. In some cases, input data models used in the simulation model were not based solely on empirical data from the real system but also on estimations. However, when an estimate was made it was always based partially on empirical data and in all cases the estimate was discussed with personnel at the case companies and adjusted when necessary. To some extent, these subjective estimations diminish the validity of the model.

The two strategies were simulated for a running time of 1,000,000 minutes, equal to approximately two years, and each was replicated 20 times. To reduce the problem of initialization and bias, two different techniques were used: 1) so-called intelligent initialization (by initiation of inventory levels), and 2) use of a warm-up period set to 1,000,000 minutes (i.e., warm-up period equals running time of the model when no results are logged). The warm-up period was established by viewing the inventory

levels for each item of the inventory in China and assembly inventory in Europe. When the inventory levels stabilised, the warm-up period ended.

3.4 Reliability and validity

This section examines the reliability and validity of the studies included in this thesis based on Yin's (2002) tactics (see Table 3.8) in order to evaluate the quality of the studies.

Table 3.8: Reliability and validity in case research (Yin, 2002)

Tests	Case study tactic	Phase of the research in which tactic occurs
Construct validity	Use multiple sources of evidence Establish chain of evidence Have key informants review draft case study report	Data collection Data collection Composition
Internal validity	Do pattern-matching Do explanation building Do time-series analysis Use logic models	Data analysis Data analysis Data analysis Data analysis
External validity	Use theory in single-case studies Use replication logic in multiple-case studies	Research design Research design
Reliability	Use case study protocol Develop case study database	Data collection Data collection

3.4.1 *Construct validity*

Construct validity is used to establish the correct operational measures for the concepts studied (Yin, 2002; Voss et al., 2002). According to Yin (2002), there are three tactics for increasing the construct validity: using multiple sources of evidence, establishing a chain of evidence and having key informants review draft case study reports. These three tactics were used in the studies of this thesis. Triangulation through the use of multiple sources of data and multiple data collection methods can strengthen the validity of the research (Voss et al., 2002). In all studies, triangulation through multiple sources were used, both by interviewing more than one person and also by collecting documents and company records to support the information from the interviews (Table 3.7). Respondents may not have had the chance to answer all questions or may have failed to be objective regarding questions about their work. These effects were minimised by asking several respondents the same questions. The interviews also took place during different visits; therefore it was possible, based on the insights of earlier interviews, to increase the understanding of what questions to ask and to determine whether other respondents should be included in the interviews. Further, in several cases have the interviewees invited other persons, more suitable to answer the questions, when necessary. Only in two of the cases studied, have the supplier been visited. However, several of the interviewees within the companies had spent a lot of time at the supplier during the outsourcing project and should therefore have a good picture of how things were at the supplier. The data is analysed only from the perspective of the focal companies as focus have been on the focal company material supply. The effect of this is that it is not possible to make any statements about how the outsourcing has affected other parts of the supply chain such as the first tier suppliers.

A further problem that has had to be dealt with is when the outsourcing process start and ends. This is a sampling problem, because the researcher has to make a choice of how far back in time he/she wants to trace the process in question (Dubois and Gadde, 2002). The start of the outsourcing process is when the question of whether or not to outsource is brought up and by asking the interviewees this question have the start of the outsourcing process been identified. The end of the outsourcing process has here been identified based on Momme and Hvolby (2002) end of process as the determination of the outsourcing contract. Though, as the focus of the thesis has not been the process in itself, but instead how to ensure materials supply during the process, the main aspect to catch in the data collection is not the exact length of the process. Instead what has been important to catch is the relationship between outsourcing and materials supply and how the organisation studied have acted to ensure materials supply in the context of outsourcing.

Notes were taken during the interviews instead of recording them; this could decrease the validity of the results because it increases the risk of misinterpretation. However, all case descriptions were sent back for review by the key informants. In the pre-study, workshops were used to connect the results from the interviews. In Study 1, flowcharts were created based on the interviews and then reviewed by the interviewees. The flowcharts represent a chain of evidence for the outsourcing processes. In Study 2, Study 4 and Study 5, the case study description, following the timeline of the development of the situation studied, was sent to respondents for review and the comments were used to update the descriptions.

3.4.2 *Internal validity*

Internal validity is used to establish a casual relationship, whereby certain conditions are shown to lead to other conditions (Yin, 2002). According to Yin (2002), internal validity is only a concern in explanatory studies, which means that it applies only to Study 3 where a simulation was used.

The validity of simulation models can be controlled by face validation, sensitivity analysis, validation of model assumptions, and validating input-output transformations (Banks et al., 2001). The most forcible and most desirable of these techniques is validating input-output transformations. Unfortunately, in this study there was no data available (company records) to perform that type of validation. Therefore, this study was reduced to validating the face validity and assumptions of the model.

The face validation was conducted by introducing the model to different people in the company with deep insight in the system studied. As these people were confronted with different sets of model inputs and coupled outputs, their responses were used to adjust and calibrate the model. The validation of the model assumptions concerns the structural and data assumptions. The validation of the structural assumptions was addressed in a face validation manner by confronting, discussing and adjusting the model structure with people in the company. To ensure the validity of the data assumptions, all input models were developed using the statistical software Stat:Fit (2001) and were based on data collected from the real system. For some parts of the model, it was not possible to obtain or collect extensive and accurate data because of the wide extent of the system studied, making it impossible for the authors to collect specific and desired data by observation in the real system, e.g., production lead times and transportation times in China and between China and Europe.

3.4.3 *External validity*

A study has high external validity if the results can be generalised outside the specific context of the study (Bryman, 2002). Yin (2002) distinguishes between two types of generalisation, "analytical generalisation" and "statistical generalisation". Case studies rely on analytical generalisation and survey research relies on statistical generalisation. According to Yin (2002), analytical generalisation is when the investigator is striving to generalise a particular set of results to a broader theory. To achieve external validity, theory in single case studies and replication logic in multiple case studies can be used (Yin, 2002).

In both single case studies conducted, Study 2 and Study 4, were a theoretical framework first developed and thereafter applied to the cases, thereby external validity was improved. In the two multiple case studies, Study 1 and Study 5, the replication logic was used to achieve external validity. Further, the first part of the research was carried out within the PROLOG project, including eight Swedish production companies. The results were presented at workshops held every quarter during 2006 and 2007, with company representatives and researchers present. The second part of the research was carried out in five companies and the results were presented to the companies at an internal workshop. Furthermore, previous versions of all the appended papers have been presented at Swedish or international academic conferences. The results have thereby been discussed at different forums with several different companies and researchers present.

The general outsourcing process developed in Study 1, including logistics, was to a large extent derived from well-established outsourcing decision frameworks as well as theories of logistics. The sourcing characteristics framework, developed in Study 2, was developed by combining several existing literature streams of logistics and materials supply in international supply chains. When developing the frameworks describing the materials planning process in the production transfer and start-up situation and the materials planning environment during production transfer and start-up in Study 4, concordant concepts were borrowed from related research areas such as materials planning in the engineering change situation, production ramp-up in product development and technology and knowledge transfer. All the processes and frameworks developed have been used in case studies with good results. Consequently, the processes and frameworks developed are possible to use in companies with similar contexts, but there is no reason that they are not applicable to other companies and industries as well. Further discussion of the generalisations of the findings is presented in Section 5.5.

3.4.4 *Reliability*

Reliability means the accuracy and certainty of the measurement and the measuring instrument (Halvorsen, 1992). The underlying issue is whether the process of the study is consistent and reasonably stable over time and across researchers and methods (Miles and Huberman, 1994). According to Yin (2002), reliability is concerned with the question of whether the study is carried out in such a way that the data collection can be replicated. To achieve reliability, it is necessary to document the procedures followed and to use case study protocol and a case study database as tactics to accomplish this.

The data collection in this thesis was well documented. Notes were taken during the interviews and observations. After the interviews and observations, the notes were compiled in documents labelled with dates, and respondents' names and companies. The first outline of a case study was written based on the interviews conducted and the documents collected. Since the interviewees were asked questions about their work, it is likely that they would give the same answers in a similar study. However, all cases are unique. The companies will never be in the exact situation again; therefore, the situation with the cases will not be able to be re-created. Due to time limits it has not been possible to only study ongoing cases, as the outsourcing process can go on for several years, and some cases studied were historical cases. When studying historical cases it can be a problem with finding the right interviewees, because these can have moved on to other positions and is no longer available. Further, as time goes by the human memory has a tendency to decrease the level of detail about what happened and what actions were taken. To decrease the impact of these two problems, the cases have been carefully selected based on available sources present within the companies and several data collection methods have been used to support the interview statements.

4 Results

This chapter presents the results and findings from the studies included in this thesis. The results and findings are also presented in the appended papers, but here the contributions of the appended papers are linked to the research questions put forward in Chapter 2.

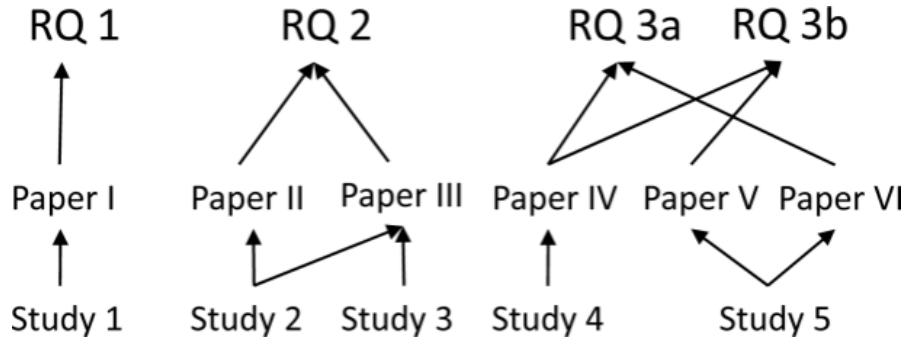

Figure 4.1: Link between the research questions, appended papers and studies.

Figure 4.1 shows the relationship between the studies, the research questions and the appended papers. Research Question 1 is used to draw the boundaries for the other two research questions and is thereby more widespread, whereas Research Questions 2 and 3 go into detail about the outsourcing process where actual materials supply takes place. To be able to handle the more detailed questions related to materials supply in depth it is necessary to combine two papers when answering Research Question 2 and three papers when answering Research Question 3, while Research Question 1 is dealt with by one paper alone.

The chapter is organised by answering each of the research questions in two steps. The first step develops a process or framework based on literature. Therefore, the first step presents the theoretical process or framework developed in the papers. The second step presents the application of the process or framework to the studies done in the papers. The sequence in the chapter corresponds to the research questions.

4.1 Research Question 1 - Integrating logistics in the outsourcing process

Research Question 1 focuses on the whole outsourcing process and is addressed by the study included in Paper I. It is answered by relating logistics categories to the phases of a derived general outsourcing process. Then, the general outsourcing process developed is applied to three cases at companies A, B and C in order to compare the derived process with how the companies worked in the cases.

Research Question 1: How can logistics be integrated into the outsourcing process?

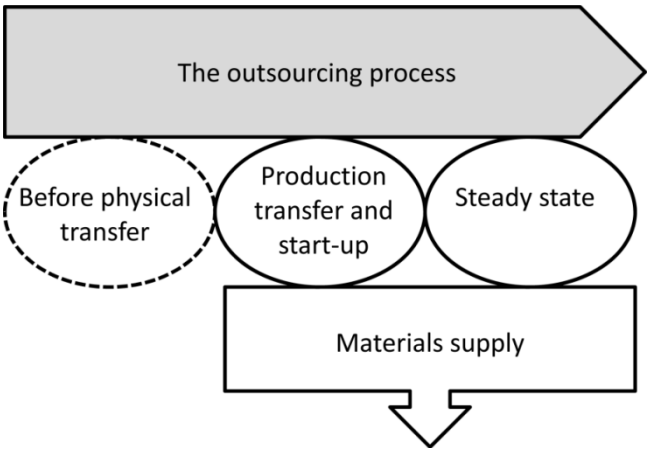

Figure 4.2: Research Question 1 focuses on the whole outsourcing process (marked in grey).

4.1.1 *Integrating logistics in an outsourcing process*

First, the derived general outsourcing process is introduced, and thereafter the logistics categories and finally the logistics categories are related to the derived general outsourcing process.

The derived general outsourcing process was based on four theoretical outsourcing frameworks: Momme and Hvolby (2002), McIvor (2000), Franceschini et al. (2003) and Zeng (2003), that were identified on the basis of frequency of citation, inclusion of logistics and focus on outsourcing of production. The frameworks were introduced in Section 2.4. To obtain the derived general outsourcing process, with seven phases, Momme and Hvolby's (2002) framework was used as a base with the addition of parts of the other frameworks. Momme and Hvolby's (2002) framework was selected as the base because of its focus on outsourcing decisions within the setting of production systems as well as relevant support functions. The derived general outsourcing process and the frameworks from which it is derived are presented in Table 4.1. The four frameworks from which the derived general outsourcing process is derived use different wordings for the same phenomenon. Therefore, the wording of the phases and activities of the derived general outsourcing process have been adjusted for greater consistency. The first three phases of the derived general outsourcing process mainly focus on what to outsource and who to outsource to, while the last four phases focus on how to outsource, how to manage the relationship and how to terminate the outsourcing contract. The final phase, "Contract termination", has been included in the derived general outsourcing process but falls outside the scope of this thesis and will not be further discussed. If during the process it is concluded that outsourcing is not a viable option or that in-house is a better option, the outsourcing process can of course be ended.

Table 4.1: The derived general outsourcing process and the contributing frameworks

Momme and Hvolby (2002)	**Zeng (2003)**	**McIvor (2000)**	**Franceschini et al. (2003)**	**The derived general outsourcing process**
1) Competence analysis a. Strategic analysis b. SWOT analysis c. Core/Non-core competence mapping	1) Investigation and tendering a. Core activities b. Analysis of company, customer and competitor c. Sourcing strategy	1) Define the core activities of the business	1) Internal benchmarking analysis a. Core competencies evaluation b. Identification of processes to be outsourced c. Possible types of relationships identified d. Activities stratification	1) Competence analysis and internal benchmarking a. Strategic analysis b. SWOT analysis c. Define core activities d. Identify possible types of relationships with supplier e. Activities stratification based on evaluation of the relationship between production activities or products involved in the outsourcing process
2) Assessment and approval a. Defining critical assessment criteria b. Detailed audit at supplier premises c. Supplier and in-house performance comparison	2) Evaluation a. Selection criteria b. Pre-screening c. Estimate economic and operating benefits	2) Evaluate relevant value chain activities	2) External benchmarking analysis a. Supplier evaluation	2) Supplier assessment, external benchmarking and approval a. Define critical assessment and supplier selection criteria b. Pre-screening c. Supplier assessment
		3) Total cost analysis of core activities a. Cost estimation of carrying out the activity internally b. Cost estimation associated with potential suppliers		3) Total cost analysis a. Cost estimation of carrying out the activity internally b. Cost estimation associated with potential suppliers
3) Contract negotiation a. Defining legal/commercial terms and conditions b. Negotiating base-line scope of delivery and contract period c. Determining mutual commitments	3) Supplier selection and development a. Negotiation b. Technical assessment c. Savings identification d. Implementation schedule	4) Relationship analysis	3) Contract negotiation a. Service level agreement b. Temporal evolution	4) Contract negotiation a. Defining legal/commercial terms and conditions b. Agreement on supply and logistics terms c. Determining mutual commitments
4) Project execution and transfer a. Establish basis for supplier integration b. Defining workflow interfaces c. Adapting organisation to supplier performance	4) Implementation a. Team, strategy and schedule b. Agreement on supply and logistics terms c. Measurement of actual performance d. Progress report			5) Project execution and transfer a. Establish team, strategy and schedule b. Establish basis for supplier integration c. Adapt organisation to supplier performance
5) Managing relationship a. Establish communication, information and monitoring systems b. Joint development projects c. Continuous performance assessment	5) Performance measurement and continuous improvements a. Monitor supplier's performance b. Relationship analysis c. Continuous improvement opportunities d. Maintain dynamic and flexible procurement process		4) Outsourcing management	6) Managing relationship a. Establish communication, information and monitoring systems b. Continuous improvement opportunities to be identified c. Continuous performance assessment
6) Contract termination a. Assessing alternatives of prolonging relationship, replacing supplier or insourcing b. Establishing basis for reviewing core competence strategy				7) Contract termination a. Assessing alternatives of prolonging relationship, replacing supplier or insourcing b. Establishing basis for reviewing core competence strategy

Logistics areas relevant to consider when making outsourcing decisions are identified based on how supply chains are affected by outsourcing, and are categorised into four categories. The categories are then exemplified. Outsourcing changes the configuration of supply chains and can increase both the number of organisations in the supply chain and the number of sites per organisation, and the configuration influences the coordination of supply chains (Rudberg and Olhager, 2003). Logistics works as the coordinator of the supply chains and the logistics setup and supply chain structure changes when the supply chain configuration changes. Therefore, a new supply chain configuration implies a need to redesign the supply chain structure for the outsourcing company. A changed configuration and new supply chain structure mean new ways of coordinating the supply chain. New ways of coordinating imply that customer service has to be re-established to achieve efficient and effective flows of goods and information in the redesigned supply chain. An altered supply chain structure and customer service will affect logistics costs. Therefore, it is important to include supply chain structure, customer service and logistics costs in outsourcing decisions. To follow up and make sure that expected customer service is given and to keep track of logistics costs the supply and logistics terms for coordination of the flows in the supply chain need to be included in the outsourcing processes and agreed upon during negotiations with the supplier. The logistics areas important to consider during the outsourcing process are thus categorised into four categories: supply chain structure, customer service, logistics costs, and supply and logistics terms.

The first category, supply chain structure, includes logistics related to how the supply chain is designed and structured on an overall and conceptual level. Areas of logistics discussed in outsourcing literature related to this group include firm infrastructure (McIvor, 2000), modes of transport, nature of the supply process, proximity to the parent company's facilities (MacCarthy and Atthirawong, 2003), number and location of production facilities, capacity at each facility, how the production can be supplied with components, and which market region to supply (Meixell and Gargeya, 2005; Kotabe and Murray, 2004).

The second category, customer service, includes delivery (Cánez et al., 2000), production lead time at the supplier and transportation time (Zeng, 2003), responsiveness of suppliers, and responsiveness and delivery time to markets (MacCarthy and Atthirawong, 2003). Some researchers only refer to customer service as such when describing consequences of outsourcing (e.g. Meixell and Gargeya, 2005; Lowson, 2003).

The third category is logistics costs. Zeng (2003) identified the following logistics costs to be affected by outsourcing: transportation, inventory holding, administration, customs, risk and damage, and handling and packaging. Ellram and Maltz (1995) include costs linked to logistics—delivery, service and communication—in the total cost of ownership.

The fourth category, supply and logistics terms, includes logistics areas that must be agreed upon by the supplier and outsourcing company to maintain a working flow of material and information during the outsourcing relationship (Zeng, 2003). For example, supply and logistics terms can include terms of deliveries and flexibility agreements.

Here it is discussed how the logistics categories fit into the different phases of the derived general outsourcing process (Table 4.2). During the first phase of the derived general outsourcing process, it is important to conduct an analysis of the current supply chain structure as well as the potential future supply chain structure if the decision will be to outsource. Such an investigation of the potential future supply chain structures supports the analysis that the activities in the first phase prescribe, i.e., strategic analysis, SWOT analysis, possible relationships with the supplier and an activity stratification analysis, as well as the analyses and evaluations during the subsequent phases. It is essential to consider the level of customer service that potential suppliers can offer during the second phase when potential suppliers are assessed, e.g., delivery time and delivery precision, in order to evaluate whether it is possible to outsource the production activity or product in question. In the third phase, it is important to take logistics costs into account in the total cost analysis. When negotiating the contract in the fourth phase, supply and logistics terms should be agreed upon in order for them to be stated clearly in the contract. Further, agreement on supply and logistics terms is already included as one of the activities in the fourth phase of the derived general outsourcing process. When performing the transfer during the fifth phase, logistics performance measures should be selected based on the drivers for outsourcing, which may include measures related to both customer service and logistics costs. It is important to measure logistics performance over the course of the entire relationship with the supplier, i.e., during Phase 5 and 6, and use this as the basis of continuous logistics improvements.

Table 4.2: The logistics categories related to the phases of the derived general outsourcing process.

The phases of the derived general outsourcing process	**Logistics categories**
1: Competence analysis and internal benchmarking	Supply chain structure
2: Supplier assessment, external benchmarking and approval	Customer service
3: Total cost analysis	Logistics costs
4: Contract negotiation	Supply and logistics terms
5: Project execution and transfer	Logistics performance measures (customer service measures and logistics costs measures)
6: Managing relationship	Logistics performance measures (customer service measures and logistics costs measures)

4.1.2 *Application of the derived general outsourcing process*

In Paper I, three cases of how companies worked when outsourcing, cases A, B and C (see Section 3.3) were mapped against the derived general outsourcing process. Each of the three cases included one project of production outsourcing. It was first analysed which of the phases in the derived general outsourcing process were included in the companies' outsourcing projects. Logistics-related problems and issues considered or experienced by the companies during the outsourcing projects were thereafter analysed in order to generate information to validate the relations between the phases of the derived general outsourcing process and the logistics categories. It was seen that the

conjunction between phases of the derived general outsourcing process and logistics categories made was coherent with how the companies worked.

Among the three companies studied, none consciously focused on logistics in their outsourcing projects. If the companies had included logistics in their outsourcing processes in a more thorough and systemised way, this could have prevented problems from arising during production transfer and start-up and steady state, because all three companies encountered logistics-related problems in Phase 5, "Project execution and transfer," and Phase 6, "Managing relationships." For example, problems related to logistics were encountered during Phase 5 by all companies as a result of information and communication difficulties. Companies B and C also experienced problems with deliveries and lead times. These problems could probably have been reduced by a structured inclusion of customer service considerations in the supplier evaluations in Phase 2, "Supplier assessment, external benchmarking and approval" and if an evaluation of the effects of future supply chain structures in Phase 1, "Competence analysis and internal benchmarking" had taken place. A structured approach to measuring logistics performance also may have facilitated the improvement work in Phase 6, "Managing relationship". The only logistics cost considered explicitly during Phase 3, "Total cost analysis", was transportation cost. However, Company A considered the cost of inventory making their final supplier decision in Phase 4 "Contract negotiation". Since price of the outsourced components was one of the final selection criteria in all supplier selections in the three cases, consideration of more logistics costs may have improved decision making. This emphasises the usefulness of having a conscious and proactive approach to logistics by companies' outsourcing.

4.2 Research Question 2 - Sourcing characteristics' effect on supply chain performance during steady state

This research question focuses on how to ensure materials supply as steady state is reached.

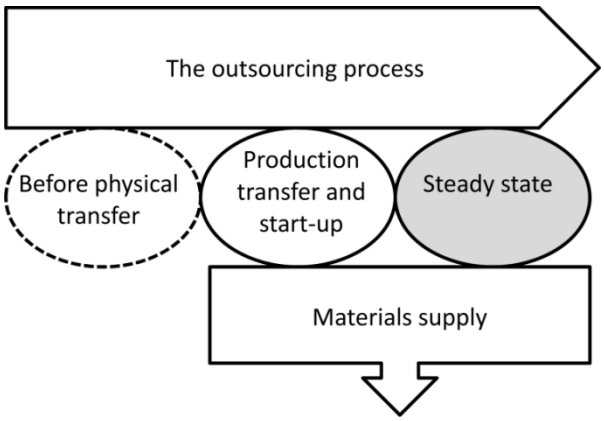

Figure 4.3: Research Question 2 focuses on steady state (marked in grey).

Research Question 2: How do supply chain structure, supply chain relationships and sourcing country characteristics affect supply chain performance?

Sourcing characteristics are used to denote the characteristics, factors, considerations, risks and criteria by which decision makers evaluate the effects of sourcing decisions. Section 2.5 demonstrated that the sourcing characteristics could be divided into three categories: supply chain structure, supply chain relationships and sourcing country characteristics. Research Question 2 is answered by Study 2 presented in Paper II and by Study 3 presented in Paper III. In Section 4.2.1 the dimensions of the sourcing characteristics categories of supply chain structure, supply chain relationships and sourcing country characteristics are detailed and the sourcing characteristics framework is presented. In Section 4.2.2, the effect on supply chain performance of the sourcing characteristics is analysed through the applications made in Papers II and III.

4.2.1 *Sourcing characteristics framework*

To develop a sourcing characteristics framework based on which the supply chain performance effects sourcing from a specific supplier can be evaluated, it is necessary to detail the sourcing characteristics categories. Because it is not possible to link supply chain structure, supply chain relationships and sourcing country characteristics directly to any consequences that can affect the supply chain performance, to do that a greater level of detail is necessary. Below, the sourcing characteristics categories of supply chain structure, supply chain relationships and sourcing country characteristics are detailed into dimensions. In Paper II are the categories denoted supply network structure, supply network relationships and sourcing country characteristics; however the denotations have here been changed for larger consistency. Table 4.3 summarises the sourcing characteristics categories and their dimensions.

Supply chain structure
Supply chains consist of suppliers, warehouses, distribution centres and so on (Simchi-Levi et al., 2003). Outsourcing and sourcing decisions affect the structure of the supply chain. Hayes and Schmenner (1978) and Skinner (1974) connect supply chain structuring to company strategy, and conclude that the structure of supply chains should be harmonised with company strategy and the company strategy with the supply chain structure. According to Harrison and Van Hoek (2002), there are at least three dimensions in the structuring of international supply chains: the layering and tiering of nodes and links, the role of plants (nodes) and the reconfiguration process of the supply chain. The supply chain structure dimensions are presented below.

Layering and tiering
Layering and tiering is the layout of information flows and the different coordination options of the physical operations, links, and localisation of nodes (Harrison and van Hoek, 2002). The localisation of assets affects the geographic distances between nodes, the length of the links, and the available means of transportation.

The roles of plants
For successful management of supply chains it is necessary to assess the strategic roles of factories in the supply chain (Ferdows, 1997). Different plants have different roles in a supply chain. Ferdows (1997) asserts that plant roles can be analysed using two questions: “What is the primary strategic reason for the factory’s location?” and “What is the scope of its current activities?” Plant roles are not definite and superior manufacturers gain competitive advantage by upgrading the strategic role of their plants (Ferdows, 1997).

The reconfiguration process of the supply chain
The reconfiguration process of the supply chain is how required changes of the supply chain setup are planned and managed (Harrison and van Hoek, 2002). Outsourcing of production leaves two options for structuring the supply chain, either complete outsourcing of an item or process or combining external sourcing and in-house production (Nordigården, 2007). The deciding strategy for how and whether to combine external sourcing and in-house production includes the selection of what items to source, as well as where and in what volumes.

Supply chain relationships
Supply chain relationships are here divided into two dimensions, business relationships and operative dependencies and transaction costs. Relationships between units in a supply chain cover both the organisational contact between the units and the physical transaction of products. The organisational contact includes the involvement between the companies doing business, while the physical transaction covers how the exchange of goods should be organised (e.g. van Weele, 2005). The supply chain relationship dimensions are described below.

Business relationships
Several studies have emphasised the importance of inter-organisational process integration based on strong cooperation, trust and commitment (e.g. Gadde and Håkansson, 2001), knowledge transfer, innovation capability, and simplification or elimination of activities (e.g. Rodriguez-Diaz and Espino-Rodriguez, 2006). It takes time to build trust in a business relationship with a foreign company and there is a need to meet socially before talking business, which means negotiations take longer (Song et al., 2007; Handfield and McCormack, 2005).

Operative dependencies and transaction costs
The transition to external suppliers may cause administrative and material transactions to become more complex and extensive. There are also operative dependency relationships between activities and material flows in the procuring company, and corresponding activities and material flows in the supplier's organisations. Availability of complete, reliable and timely planning information in the supply chain is identified as important for successful global sourcing (Trent and Monczka, 2003) and should be especially important when there are strong operative dependencies and there is customer-order-driven production.

Sourcing country characteristics
Every country can be described by a set of characteristics. Prasad and Sounderpandian (2003) divide sourcing country characteristics into endowment factors such as infrastructure and access to skilled labour, cultural factors, arbitrage and leverage, and government incentives and regulations. Graf and Mudambi (2005) make another, although similar, division of sourcing country characteristics into infrastructure, country risks, government policy and human capital. Arbitrage and leverage describe comparative advantages between countries while country risks describe risk factors for a country compared to another country. Comparing countries is not the purpose of the sourcing country characteristics presented here and therefore this is not included. Sourcing country characteristics on the basis of this discussion are divided into four dimensions: infrastructure, culture, human capital, and policies and regulations. The sourcing country characteristics are described below.

Infrastructure
The infrastructure in low-cost countries, is nowhere near European standards in most cases; there are bottlenecks and congestion due not just to capacity constraints and equipment performance, but also depending on politics and low ability in logistics planning (Handfield and McCormack, 2005). Less reliable communication infrastructure and more time-consuming transports increase lead times and decrease delivery dependability.

Culture
Cultural differences and language difficulties create obstacles to effective communication (Handfield and McCormack, 2005; Levy, 1995). Cultural differences can also result in innovation barriers and different understandings of tolerances and specifications of products (Nellore et al., 2001; Smith, 1999).

Human capital
Lack of skilled labour may have a negative impact on outsourcing (Graf and Mudambi, 2005). It takes time and can be costly to train the suppliers in producing the companies' products. Also, their inexperience makes it less likely that the parts meet specifications, which affects the cost of product quality (Markides and Berg, 1988).

Policies and regulations
In some countries, intellectual property rights protection and legal systems are less mature (Song et al., 2007). Also, there are cultural differences in the interpretation of contracts and how they should be used in society and in legal proceedings (Schniederjans and Zuckweiler, 2004; Handfield and McCormack, 2005).

Table 4.3: The sourcing characteristics framework

Category of sourcing characteristics	**Sourcing characteristics dimension**
Supply chain structures	Layering and tiering Plant roles The reconfiguration process of the supply chain
Supply chain relationships	Business relationship Operative dependencies and transaction costs
Sourcing country characteristics	Infrastructure Culture Human capital Policies and regulations

4.2.2 *The effect of the sourcing characteristics on supply chain performance*

In section 2.3 it was said that the supply chain performance measures used in this thesis will cover issues within reliability, time, cost, flexibility and quality. In Research Question 2 supply chain performance is analysed through tied-up capital, product quality, customer service and delivery flexibility. The analysis in Paper II and Paper III is based on the same case study of Company D, which has outsourced part of its casting processes to Chinese suppliers. The supply chain is made up of Company J in China, which supplies Company D with castings produced by the Chinese suppliers (see Section 3.3).

The analysis in Paper II showed how the sourcing characteristics dimensions alone and in combination could create negative effects for a European company sourcing from China (lower flexibility, higher cost of tied-up capital, lower product quality and lower customer service) (see Table 4.4). For example, the long lead times in China and the shipping time to Europe of seven weeks, depending on the layering and tiering of the supply chain, increased the planning horizon for Company D and made it necessary to base Chinese purchase orders on forecasts. Further, to ensure product quality and to ensure or reduce lead times to Company D from China, i.e., to increase overall delivery dependability, it has been necessary for Company J to take the plant role as an intermediary and handle quality control and communication, and to hold inventories. In addition, there have been a number of culture-related problems between Company J and Company D resulting from language difficulties and differences in thinking, especially between departments of the two companies that do not regularly meet. As a result of lack of a common mindset, both sides consider the quality of communicated information to be low, leading to extra administration and having a negative effect on the planning processes.

Table 4.4: Summary of consequences and performance effects per sourcing characteristics dimension seen in the study of the supply chain from the Chinese suppliers via Company J to Company D

Sourcing characteristics dimension	Consequences	Performance effects
Layering and tiering	• Long distance Company D and Company J • Transport by sea • Long planning horizon • Long ramp-up times • Inventory and quality control both at Company D and Company J • Several suppliers in China	Increased cost of tied up capital Decreased flexibility Decreased product quality
Plant role	• Company J acts as intermediary between Chinese suppliers and Company D • Company D needs Company J to use Chinese supply • Company J would like to be more independent of Company D	Increased customer service for EM Increased product quality EM Decreased flexibility for CM Increased cost for tied up capital Decreased customer service for CM's other customers
Business relationship	• Communication misunderstandings • Lack of knowledge transfer • Lack of cooperation • Low levels of trust	Decreased product quality Decreased customer service Increased cost of tied up capital
Operative dependencies and transaction costs	• Long time from order to delivery • Unreliable Chinese suppliers • Company J delivers to Company D from inventory • Company J needs to quality check all items	Decreased flexibility Decreased customer service Increased cost of tied up capital
Culture	• High employee turnover at Company J • Differences in thinking • Low quality of information exchange	Decreased product quality Decreased flexibility
Human capital	• Hard to find skilled personnel in China • Hard to find suppliers with supply chain management knowledge	Decreased product quality Increased cost of tied up capital
Policies and regulations	• Hard to make Chinese suppliers keep their promises and take responsibility	Decreased customer service Decreased product quality Increased cost of tied up capital
Infrastructure	• No significant effect	

To reduce the negative effects of low-cost sourcing seen in Study 2, it was necessary to take a holistic view of the sourcing characteristics dimensions; it was not sufficient to improve one of the dimensions in isolation since they are interconnected. For example,

Company D was dependent on supply from China. However, the Chinese suppliers were not reliable enough, which affected Company J's plant role. Thus, it is proposed that layering and tiering affect the operative dependencies, the operative dependencies affect the plant role and the plant role affects the layering and tiering. It was also observed that the business relationship between both Company J and the Chinese suppliers and Company J and Company D led to low customer service and product quality problems. To handle this it was necessary to use Company J as an intermediary, shortening the distances (in time, culture and communication) between the Chinese suppliers and Company D. Thus, it is proposed that the business relationship affects the plant role and the operative dependencies and transaction costs. Further, in Paper II it was seen that the culture and human capital together affected how information was interpreted and exchanged. To make the cooperation and communication work it was necessary for Company J to take the role of an intermediary between the Chinese suppliers and Company D. Therefore it is proposed that the sourcing country characteristics of culture and human capital affect policies and regulations, business relationships and the plant role.

In Paper II, a two-directional cause and effect relationship between the sourcing characteristics dimensions and the supply chain performance effects was identified. The sourcing characteristics not only affect supply chain performance but they are also affected by supply chain performance, and especially by product quality and cost of tied-up capital. It was identified that layering and tiering, operative dependencies, business relationships and plant roles were affected by the product quality of the Chinese suppliers. Therefore, improving product quality from the Chinese suppliers would increase the possibility of improving the layering and tiering of the supply chain structure and the relationships. The analysis could identify an interconnection between the types of supply chain performance effects of sourcing. In order to manage product quality problems, low flexibility, and long lead times and to improve customer service it was necessary to have high inventory levels in the supply chain.

Paper III studied the reconfiguration process of the supply chain (part of the supply chain structure category). A simulation study was used to test two ways of combining in-house manufacturing and global low-cost supply. The first way was close to how Company D managed the combination, i.e., to source a percentage of the total needed casting volumes from China and to let the choice of what items and what volumes be distributed randomly. The second way was to use a sourcing strategy of sourcing volumes with predictable and stable demand in China and volumes with uncertain demand in-house in Europe, i.e., a so called base-surge strategy. The result variable was inventory levels in China, and work in process (WIP) and inventory in Europe, which all relate to tied-up capital in the supply chain performance measure. The simulation study showed that it is advantageous to have a sourcing strategy of how to utilise the combination of in-house manufacturing and global low-cost supply (see Table 4.5). The study showed at significance level $p<0.01$ that inventory levels in China decreased 23 percent and inventory levels in Europe decreased 6 percent when sourcing predictable and stable demand in China and uncertain demand in-house in Europe. At Company J, the decrease in inventory levels with predictable and stable demand is expected based on conceptual papers presented by authors such as Christopher and Towill (2001), since lowered supply chain uncertainty decreases safety stock levels. Decreased inventory at Company D depends on the decrease in volume and product mix uncertainty, making lead time uncertainty from China the only uncertainty. This result is interesting, since it

shows that inventories decrease by having a sourcing strategy. Decreased inventories also decrease the risk of obsolescence. Sourcing items or parts of items with predictable and stable demand in China would mean lowered cost of tied-up capital, lowered cost for obsolescence, and improved customer service for the case company. Paper III demonstrates that strategies used by industries such as the fashion industry for allocating goods in the supply chain by combining in-house manufacturing and global low-cost supply chains by separating predictable and stable demand (Ferdows et al., 2004) also apply to other industries and can improve supply chain performance.

4.3 Research Question 3 - The materials planning environment and the materials planning process during production transfer and start-up

This research question focuses on how to ensure materials supply during production transfer and start-up, see Figure 4.4.

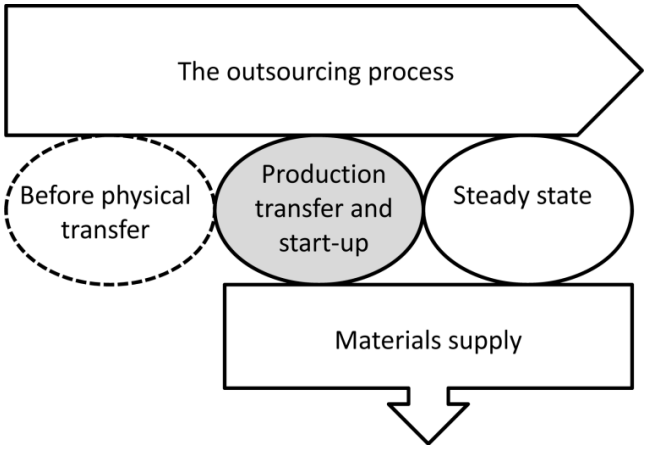

Figure 4.4: Research Question 3 focuses on production transfer and start-up (marked in grey).

Research Question 3a: How do the production transfer and start-up affect the materials planning environment supply chain uncertainty?

Research Question 3b: How does the choice and application of the materials planning process affect supply chain performance during production transfer and start-up?

Research Question 3a was addressed by Study 4 and Study 5 included in Papers IV and VI and Research Question 3b was addressed by Study 4 and Study 5 included in Papers IV and V. First, Research Question 3a is answered in sections 4.3.1 and 4.3.2. In Section 4.3.1 is a framework describing the materials planning environment during production transfer and start-up presented and in Section 4.3.2 this framework is applied to the cases included in Study 4 and Study 5. Second, Research Question 3b is answered in sections 4.3.3 and 4.3.4. In Section 4.3.3 a theoretical framework describing the materials planning process during production transfer and start-up is presented and in Section 4.3.3 the framework is applied to the cases included in Study 4 and Study 5.

4.3.1 *The materials planning environment during production transfer and start-up*

The materials planning environment describes the current circumstances, i.e., the reality, within which the materials planning process has to be carried out (Olhager and Wikner, 2000). Thereby the materials planning environment constitutes the prerequisites for the materials planning process that has to be taken into consideration as decisions about what to produce and when, and when to deliver and replenish stocks are made. The applicability of different materials planning methods is dependent on the materials planning environment (Berry and Hill, 1992). In Paper IV a theoretical framework describing the materials planning environment during production transfer and start-up based on the production transfer and start-up characteristics was developed. The production transfer and start-up characteristics are made up of four cornerstones: "production process characteristics," "product characteristics," "demand characteristics" and "materials supply characteristics". Section 2.6 showed that earlier studies (Jonsson and Mattsson, 2003, Wänström and Jonsson, 2006) have described the materials planning environment in other situations based on these four cornerstones. Jonsson and Mattsson (2003) used 20 characteristics as a basis for evaluating the appropriateness of materials planning methods in different planning environments, and Wänström and Jonsson (2006) used 28 characteristics to differentiate between materials planning environments during engineering change situations. Both sets of characteristics have been used to generate the production transfer and start-up characteristics in Paper IV. However, the production transfer and start-up is separate from earlier situations studied by the technology and knowledge transfer to and start-up at a new supplier—often one located in a distant country. Therefore new characteristics were added by examining the literature on technology and knowledge transfer, production ramp-up and global supply chains.

The production process characteristics are both related to the manufacturing left behind when outsourcing as well as the start-up at the supplier. For example, during the preparations for the physical transfer, capacity and materials have to be reserved to allow the production organisation to execute the extra tasks required (Madsen, 2009; Galbraith, 1990). Further, the pace and size of the transfer affect the preparations of the transfer. Also, the extent of the adaptations made to the production process to fit the new environment gives an indication of the process robustness (Grant and Gregory, 1997a). The production process characteristics are described based on the: Preparations for the transfer, Pace of the physical transfer, Volume flexibility, Product mix flexibility, Production technology, Production process robustness, Supplier absorptive capacity, Throughput time, Batch sizes, and Number and order of operations (Table 4.5).

The product characteristics describe how the product itself affects the materials planning environment. The product itself affects the uncertainty of the start-up, determining the preparations that should be made. For example, the product tolerances are important in that the less variance in the production, the smaller the risk of quality failure (Taguchi and Clausing, 1990). It is also crucial to determine at which stage of completion the product should be brought in from the supplier, as this affects product configuration flexibility (Kumar and Wilson, 2009; Lee and Billington, 1993). The product characteristics are described based on the: BOM complexity, Product

architecture, Product lifecycle, Engineering change, Product tolerances, Number of possible product configurations, and Degree of value added at order entry (Table 4.5).

Demand characteristics describe the aspects of the customer demand pattern and behaviour that affects the materials planning environment. For example, demand uncertainty has a direct impact on tied-up capital, obsolescence and stock-out risks, as it requires safety stocks (Reidelbach, 1991; van der Vorst and Beulens, 2002). Unexpected increases in demand combined with long transport distances lead either to shortages or to the use of air freight, and lower demand than expected expands inventories (Levy, 1995; Bathnagar and Teo, 2009). The demand characteristics are described based on the: Demand uncertainty, P/D ratio, Demand type, Demand lumpiness, Changing customer behaviour, and Demand volume (Table 4.5).

The materials supply characteristics describe which factors related to the physical and information exchange in the new supply chain affect the materials planning environment. For example, the layering and tiering of the supply network (the location and number of nodes and the links between them) determines the distances and available transport modes (Levy, 1995; Klingenberg and Boksma, 2009). Knowledge transfer is also dependent on a close relationship, including trust and frequent contact, between the sender and the receiver (Szulanski, 1996; van Wijk et al., 2008). The materials supply characteristics are described based on the: Layering and tiering of the network, Transport modes, Information sharing, Supplier/buyer relationship, Sourcing country characteristics, and Second-tier suppliers (Table 4.5).

Table 4.5: Summary of the production transfer and start-up characteristics

Production process characteristics	**Product characteristics**	**Demand characteristics**	**Materials supply characteristics**
Preparations for the transfer: resources and materials needed to build-up buffers, etc.	*BOM complexity:* number of levels in the bill of material and the typical number of items on each level	*Demand uncertainty:* uncertainty in demand	*Layering and tiering of the supply chain:* location of nodes and length of links
Production process robustness: the extent of the change in the production process	*Product architecture:* the relationship to the other components of the final product	*P/D ratio:* ratio between the accumulated production lead time and the delivery lead time to the customer	*Transport modes:* available transport modes
Throughput time: typical production through-put times	*Product life cycle:* new or established product	*Demand type:* demand based on forecast, calculated requirements or customer order allocations	*Information sharing:* how information can be shared between parts of the supply chain
No. and order of operations: shop floor layout	*Engineering change:* changes made to drawings, BOM or product tolerances	*Demand lumpiness:* the number of times per year that the products are ordered	*Supplier/buyer relationship:* length of cooperation and closeness of contact
Pace of the physical transfer: stepwise or clear cut	*Product tolerances:* range of acceptable quality	*Changing customer behaviour:* customer safeguarding against reduced customer service	*Sourcing country characteristic:* human capital, culture, infrastructure and policies and regulations
Production technology: the complexity and uncertainty of the production technology used	*No. of possible product configurations:* if the product has one or several final configurations	*Demand volume:* annual volume of demand	*Second tier supplier:* ability of second-tier suppliers to respond to demands
Supplier absorptive capacity: the ability of the supplier to learn	*Interchangeability:* the possibility of using another product instead		
Batch sizes: typical production order quantity	*Degree of value added at order entry:* the extent to which the manufacture of the products is finished prior to receipt of customer order		
Volume flexibility: ability to handle the variability in demand volumes			
Product mix flexibility: ability to handle the variability between products in marketed product lines			

4.3.2 *The effect of production transfer and start-up on the materials planning environment supply chain uncertainty*

In Paper IV and Paper VI the production transfer and start-up characteristics were used to analyse the materials planning environment supply chain uncertainty of four cases, E, F, G and H (see Section 3.3). Supply chain uncertainty was seen as variations in quality, quantity and lead time. Papers IV and VI showed that the supply chain uncertainty during production transfer and start-up can be described via the production transfer and start-up characteristics. Table 4.6 summarises the relationship between the production transfer and start-up characteristics and supply chain uncertainty.

Table 4.6: The relationship between the production transfer and start-up characteristics and supply chain uncertainty identified in Paper VI.

		Supply chain uncertainty		
		Product quality uncertainty	**Quantity uncertainty**	**Time uncertainty**
Production transfer and start-up characteristics	**Production process**	Production process robustness Production technology Absorptive capacity	Preparations for the transfer Volume flexibility Pace of the physical transfer Through-put time	Product mix flexibility No. and order of operations Batch sizes
	Product	Product tolerances Product life cycle BOM complexity Engineering change		Product architecture Degree of value added at order entry Interchangeability No. of possible product configurations
	Demand		Demand volume Demand uncertainty Demand type	P/D ratio Demand lumpiness Changing customer behaviour
	Materials supply	Supplier/Buyer relationship Second tier supplier Sourcing country characteristics		Information sharing Transport mode Layering and tiering of the network

That the progress of the production transfer and start-up follows the planned progress is important for the materials planning process. The fewer the deviations from the plan, the less uncertainty for the materials planning process to deal with and the lower the costs for corrective and preventive actions. In Paper VI it was seen that product quality problems affected the time to reach steady state. In Paper VI there were production transfer and start-up characteristics present in all four cases, delaying the reach of expected product quality levels. For example, receiving supplier experience with the production technology and product tolerances impacted the time necessary to reach expected product quality levels. In cases G and H the transfer was to newly established suppliers and product quality problems beyond those related to product tolerances were experienced. The product quality problems experienced in cases G and H were also dependent on quality awareness and problem solving approaches of the supplier, whereas the product quality problems in cases E and F were related to product tolerances and un-updated drawings and instructions. Therefore, when preparing the

transfer, it is important to consider the values of the production transfer and start-up characteristics affecting product quality uncertainty such as quality awareness, the experience of the supplier, tightness of product tolerances, and production technology (see Table 4.6). If there is a combination of several production transfer and start-up characteristics with values increasing the quality uncertainty, it increases the risk of a delayed reach of steady state. The materials planning environment supply chain uncertainty during production transfer and start-up can be decreased by improving the value of the production transfer and start-up characteristics impacting product quality uncertainty.

An interrelationship between the production transfer and start-up characteristics was identified in Paper VI, making it necessary to take a holistic view of the production transfer and start-up characteristics in order to describe the supply chain uncertainty during production transfer and start-up. Cases E, F, G and H showed that the preventive actions were not enough as the suppliers ran into quality problems. Quantity uncertainty was a result of a combination between product quality problems and an inability to increase volumes produced in the different nodes of the supply chain. This was especially evident in case E, where there was a clear-cut transfer and where it was not possible to use capacity in other locations when the start-up took longer than expected, in combination with a massive demand increase. In cases F, G and H the phase out was stepwise, and capacity could be increased in the home facility or through other suppliers when needed. Depending on how the characteristics affecting the product quality uncertainty and the characteristics related to demand pattern, available volume, pace of the transfer, and preparations of the transfer were combined, it led to different quantity uncertainty.

To estimate the lead time uncertainty it is not enough to evaluate each production transfer and start-up characteristic on its own; it is necessary to evaluate what combinations of production transfer and start-up characteristics values are present. For example, in cases E and H, lumpy demand and demand based on forecasts, in combination with an increase in P/D ratio (depending on the layering of tiering of the network/prolonging lead times) led to increased lead time uncertainty.

Paper VI showed that the same production transfer and start-up characteristics could have values decreasing the supply chain uncertainty of the materials planning environment in one case and increasing supply chain uncertainty in another case. For example, the production transfer and start-up characteristic production process robustness. In case E a new test station was added to a production line that was already in place at the supplier, and was the case with the most stable production process. In the other three cases changes to the production process led to untrimmed machines and tools that no longer fit, which caused problems reaching product quality levels. Based on this it can also be proposed that the materials planning process has to be managed differently in different production transfer and start-up situations.

4.3.3 *The materials planning process during production transfer and start-up*

In Paper IV and V a theoretical framework describing the materials planning process during production transfer and start-up was developed. In Section 2.4.3 it was seen that the materials planning process during production transfer and start-up can be described based on the materials planning activities carried out, the planning parameters and

materials planning data quality. Below, the materials planning process during production transfer and start-up is presented, by first introducing the materials planning activities, second, materials planning parameters and third, materials planning data quality.

Materials planning activities before and after physical transfer

materials planning activities before the physical transfer can be divided into two areas: preparing and taking preventive actions such as building up stock, and upgrading documentation, equipment, control systems, etc. (Madsen, 2009) (see Table 4.7). Preventive actions are supply chain uncertainty hedging actions including safety stocks in raw materials and finished goods inventories, safety capacity, safety lead times and overplanning (Forslund and Jonsson, 2007). The supply chain uncertainty in combination with materials planning methods used decides the size and sort of preventive actions (Whybark and Williams, 1976; Chopra et al., 2004; Talluri et al., 2004).

The preparations to be made before an engineering change show several similarities with the preparations of production transfer and start-up. An engineering change also incorporates a phase-in and a phase-out of production of an item or product and therefore it can be assumed that most materials planning activities that have to be carried out during an engineering change also have to be carried out during production transfer and start-up. Wänström and Jonsson (2006) have summoned the materials planning activities to be carried out during an engineering change. Based on whether the materials planning activities during an engineering change relate to preparing and taking preventive actions or to upgrading documentation, equipment, control systems, etc. they can be found in respective columns in Table 4.7. Further, outsourcing, in many cases, increases transport distances and delivery times, which increases the probability of damage and delays and reduced delivery flexibility. To retain high delivery flexibility it is sometimes necessary to identify second sources closer to the outsourcing company than the receiving supplier. It can also be necessary to adapt or change customer order fulfilment strategy (e.g., MTS, ATO, MTO) and materials planning method (e.g., MRP, kanban, reorder point, fixed-order interval) (Olhager and Wikner, 2000). These activities specific to the production transfer and start-up situation have been added to the engineering change activities in Table 4.7.

After the physical transfer, new conditions arise as there are unforeseen events affecting the progress of supplier start-up. It is important to react quickly to unexpected events and revise plans in a cost effective manner (Vieira et al., 2003). It becomes necessary to monitor supplier start-up progress and, depending on start-up progress, it might be necessary to take corrective actions to assure materials supply. Corrective actions generate additional costs and include the following: subcontracting, expediting, part delivery, rescheduling, reservation breaking, overtime and express transport (Forslund and Jonsson, 2007). After physical transfer new routines for information exchange (e.g., orders and forecasts) between company and supplier have to be established. Further, if the physical transfer is stepwise, it is necessary to allocate production volume between the supplier and outsourcing company. A final activity after physical transfer is to follow up again to be sure an accurate standard cost has been entered. materials planning activities after physical transfer are presented in the third column in Table 4.7.

In the analysis of the cases in Paper V, it was seen that the materials planning activities before physical transfer also included the question of how to deal with first tier suppliers. The question of whether first tier suppliers should become second tier suppliers or if new second tier suppliers should be identified was an issue in all the cases of Paper V. One major reason for quality problems during production start-up is incoming materials (Almgren, 1999b). There is a greater risk of running into quality problems if first tier suppliers are not transferred to become second tier suppliers. Further, in all four cases of Paper V companies E, F, G and H also controlled the planning of raw material after the transfer. Boulaksil and Fransoo (2010) conclude from their case studies of operations planning of outsourced activities that it is not possible to control and plan a supplier in the same way as the internal production. A conclusion by Company F was that they had not transferred control and responsibilities in combination with the physical transfer which had led to cooperation problems. Therefore the transfer of first tier suppliers to second tier suppliers and the transfer and control of planning and ordering of raw materials were added to Table 4.7. Table 4.7 summarises the materials planning activities to be carried out before and during production transfer and start-up.

Table 4.7: Materials planning activities before and after physical transfer

Materials planning activities prior to physical transfer		**Materials planning activities after physical transfer**
Preventive actions, i.e., building stock before transfer (Wänström and Jonsson, 2006)	**Upgrade documentation, equipment, control systems, etc. before transfer (Wänström and Jonsson, 2006)**	
• Estimate duration of physical transfer and start-up time	• Check the BOM	• Monitor start-up progress
• Estimate new lead times and quality levels	• Coordinate production control (e.g., new sub-assembly routings or process sheets)	• Decide if corrective actions should be taken to assure supply
• Determine the gross requirement for raw materials, each part or component	• Ensure that all non-production contractual requirements such as the updating of technical manuals, spare part lists, and training aids are fulfilled	• If a step-wise transfer allocate demand between own production and supplier
• Establish and adjust master schedules and effective dates	• Follow up to be sure that an accurate standard cost has been entered for the new item(s)	• Establish new routines for ordering and forecasting
• Initiate necessary new purchasing or production order(s)	• Determine the disposition (reuse, scrap, etc.) of item(s)	• Develop new safety mechanism
• Reduce/increase the inventory of the components being transferred to • Identify second sources (added) • Transfer of first tier suppliers to second tier suppliers (added)anticipated demand levels	• Choice of customer order fulfilment strategy and materials planning method (added)	• Follow up to be sure that an accurate standard cost has been entered for the new item(s) • Transfer of control of planning and ordering of raw materials

Materials planning parameters

Each materials planning method depends on a number of planning parameters which describe how the method should be run (e.g. Vollmann et al., 2005). During production transfer and start-up it is important that the materials planning process can deal with changes to handle disturbances caused by variations in lead time, product quality and quantity. Short planning periods (e.g., bucketless or daily time buckets) are more adaptive to changes than long planning periods (e.g., weekly time buckets) (e.g., Vollman et al., 2005). Planning frequency and time fences (e.g., release time fence and planning time fence) also affect the ability to adapt to changes in demand (Wänström and Jonsson, 2006). Further, outsourcing does in most cases increase lead times. The planning horizon must as a minimum be equivalent to the longest accumulated lead time for production and purchasing of all items included in the end products; therefore the planning horizon needs to be adjusted if the longest accumulated lead time is changed (Jonsson and Mattsson, 2009). Thus, the following planning parameters affect the materials planning process during production transfer and start-up:

- *Planning periods:* Bucketless, daily or weekly time buckets
- *Planning frequency:* Transaction-based daily or weekly planning
- *Planning horizon:* How far into the future the plans reaches
- *Time fences:* Specifies the periods in which various types of change can be dealt with

Materials planning data quality

Materials planning data quality is critical for the materials planning process (Gustavsson and Wänström, 2009). The main types of materials planning data are: item data, bill-of-material (BOM) data, routing data and work centre data (Jonsson and Mattsson, 2009). Item data contain basic data, price and cost data, forecasting data, sales data, planning data and inventory data (ibid). Sales data are not affected by outsourcing and are therefore not further discussed here. Basic data and price and cost data must be updated with supplier information when outsourcing. Forecast data are used as input when taking preventive actions and the quality of the preventive actions are dependent on forecast data accuracy (Verganti, 1997). To have the right order release strategy it is necessary that planning data such as lead times, capacity and lot sizes is up to date (Boulaksil and Fransoo, 2009). Inventory data accuracy is important when outsourcing because it affects the safety mechanisms. Having a correct and updated BOM, and basic data in the form of drawings, instructions etc. is essential when transferring products or production processes (Madsen, 2009). Routing data and work centre data need to be updated according to the changes in the production process coming with the physical transfer. Thus, the quality of the following types of materials planning data impact the materials planning process during production transfer and start-up:

- *Basic data:* The information that describes, characterises and specifies items as physical phenomena
- *Price and cost data:* Data on prices, overheads and costs
- *Forecast data:* Data on which future demand estimations are based
- *Planning data:* Data describing supplier service levels
- *Inventory data:* Accuracy of stock-on-hand data
- *BOM data:* The relationship between the items in a product
- *Routing data:* The routings of the product through the production process
- *Work-centre data:* The data describing the work to be carried out on the product at each work centre the product passes through in the production process

4.3.4 *The impact of the materials planning process before and during production transfer and start-up on supply chain performance*

In section 2.3 it was said that the supply chain performance measures used in this thesis will cover issues within reliability, time, cost, flexibility and quality. Research Question 3b analyses supply chain performance through materials availability. Paper V analysed how the choice and application of the materials planning process before and during production transfer and start-up affected materials availability in four cases: E, F, G and H (see Section 3.3).

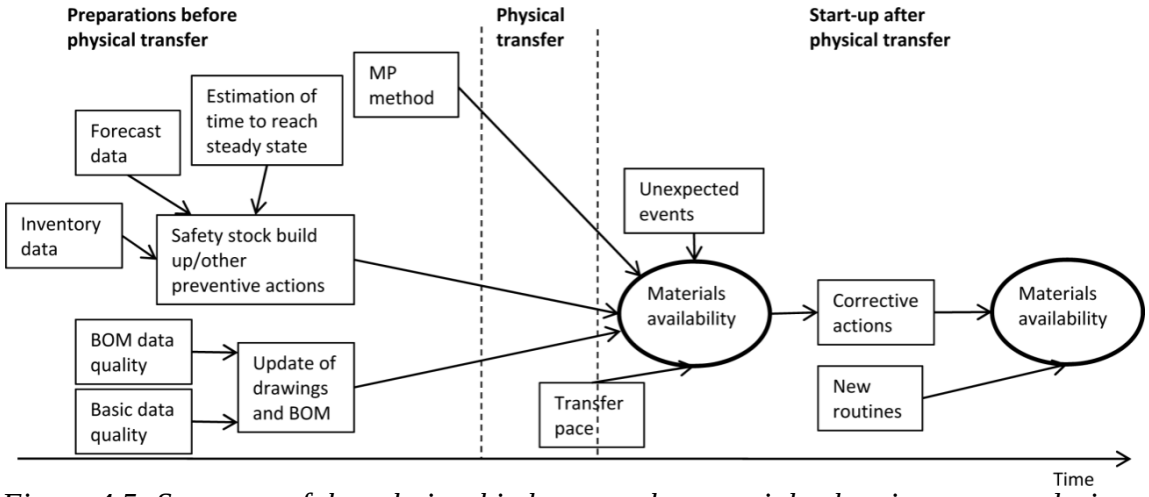

Figure 4.5: Summary of the relationship between the materials planning process during production transfer and start-up and material availability.

Based on the cases in Paper V a relationship between the materials planning process before the physical transfer and materials availability and the materials planning process after the physical transfer was established (see Figure 4.5). The aim of the materials planning process before the physical transfer is to accomplish failure prevention by taking preventive actions to avoid material shortages and decreased delivery flexibility. The division of the materials planning activities before physical transfer into preparing and taking preventive actions and upgraded documentation, equipment, and control systems complied well with the materials planning activities that were performed in the cases presented in Paper V. In Figure 4.5 it can be seen that these two areas of activities are also important for material availability after physical transfer.

In case E and F, customer demand during production transfer and start-up increased as an effect of the customer awareness of the increased supply chain uncertainty. This behaviour of the customers complicates the estimations of quantity and lead time uncertainty. Lead time uncertainty during production transfer and start-up in cases E, G and H also increased as outsourcing increased lead times. Further, as an effect of the lead time increase it was necessary in case G and H to change materials planning method and in case E to change the customer order fulfilment strategy. Before physical transfer not only do the lead time and quantity uncertainty as in established safety stocks and safety lead time need to be taken into account when deciding upon preventive actions for production transfer and start-up, but it is also necessary to include estimations of quality uncertainty and the time to reach a steady state. Earlier descriptions of safety stock calculations (e.g. Chopra et al., 2004; Eppen and Martin,

1988) consider lead time and quantity uncertainty. However, during production transfer and start-up there is an uncertainty related to the quality of the goods received. This means that the outsourcing company can receive the expected quantity though it can show that the quality levels of the received quantity are not enough and the whole batch has to be scrapped and new components ordered (this was seen in cases E and F). Because of this, lumpiness in supply was experienced. In cases E, F and H, the combined capacity of the outsourcing company and the supplier, i.e., the capacity of the supply chain, during production transfer and start-up was not enough to cover customer demand. Thereby, one important issue when deciding upon preventive actions is to estimate that time supply chain capacity will be less than customer demand, i.e., how long it will take to reach steady state. However, it could be seen in all four cases that the time to reach steady state was underestimated.

Further, the quality of the materials planning data (forecasts, inventory, BOM and basic) affects materials availability. The forecast data was used to estimate demand during the production transfer and start-up and thereby it was used as a base for the preventive actions taken. In cases E, F and H the forecast data quality was not up to standard and this affected materials availability. Further, in case F the quality of the inventory data (available inventory was not correct) led to material shortages. The quality of the BOM and basic data was important for material availability because it affected the quality uncertainty (seen in all four cases); however, this data was also affected by the materials planning activities of upgrading documentation, equipment etc. (seen in cases E, F and H). Thereby it can be seen that the quality of the materials planning data affects material availability, though the materials planning activities affect the materials planning data.

After the physical transfer, to assure materials availability, it is important to adapt the materials planning process to new circumstances and to handle unexpected events through corrective actions. In all four cases included in Paper V there were unexpected events requiring corrective actions. It is important when preparing for the production transfer and start-up to plan for unexpected events, i.e., all events during the start-up cannot be foreseen and it is thereby not possible to take direct preventive actions against these. It could be seen that the effect of the unexpected events on material availability was different depending on transfer pace.

In all cases except H it was necessary to change the internal organisation of how to plan the supply of the outsourced item. In case H, the company planned their supplier's production in the joint computer system and therefore did not need to change their organisation. In the other three cases, planning responsibility was moved to purchasing.

In case E low planning frequency and long time fences and in case H long time fences led to problems with delivery flexibility. Achieving high delivery flexibility in a steady state situation, i.e., a normal purchasing situation, with low planning frequency and long time fences is challenging enough, but the increased supply chain uncertainty during production transfer and start-up makes it even more challenging. Achieving high delivery flexibility with low planning frequency and long time fences will generate high inventories and thereby increase the cost of tied-up capital. Thus, Paper IV and V show the importance of examining the materials planning parameters carefully before production transfer begins.

5 Discussion and further research

The results of the studies are presented in the appended papers and are related to the research questions in Chapter 4. Here in Chapter 5, the answers to each research question and the practical and theoretical contributions are discussed. Second, the results of the three research questions are brought together and a framework of how to ensure materials supply during the whole outsourcing process is outlined. By outlining the framework of how to ensure materials supply during the whole outsourcing process the results of the research questions are related to the purpose of this thesis. Third, further research and the generalisability of the results are discussed.

5.1 Discussion of results

This section discusses the result of respective research questions.

5.1.1 *Integrating logistics in the outsourcing process*

The result of the first research question is the identification and description of the logistics categories of supply chain structure, customer service, logistics costs, and supply and logistics terms and how these four categories can be integrated in a derived general outsourcing process.

Research Question 1 contributes to practice through structuring of the outsourcing decision from a logistics point of view. Through the linkage between the logistics categories and the phases of the derived general outsourcing process it becomes possible for decision makers to understand what logistics issues are important to deal with in each specific phase. When analysing possible supply chain structures in the first phase, "Competence analysis and internal benchmarking," it is possible to evaluate what possible supply chain structures implies for the supply chain based on location of nodes, length of links, transport modes and lead times. This analysis of supply chain structures shows which of the structural options are aligned with company strategy. For example, if the company has a strategy for JIT deliveries, it is hard to combine with long links and long lead times; the management should carefully consider an alternative of outsourcing to a distant supplier (Svensson, 2001). In the second phase, "Supplier assessment, external benchmarking and approval," logistics becomes integrated in the supplier evaluation and selection, enabling the companies to foresee how the relationships in the supply chain will change and what customer service to expect. It is also important to highlight for the management that there are more logistics costs than transportation costs, which was the only logistics cost considered in cases A, B and C. Including logistics costs in the third phase, "Total cost analysis," allows management to focus on which logistics costs are affected by the decision alternatives. Including supply and logistics terms in the contract negotiations makes all parts aware of what is expected from the relationship, in the form of, for example, delivery reliability. It can be seen that integrating the logistics categories in the derived general outsourcing process allows companies to improve their analysis of how logistics and manufacturing operations are affected by outsourcing early in the outsourcing projects.

The companies in cases A, B and C were not aware of the derived general outsourcing process during their outsourcing projects, but nevertheless they included all phases of the derived general outsourcing process. Therefore, the derived general outsourcing process proposed in Section 4.1.1 mirrors how these companies managed their

outsourcing projects covered in Study 1. This makes it possible for other companies to use the derived general outsourcing process, at least as an inspiration for how to conduct outsourcing projects. To follow a process, like the derived general outsourcing process, could also reduce the possibility of overlooking important considerations, especially related to logistics, during outsourcing projects. The derived general outsourcing process with logistics included connects the phases after physical transfer with the phases before physical transfer. Thereby it becomes possible to consider and prepare for the problems related to logistics when material supply starts before the decision is made and carried out. Thereby, the logistics and materials supply problems no longer need to appear, surprisingly, as supply starts. This is especially important for a first time outsourcer. Through the result of Research Question 1 it becomes possible to foresee without actual experience. A proactive approach towards logistics and materials supply problems becomes possible and resources can be focused on improvements instead of on problems. Because including logistics performance measures during the transfer and the management of the relationships facilitates continuous improvements of the logistics and the supply chain. Further, the result of Research Question 1 should enhance the effectiveness of outsourcing projects because an improved and more systemised outsourcing process could decrease the time necessary for outsourcing projects. This is especially interesting as the companies in cases A, B and C observed that the time required for the outsourcing project was longer than planned for.

The theoretical contribution of Research Question 1 is the integration of the logistics categories into a derived general outsourcing process. There are several outsourcing processes in literature today, but few include any focus on how to facilitate logistics considerations during the decision making process. Brannemo (2006) presents a list of logistics factors that should be considered when outsourcing, but does not relate them to an outsourcing process. Platts (2000) also says that supply chain management and logistics should be considered, but not how. Momme and Hvolby (2002) present an outsourcing process that links operational and tactical considerations to strategic planning, but do not focus on logistics and materials supply aspects. Other well referenced frameworks (e.g. McIvor, 2000; Franceschini et al., 2003; Greaver, 1999; Schniederjans and Zuckweiler, 2004) focus on the strategic aspects of outsourcing such as identifying the core competencies of the company, identifying possible relationships with suppliers and deciding on the governance structure of the outsourcing relationship. However, they do not focus on operational aspects, such as how to ensure materials supply. Thereby, by identifying the logistics categories and how these categories should be integrated into the phases of a derived general outsourcing process Research Question 1 contributes to the outsourcing literature by adding a new perspective.

5.1.2 *Sourcing characteristics' effect on supply chain performance during steady state*

The result from the second research question is how the developed sourcing characteristics framework can be used to evaluate the consequences and supply chain performance effects of sourcing. The results show that all dimensions of the sourcing characteristics framework, except infrastructure, generate consequences that affect supply chain performance and should thus be considered in different types of sourcing assessments. In the case in Paper II, infrastructure did not affect the supply from China; however, infrastructure may affect possible supply chain structures and therefore should be taken into account as a sourcing characteristic when evaluating supply sources.

Research Question 2 contributes to practice by describing what consequences are linked to different sourcing alternatives. For example in case D, to handle the long lead times, the customer service, product quality and flexibility of sourcing from China, it was necessary to use relatively high inventory levels. Through the description of the consequences of sourcing from a specific location it is possible for managers to see how the different dimensions of supply chain structure, supply chain relationships and sourcing country characteristics will affect supply chain performance. A two-directional relationship between the sourcing characteristics and the supply chain performance measures was also identified. For example, the plant role of Company J was influenced by the product quality levels of the Chinese suppliers. Because due to the product quality levels of the Chinese suppliers, Company J had to take the role as intermediary in China in order to avoid shipping products of deficient quality. The solution with Company J as an intermediary improved supply chain performance to Company D. Thereby, supply chain performance was improved through changing the plant role of Company J, even though it was the supply chain performance that in the first place forced Company J to take the plant role of an intermediary. This two-directional relationship between the sourcing characteristics and supply chain performance should make managers aware of the fact that re-organising the supply chain can improve supply chain performance, but also that an improved supply chain performance opens up for changing the supply chain structure.

The example of Company J plant role also points on the interrelationship between the sourcing characteristics categories affecting supply chain performance. To reduce the negative effects of low-cost sourcing, it is necessary to take a holistic view of the sourcing characteristics; it is not enough to look at one of the dimensions in isolation, but it is necessary to combine them. Company J was forced to take the plant role as the intermediary between Company D and the Chinese suppliers in order to decrease the negative supply chain performance effects of the layering and tiering, the cultural differences and the business relationship. However, the establishment of Company J as the intermediary was not positive for the layering and tiering of the supply chain and if only the supply chain structure had been in focus the extra node of the intermediary would have been seen as unnecessary. But, without this node the cost of product quality and tied-up capital would have increased. Therefore, it is important for managers to take a holistic view of the sourcing characteristics in order to choose the solution that is most advantageous for the supply chain as a whole.

Through Study 3 it was shown that to use a sourcing strategy of sourcing stable demand in China led to lower costs of tied-up capital because of decreased uncertainty in product mix and volumes, which also increased customer service for the outsourcing company. The result of Research Question 2 is a practical contribution, since it shows that a sourcing strategy and working consciously to utilise and organise the supply chain can decrease inventories and improve supply chain performance in comparison to the use of randomly distributing the products and volumes between the production sites. However, in order to fully understand how to decrease the negative performance impact of the sourcing characteristics, Study 2 and Study 3 consequently reveals a need for further research, explaining the levels of relationship between sourcing characteristics and supply chain performances.

Research Question 2 contributes to theory by combining the three categories of sourcing characteristics into one framework and dividing these three categories into nine

dimensions. The sourcing characteristics and the dimensions are not new or novel—there are earlier studies that focused on the structure and relationships of the supply chain (e.g. Fill and Visser, 2000; Fraering and Prasad, 1999) or the characteristics of the sourcing country (e.g.MacCarthy and Atthirawong, 2003; Handfield and McCormack, 2005). However, evaluating the three categories of characteristics at the same time highlights their interconnection. This has been disregarded by the narrow focus of earlier studies. However, the interrelation between the sourcing characteristics renders it difficult to understand the resulting effect of the sourcing characteristics on a supply chain. This, for example, complicates improvement works in the supply chain, since it is hard to identify where to start and how and what effects to expect. Further research is needed to reveal how the interrelationship between the sourcing characteristics should be dealt with.

Nordigårdens (2007) observed that "a heavy resource-based focus in terms of a core competence approach in the formulation of outsourcing strategies risks forgetting that components can still be very vulnerable to supplier failure" (p. 248). The sourcing characteristics contribute to the outsourcing literature by providing a framework that enhances the materials supply effects for the outsourcing company. The sourcing characteristics framework provides a basis for a more accurate cause and effect analysis between the supply chain organisation and supply chain performance, which are missing in previous research. To show the cause and effect relationship between supply chain organisation and supply chain performance, improve the analysis of the cost of exchanging information, plans and physical products. A better estimation of the transaction costs should hopefully lead to more long-term profitable decisions.

5.1.3 *Materials planning environment and materials planning process during production transfer and start-up*

The result of Research Question 3a was the description of the supply chain uncertainty of the materials planning environment during production transfer and start-up. The result of Research Question 3b was how the choice and application of the materials planning process during production transfer and start-up affected supply chain performance in form of materials availability.

A practical contribution of Research Questions 3a and 3b is the operationalisation of the supply chain uncertainty of the materials planning environment during production transfer and start-up and how the materials planning process should be adapted to fit with this. It was previously only possible to say that the supply chain uncertainty of the materials planning environment increased during production transfer and start-up, but not how. By describing the relationship between the production transfer and start-up characteristics and supply chain uncertainty Research Question 3a contributes with knowledge regarding how the materials planning environment is affected during production transfer and start-up. In cases E, F, G and H it was seen that the supply chain uncertainty was increased due to the values of different production transfer and start-up characteristics present in the cases. For example, in cases B and D, lumpy demand and demand based on forecasts, in combination with an increase in P/D ratio (depending on the layering of tiering of the network, prolonging lead times) led to increased lead time uncertainty. The relationship between these production transfer and start-up characteristics is expected (Olhager, 2003). However, it is important for the outsourcing company to be aware of this as it increases the need of safety stocks in order to achieve delivery flexibility (Reidelbach, 1991; Levy, 1995).

Implementation always involves the unexpected, withholding a multitude of unforeseen circumstances (Chew et al., 1991). The materials planning activities in cases E, F, G and H during start-up after the physical transfer were to a large extent related to handling unexpected events through corrective actions. It is important for managers preparing for the production transfer and start-up to plan for unexpected events, i.e., all events during the start-up cannot be foreseen and it is thereby not possible to take direct preventive actions against these (Zhu et al., 2001). Instead it is perhaps better to prepare for the fact that there will be corrective actions during the start-up and deposit resources for these on beforehand. How fast the events affecting materials availability can be detected should impact what corrective actions are possible and the cost of them. The sooner an event can be detected the easier it should be to correct them and the smaller effects on materials availability they should have. However, to see the full possible effects of an unexpected event early and to decide upon what is the most suitable corrective action it is necessary to have knowledge about the entire situation present, i.e. to be able to describe the materials planning environment which show the supply chain uncertainty present in the specific case.

The processes for how to prepare and carry out the physical transfer followed in cases E and G were the production start-up part of the product development processes. However, there is a difference between production start-up of new products and production transfer and start-up. For a new product, most customers accept that there will be lower capacity and quality to start with. However, in none of cases E, F, G or H did demand during production transfer and start-up decrease. Further, customers should not be eager to accept decreased quality levels because of an inexperienced supplier either. In accordance with Zhu et al. (2001), it can be said that to deal with all the questions and tasks coming from production transfer and start-up, a transition plan should be a good help. However, further research is needed to develop a structure for such a transition plan.

The studies presented in Papers IV and V point to the importance of analysing the effect on materials availability of the materials planning parameters and materials planning data quality during production transfer and start-up. It was seen that low planning frequency and time fences locking the schedule long in advance of delivery date led to problems with delivery flexibility. Achieving high delivery flexibility in a steady state situation with low planning frequency and long time fences is challenging enough, but the increased supply chain uncertainty during production transfer and start-up makes it even more challenging. Good materials planning data quality is a prerequisite for the preparations of the transfer (Madsen, 2009). The forecast data and inventory data was used as a base for the preventive actions taken. In cases E, F and H it was seen that the quality of the BOM and basic data was important for material availability because it affected the quality uncertainty. However, this data was also affected by the materials planning activities of upgrading documentation, equipment, etc. To improve materials availability during production transfer and start-up managers should examine the materials planning parameters and the quality of the materials planning data carefully before production transfer begins.

Outsourcing did in three of the studied cases increase lead times and it was necessary to change materials planning method. Further, in one case it was also necessary to change the customer order fulfilment strategy. Several authors have pointed to the importance

of fit between the company strategy and the manufacturing planning and control system (e.g. Berry and Hill, 1992; Olhager and Rudberg, 2002). For example, by considering how customer order fulfilment strategy and materials planning methods are affected by longer lead times (which is common when outsourcing to low cost countries), companies can determine whether the materials planning strategy and materials planning methods have to be changed in such a way that it conflicts with the company's strategy. A practical contribution is made by elucidating this issue.

The aim of the materials planning process before the physical transfer is to accomplish failure prevention by taking preventive actions to avoid material shortages and decreased delivery flexibility. Input to preventive actions, such as safety stock and safety lead times, are lead time and quantity uncertainty (Chopra et al., 2004; Eppen and Martin, 1988). Quality uncertainty is not taken as an input in earlier descriptions of safety stock calculations. However, during production transfer and start-up there is an uncertainty related to the quality of the goods received, because the production process has not yet reached steady state (Almgren, 1999b). This means that the outsourcing company can receive the expected quantity though it can show that the quality of the received quantity is not sufficient and the whole batch has to be scrapped and new components ordered (case E and F). This creates lumpiness in supply. Earlier researchers have recommended the use of overplanning when lumpiness is in demand (e.g. Verganti, 1997) and perhaps this should be used to complement safety stocks during production transfer and start-up in order to handle the lumpiness in supply. However, further research is needed to look at this relationship. Further, during production transfer and start-up the combined capacity of the outsourcing company and the supplier, i.e., the capacity of the supply chain, can be less than necessary to cover customer demand. Thereby, one important issue when deciding upon preventive actions is to estimate that the time supply chain capacity will be less than customer demand, i.e., how long it will take to reach steady state. Thus, what has to be taken into account when deciding upon preventive actions is not only the lead time and quantity uncertainty as in established safety stocks and safety lead time calculations. It is also necessary to include estimations of quality uncertainty and the time to reach steady state. A theoretical contribution is made by the identifying the need to combine the lead time, quantity and quality uncertainty and the time to reach steady state in the calculations of the preventive actions. This can also lead to the need of combining several preventive actions, i.e., not only building safety stock, but also making use of safety lead time, overplanning and/or safety capacity. Further research is needed to identify the relationship between supply chain uncertainty and preventive actions.

Production ramp-up or production start-up has previously been studied from two perspectives, technology and knowledge transfer, and production ramp-up. Processes for how to transfer technology and knowledge and what factors improve knowledge incorporation have been identified (Galbraith, 1990; van Wijk et al., 2008; Szulanski, 1996; Steenhuis and de Bruijn, 2005; Salomon and Martin, 2008; Lyles and Salk, 1996; Grant and Gregory, 1997b; Cheng et al., 2010). Many earlier studies of technology and knowledge transfer have been surveys of large populations at the industry level. Some authors have linked technology and knowledge transfer to production start-up and the time to volume and studied it through case studies (e.g. Terwiesch et al., 2001; Terwiesch and Bohn, 2001; Madsen, 2009). Production start-up or ramp-up, on the other hand, have mainly been studied through deep case studies focusing on identifying the factors that affect the time to volume in new product launches (Almgren, 1999b;

Almgren, 1999a; Fjällström, 2007; Baloff, 1970; Terwiesch and Bohn, 2001; Terwiesch et al., 2001). However, earlier research in technology and knowledge transfer and production start-up has not linked the efficiency of technology and knowledge transfer and production start-up to outsourcing. Research Question 3a makes a theoretical contribution by relating the research of these two streams to outsourcing and materials planning.

5.2 How to ensure materials supply during the whole outsourcing process

The purpose of the thesis is to understand how to ensure efficient and reliable materials supply during the whole outsourcing process. This subsection outlines a framework of how to ensure materials supply during the whole outsourcing process by combining the results of the three research questions. Because, how to ensure materials supply implies different answers depending on the stage of the outsourcing process looked upon and the research questions have together covered the whole outsourcing process, i.e., the decision making before physical transfer, the physical transfer and start-up, and the steady state. Below the framework is first outlined; second and third, its theoretical and practical contributions are discussed.

5.2.1 *The framework*

The result from Research Question 1, the derived general outsourcing process (see Table 4.1), will be used as the backbone for the framework developed here because it covers from before the decision is made till steady state with continuous supply from the new source. Below, it is elaborated on how the results from Research Questions 2 and 3 should be used to detail the logistics categories in the derived general outsourcing process from Research Question 1. The outlined framework is presented in Figure 5.1.

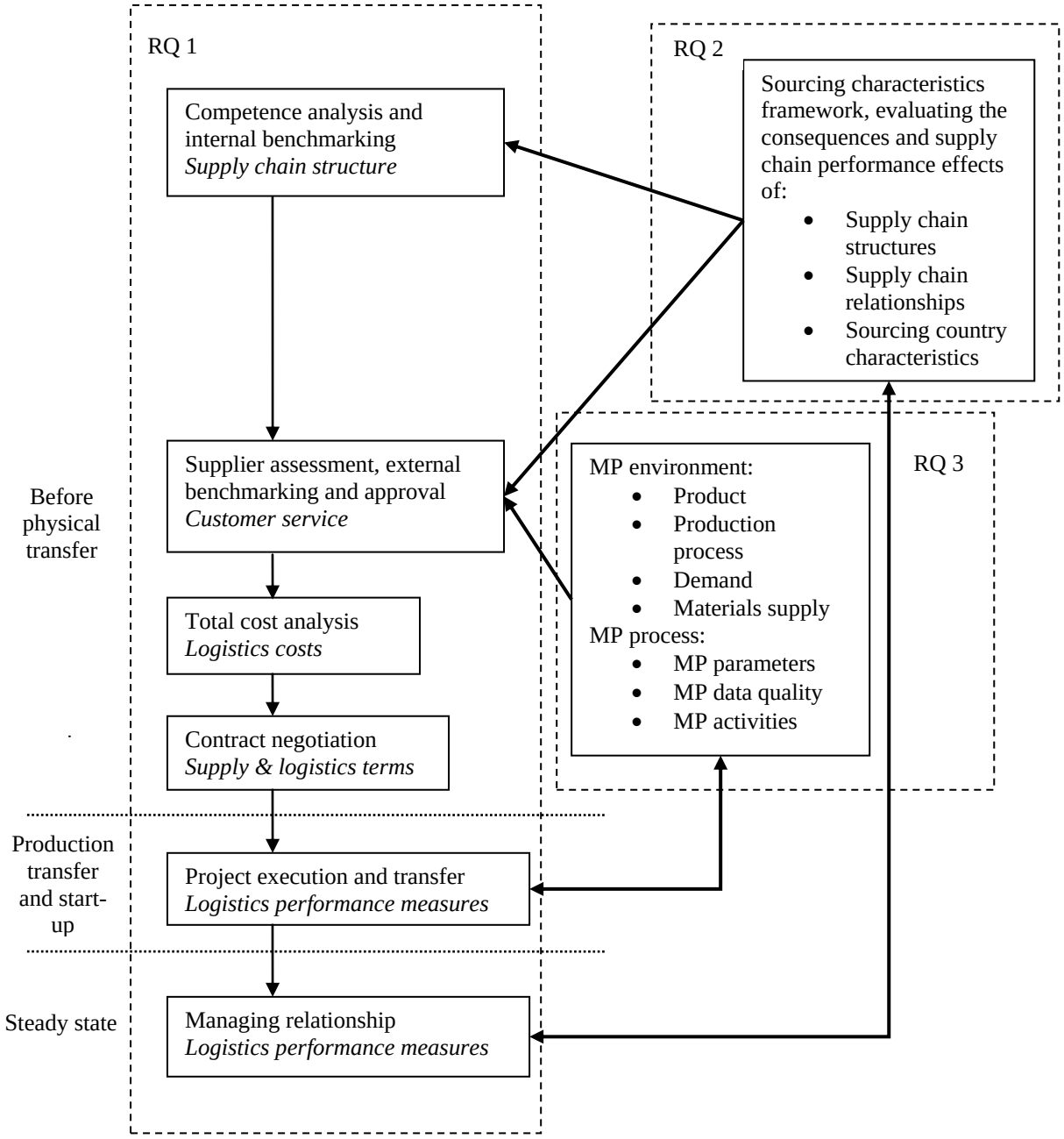

Figure 5.1: The outlined framework for how to ensure materials supply during the whole outsourcing process

During the first phase of the derived general outsourcing process, "Competence analysis and internal benchmarking," it is important to compare the current supply chain structure with potential future supply chain structures and be able to analyse what the difference would imply for materials supply. The first step in risk identification typically starts as soon as the opportunity of sourcing from outside the company is recognised by the firm (Manuj and Mentzer, 2008). Based on the sourcing characteristics framework, from Research Question 2 (Table 4.3), it is possible to evaluate how the future supply chain structures, supply chain relationships and sourcing country characteristics will affect supply chain performance to the outsourcing company. Thereby the risks and effects for materials supply of different alternatives can

be compared and a better estimation of what a change of supply chain structure coming with outsourcing would imply and require for the company can be made.

In the second phase, "Supplier assessment, external benchmarking and approval," it is important to compare the supply chain performance effects of possible suppliers, in order to select the supplier that best fits the prerequisites of the outsourcing company and its market. The sourcing characteristics' effect on supply chain performance is one way to identify the expected customer service of a sourcing alternative. An evaluation of the sourcing characteristics during the "Supplier assessment, external benchmarking and approval" phase should improve the possibility of making more long-term profitable decisions. Because, by knowing what supply chain performance and customer service a supplier will provide it is possible to estimate inventory sizes, the need for extra transports and quality checks. Thereby, more reliable cost estimations in the third phase, "Total cost analysis," can also be done.

Phase 6, "Managing relationship," corresponds to the steady state covered by Research Question 2. Including the sourcing characteristics framework in Phase 6 enables continuous improvement of supply chain performance during the relationship. The dimensions of the sourcing characteristics framework are on a detailed level. The detailed level of analysis enables taking action to improve supply chain performance. Through the dimension, "the reconfiguration process of the supply chain," the sourcing characteristics framework also opens up for adjusting the supply chain structure to better fit with the supply chain relationship and sourcing country characteristics, thereby improving the supply chain performance during steady state.

Now, focus is moved from Research Question 2 to Research Question 3. During the second phase of the derived general outsourcing process, "Supplier assessment, external benchmarking and approval," it is important to define critical supplier assessment criteria and evaluate the supplier. One of the biggest uncertainties from a materials supply point of view is to estimate the supply chain uncertainty during production transfer and start-up and the time to reach steady state. As long as expected capacity and quality levels are not reached, supply chain uncertainty will be increased and there is a risk that material availability will be affected. The supply chain uncertainty during production transfer and start-up are dependent on the materials planning environment present in the specific case because how quickly a new supply chain reaches expected capacity and quality levels depends on the transfer of technology and knowledge and the start-up progress which is highly dependent on the receiving suppliers abilities and experiences. Including an analysis of the production transfer and start-up characteristics in the supplier assessment criteria allows an analysis of how a certain supplier would affect the materials planning environment during production transfer and start-up. With knowledge about the materials planning environment it is possible to say, how the materials planning process needs to be adapted to fit with the supply chain uncertainty present. Thereby it becomes possible to see if materials planning methods and customer order fulfilment strategy have to be adapted in such a way that it conflicts with company strategy. By the inclusion of the results from Research Question 3 in the second phase of the derived general outsourcing process the supplier evaluations would give input of how supplier choice affect materials availability.

Phase 5, "Project execution and transfer" corresponds to the production transfer and start-up stage covered by Research Question 3. In order to prepare for how to ensure

materials supply during the "Project execution and transfer" phase it is essential to include the results from Research Question 3. Using the results of Research Question 3 in the preparations for Phase 5, "Project execution and transfer" would allow taking appropriate preventive actions before and corrective actions during production transfer and start-up. This would increase the possibility of a smooth physical transfer from a materials supply point of view. Hopefully decreasing the cost of how to ensure materials supply during the fifth phase.

Based on the above discussion, it has been shown how the research questions together contribute to the purpose and a framework describing how to ensure materials supply during the whole outsourcing process has been outlined. The framework is presented in Figure 5.1.

5.2.2 *Theoretical contributions*

This thesis has as its starting point the practical problem of how to ensure materials supply during the whole outsourcing process. To deal with this problem two theoretical streams are used, materials supply and outsourcing. Below it is described how this thesis contributes to the materials supply and outsourcing streams. The discussion below is on a general level and therefore the contributions are not compared to earlier contributions by other authors. What the results of this thesis contribute with compared to earlier authors' contributions is presented under each research question in section 5.1.

The contribution to the materials supply research area is how existing processes and methods within the materials supply research area have to be adapted to fit with the specific conditions of outsourcing. The thesis thereby helps to answer the question of how companies should respond to changes in conditions of their operations that come with outsourcing. This thesis contributes by combining the areas of technology and knowledge transfer and production start-up to describe how supply chain uncertainty during production transfer and start-up is affected. This is used to further develop an existing framework, describing the materials planning environment during engineering change, into a framework by which the materials planning environment during production transfer and start-up can be described. Through this framework, the input to the materials planning process needed to take the right preventive measures to ensure materials supply during production transfer and start-up are identified. The materials planning environment and the materials planning process during production transfer and start-up was not investigated earlier. Furthermore, the thesis contributes by combining already existing frameworks for evaluating sourcing decisions to develop a framework by which the consequences and supply chain performance effects of sourcing from a specific location and supplier can be identified. It is also seen that supply chain performance is improved by having a sourcing strategy for how sourcing alternatives should be combined and utilised.

The results of the thesis contribute to the outsourcing research area by showing that to ensure materials supply all three stages of the outsourcing process (before physical transfer, production transfer and start-up, and steady state) has to be in focus. The thesis has covered the whole outsourcing process and the materials supply implications of all three stages of the outsourcing process have become visible. Earlier research has often focused either on the strategic decision making before the physical transfer or supply chain management during steady state. The production transfer and start-up have just been seen as a very short time period. However, it can take years to reach steady state

(Madsen, 2009). A theoretical contribution is made by the description of production transfer and start-up and the highlighting of the importance of this stage for material availability during the outsourcing process. Also, this thesis has contributed by describing the stages of production transfer and start-up and steady state on a detailed level and what they imply for materials supply. The results of this thesis make the relationship between the strategic decision to outsource and material availability more visible. A result sought by other authors such as Nordigården (2007) and Boulaksil and Fransoo (2010). The research presented in this thesis contributes by providing an understanding how to ensure materials supply during the whole outsourcing process; however further research confirming the relationship seen and testing the frameworks proposed is a next step.

5.2.3 *Practical contributions*

In this section the practical contribution of the entirety of the thesis is discussed.

Intended strategies are also likely to produce unintended outcomes affecting the operational reality in the outsourcing company (Slepinov and Vejrum Weahrens, 2008). Outsourcing is a strategic decision with operational effects. However, the effects do not show immediately after the decision is made; instead they appear as the decision is carried out. The operational effects are the effects on the remaining parts of the production that are dependent on availability of the outsourced item. In all eight cases included in this thesis, the companies experienced problems with materials availability and supply after the outsourcing decision was carried through, i.e., during production transfer and start-up and steady state. The effects of outsourcing on materials supply can stem from several different sources; for example, the exchange planning and forecast information leading to planning nervousness (Boulaksil and Fransoo, 2010), lack of tacit knowledge transfer leading to quality problems (Grant and Gregory, 1997b) and the transport and package of products leading to damages during transit (Zeng and Rossetti, 2003). These effects show the complexity of outsourcing from the operational point of view and that the organisational consequences are widespread and interrelated. The framework introduced in Figure 5.1 bridges the gap between the decision makers and the doers in the organisation outsourcing because it shows the operational effects of outsourcing.

A common expectation, at least of first time outsourcers, is that as soon as the production at the supplier has started, material availability will not be affected. However, this thesis has shown that this is not the case. Cases E, F, G and H showed that it takes time before a steady state is reached and even though these companies were experienced outsourcers they predicted the time to steady state as shorter than it actually was. By using the outlined framework of how to ensure materials supply during the outsourcing process, the problems related to materials supply during production transfer and start-up and steady state can be decreased. This is because the framework helps to bring up possible operational effects before they appear and thereby they can be an input in the decision making. The framework outlined in Figure 5.1 also helps companies to transfer the available information about the context into concrete preventive actions ensuring materials availability and supply. It becomes possible to evaluate what internal and external conditions need to be handled in order to ensure a stable materials supply situation before the decision is carried out. Thereby the outlined framework also improves the possibilities of taking a proactive approach to materials supply when outsourcing. Through this it becomes possible to evaluate the strategic

impact of ensuring materials supply when outsourcing. Components considered non-core components can be very risky to outsource because of the need for component availability (Nordigården, 2007). The proactive approach regarding materials supply makes it possible to consider how sensitive the company is to materials supply uncertainty of the component considered for outsourcing. Further, the question of how the supply chain uncertainty is inflicted by outsourcing to a specific supplier and location can be estimated. This is information based on which the organisation can prepare how it should adapt its ways of working, because management practices that work well in one set of conditions may not work well as conditions change and therefore it can be necessary for organisations to adapts its procedures and methods to the new conditions. For example, it could be seen that Companies E, G and H had to adapt their materials planning methods to the new lead times coming from outsourcing and because of this they became more dependent on forecasts in their materials planning process.

Outsourcing processes in practice are dealt with differently depending on which stage is viewed (before physical transfer, production transfer and start-up, or steady state). Each stage is run by different parts of the organisation. Typically, before the physical transfer, the strategic decision to outsource is made on a managerial level. Then, the responsibility to carry out the physical transfer is given to a project organisation. Finally, the management of the supply chain during steady state is run by the purchasing organisation. The outlined framework provides a structure for how to ensure materials supply during the whole outsourcing process. Based on this framework it is possible for the outsourcing company to see the linkage between the three stages and thereby make the transparency between the stages better; see Figure 5.2. A better transparency between the stages should improve the pass over of the project between the parts of the organisation and also increase the understanding of what can be done in earlier stages to improve materials availability and supply in later stages.

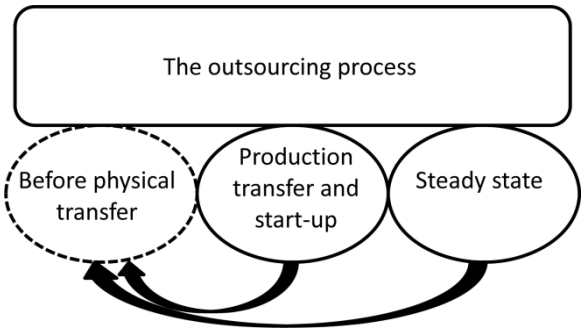

Figure: 5.2: The bringing back of experiences of production transfer and start-up and steady state stages into the decision making process before physical transfer.

The structure provided by the framework in Figure 5.1 also provides possibilities of keeping track of decisions made and the foundation of these. The outsourcing project organisation is not a stable organisation. Different persons and functions are responsible for the different stages of the outsourcing process and it is a project organisation carrying out the transfer. This means that the next outsourcing project will not necessarily have the same organisation. Thereby it becomes harder to transfer knowledge between the projects and the risk of running into the same problems next time increases. For example, earlier experience of knowledge transfers within both the sender and recipient improve the adaptation of the knowledge within the receiver (van

Wijk et al., 2008; Szulanski, 2000; Ferdows, 2006). The use of the framework outlined here improves the transfer of knowledge between projects, because the framework provides structure which can be updated based on earlier experiences. However, to really be able to transfer knowledge between projects it is also necessary to evaluate the decision after steady state is reached.

5.3 Further research

Based on the research presented in this thesis, it is possible to identify streams for further research. The identification of further research is made through the limitations of the research presented in this thesis and the possibilities of complementing or expanding the studies. Further research is also identified based on how the results of this thesis relate to trends in the surrounding world. Below are first further research based on the limitations of the research presented, second based on the possibilities of complementing or expanding the presented studies and finally based on how the results relate to trends in the surrounding world.

The whole outsourcing process is a large area to study in a thesis. One limitation of the results presented is that they cannot explain all the relationships seen in the thesis, because a more detailed view would have been necessary to do this. For example, what sourcing strategies are possible for allocating demand during parallel production was one stream identified for further research in Section 5.1.2. It is not possible based on the results in this thesis to exactly describe how parallel production should be organised, because there are several ways possible to organise parallel production, though only two strategies were tested in this thesis. Further research is necessary to describe what other sourcing strategies there are and the implications for supply chain performance of using these. However, by studying the whole outsourcing process the connections between the stages of the outsourcing process became visible. The capturing of the connections between strategic decisions making before the physical transfer with the operational effects of materials supply after physical transfer is a contribution of this thesis and therefore a wide approach was necessary.

The derived general outsourcing process which is the basis for the framework of how to ensure materials supply during the whole outsourcing process (Figure 5.1) has been compared with already completed outsourcing projects only. This is a limitation, because by the use of only historic cases details gets lost as the interviewees only remember the big issues and not the small daily intermezzos. The whole outsourcing process takes a long time from the beginning until reaching steady state. Therefore, historical cases have been a time efficient way to cover the whole timeframe. It can also be hard to get access to the decision making stage of the outsourcing process as outsourcing is a sensitive decision which the management does not want to be known outside the office before everything is finalized. Historical cases do not have that problem because the information is already public. To use the framework of how to ensure materials supply during the whole outsourcing process in an outsourcing project from the start of the outsourcing process to reaching steady state would give interesting insights into how the framework impacts the outsourcing decision and the satisfaction of the decision. One way to accomplish this is to complement the research included in this thesis with an action research approach in order to observe the use of the framework in real time.

The research carried out here has been from the outsourcing company's view and most of the interviewees have been from the outsourcing company. This limits the research presented in this thesis to only present results usable for the outsourcing company. Though, as the focus of the thesis has been the materials supply to or material availability in the outsourcing company, the perspective was natural. However, it would be very interesting, as a next step, to expand the research to also cover other parts of the supply network's point of view; for example, to study the receiving supplier's conditions and context, for example to study the insourcing process and the supplier's point of view on what affects the supplier's ability to deliver during the insourcing process. Therefore, further research viewing production transfer and start-up from the receiving suppliers' point of view would complement the studies of this thesis by providing the other side's perspective.

In Section 5.1.2, it was identified that further research is needed to reveal how the interrelationship between the sourcing characteristics should be dealt with. Based on case D it was proposed that the sourcing characteristics in the form of sourcing country characteristics, supply chain structure and supply chain relationships are mutually interconnected and affect each other. Several relationships are proposed but the conducted single case study is not enough for identifying, formulating and validating all existing relationships. Further studies that identify other relationships and test the proposed relationships are consequently needed. This would provide a more detailed description of how the sourcing characteristics relate to each other and supply chain performance and what this relationship imply for companies designing their supply chain.

In Section 5.1.3 it was seen that a process for production transfer and start-up of existing products should be developed. Because there is a difference between new products and existing products regarding demand and expected product quality levels it is perhaps not the optimal solution to use a part of the product development process to transfer and start-up production of an existing product, as in case E and G. According to Rudberg and West (2008), standardised processes for transferring and ramping-up production are a platform for achieving volume objectives and maintaining quality. Therefore, in accordance with Zhu et al. (2001) it is proposed that to deal with the questions and tasks brought about by the production transfer and start-up, a transition plan containing information about the functions to be performed to accomplish a successful physical transfer and start-up should be a big help. However, further research is needed to develop such a process. But, the studies of production transfer and start-up presented in this thesis can be used as one input to such a process for production transfer and start-up.

A trend observed in the surrounding world is that world is becoming more and more volatile and the future holds several issues that can dramatically affect the structure of supply chains. Thereby structural flexibility is becoming more important (Christopher, 2010). Outsourcing and insourcing are only two ways of restructuring manufacturing networks. There are several other ways too, such as establishing a new factory, moving production lines between existing factories in order to prolong the product life cycle etc. The reasons behind the decision to restructure are different. Though one goal is the same, to accomplish the restructuring as smoothly as possible and reach steady state as quickly as possible. Structural flexibility implies the ability of handling changes in the supply chain structure. With low structural flexibility it will take longer to reach steady

state after outsourcing and thereby decisions to restructure will be less profitable. Today, carrying out the process of restructuring (at least when outsourcing) and reaching steady state takes in most cases longer than expected. This makes it hard to achieve supply chains that are structurally flexible because changing supply chain structure is costly and claims a lot of the organisations' resources and when steady state is finally reached the company has no wish to start such a project again. However, the supply chain structure can always be improved and there will always be new contextual factors making it more profitable to change the structure. However, more research is needed in cases of frequent transfers, to explore how structural flexibility can be accomplished in practice in order to improve the structural flexibility.

5.4 Discussion of the generalisability of the results

This section discusses the general character of the results. The generalisation of the results is always of interest because it describes for which contexts the findings are valid.

All the frameworks developed in this thesis were developed from literature and the variables were operationalised using well established definitions from the outsourcing, supply chain management and materials planning research areas. The frameworks were also applied to the cases studied in this thesis. They are thereby developed with the aim of being generalisible over several contexts and they should therefore also be possible to apply within several companies and contexts.

The result of Research Question 1, the derived general outsourcing process aims to apply to all outsourcing decisions of production, i.e., domestic, nearshore and offshore outsourcing. As the derived general outsourcing process was derived from four published and well cited outsourcing processes, it corresponds well to how outsourcing processes are presented in the literature. The derived general outsourcing process was tested within the context of cases A, B and C (see Section 3.3.1) and should therefore also be possible to use in outsourcing projects within companies of similar contexts, i.e. large multinational companies. Though, as the question of what to consider during the outsourcing process is similar across sizes of companies should the process also be possible to use in smaller companies. The drivers for outsourcing varied between cases A, B and C and included increase capacity, cost reductions and focus resources on core competences, therefore should the derived general outsourcing process also be applicable to outsourcing projects with differing drivers.

The result from Research Question 2, the sourcing characteristics framework, joins issues from several other frameworks in the supply chain management and operations management literature. Therefore, the categories and dimensions of the characteristics were known as the case study was entered. This increases the possibility of using the sourcing characteristics in other contexts than the one in which it was applied to give a good picture of how the supply chain affects supply chain performance. The framework was applied to a single case study of a Swedish company sourcing from China, though in other contexts there could be other relationships the sourcing characteristics and supply chain performance. However, Sweden is counted as a part of Western Europe. Thereby, for other Western Europe and North American companies to use the results when outsourcing should also be possible. Though some Western companies might have the advantage of outsourcing to a supplier speaking the same language decreasing the risk of misunderstandings, one issue affecting materials supply shown in the case

study. Further, it is not uncommon for Western companies to change sources by moving from a Western supplier to a low-cost supplier. It should be possible to use the framework in these situations as well, since the similarities between switching from local to global supply and offshore outsourcing are large.

The results from Research Question 3a, the production transfer and start-up characteristics were developed from earlier studies of materials planning environments within the engineering change context. The difference between engineering change, in which the materials planning environment has been studied before, and the production transfer and start-up are the production transfer and the start-up of in most, cases a long distant supply chain. Therefore, new characteristics were added from the technology and knowledge transfer, production start-up and global supply chain literature. The production transfer and start-up characteristics were developed to describe all types of materials planning environments in the production transfer and start-up situation. It was applied to cases E, F, G, and H, which were chosen to represent different materials planning environments. Though, in Table 3.4 can be seen that the uniqueness of the production process was relatively low in all four cases. Thereby, the framework for describing the materials planning environment have not been applied to cases with highly unique production processes. However, the framework should be possible to apply also to production transfer and start-ups where there is a highly unique production process as the production process is one important input to the description of the materials planning environment.

The materials planning process in the production transfer and start-up situation, the result from Research Question 3b, was developed based on earlier studies of the materials planning process in engineering change situations. The engineering change situation and the production transfer and start-up situation both incorporate a phase-in and a phase-out of products or production. That the materials planning process is developed with the focus of a phase-in or phase-out of production or products increases the possibility to use the materials planning process in other contexts where phase-in and phase-out take place, such as change of supplier. In Table 3.4 can be seen that the focal company control of the supply chain have been neither high nor low in the cases where the materials planning process was applied. However, the materials planning activities to carry out before and during production transfer and start-up should be the same, no matter control over the supply chain. Though, the higher company control over the supply chain the easier it should be to get knowledge about the suppliers' schedules and start-up progress, which should make it easier to carry out the materials planning process.

The context of the studied cases was described in Section 3.3.1. Some of the results in the cases are relatively case specific, such as the effects of the product quality problems during production transfer and start-up. However, all eight companies experienced product quality problems, but exactly how it showed was case specific. The cases cover many factors common between producing companies, which presents an opportunity to use the results in producing companies in different industries with different production set-ups. For example, all eight Swedish companies studied are international producing companies working in business-to-business markets. Even though the geographic distance has differed, outsourcing increased lead times in all cases except one. None of the cases have been failures, leading to in-sourcing again. However, the cases have not reached expected gains as quickly as the companies thought when making the decision

to outsource. This variety in the characteristics of the outsourcing projects makes it possible to use the results of this thesis in various outsourcing projects of outsourcing production. That the products studied have been items used in the final products of the outsourcing companies should not be seen as a hindrance to use the results in outsourcing of production of consumer products. The considerations made to ensure materials supply when outsourcing should be the same.

6 Conclusions

This chapter presents the conclusions of this research project, the problems and how they were solved, as well as how the purpose was fulfilled.

Supplier and customer markets become more and more global and make companies consider restructuring their supply chains to take advantage of opportunities in terms of costs, competence, etc. at different locations. One way to take advantage of opportunities in other locations is to redesign the value adding chain by outsourcing parts of the production to suppliers. Meijboom and Voordijk (2003) ask the very relevant question: How does globalisation affect the "home" facilities? The focus of the research in this thesis is within that question. The focus of this thesis is how to ensure materials supply when outsourcing production. Outsourcing of production implies a change from in-house materials supply for production to purchasing from a supplier and thereby outsourcing of production can affect the supply chain and materials supply in the form of delivery reliability, lead times and product quality. In order for companies to be successful with outsourcing it is important to understand how to ensure materials supply for the "home" facility. Therefore, the purpose of this thesis is to understand how to ensure reliable and efficient materials supply during the whole outsourcing process. With the whole outsourcing process is implied from before physical transfer where the decision to outsource is made until after steady state is reached with continuous supply from the new source.

The purpose is fulfilled through answering three research questions by using the results of six appended papers. The six papers are based on five studies: two single case studies, two multiple case studies and one simulation study. Empirical data in the case studies have mainly been collected through interviews with staff working in the companies outsourcing.

The result of Research Question 1 shows how logistics categories (supply chain structure, customer service, logistics costs, and supply and logistics terms) can be included into a derived general outsourcing process. It is applied to three cases where all three companies experience logistics related problems during the outsourcing process that could have been decreased if logistics had been included in their outsourcing processes. The first research question contributes to the purpose by increasing the understanding of what logistics considerations are necessary to make during each of the phases of the outsourcing process to accomplish a well functioning supply chain after outsourcing.

Research Question 2 contributes by providing a framework for evaluating the supply chain performance effects of the sourcing characteristics supply chain structure, supply chain relationships and country characteristics after physical transfer as a steady state is reached. The sourcing characteristics framework was applied to a single case and it was seen that the dimensions of the framework could be used to analyse the supply chain performance effects of sourcing from China. Further, the simulation study showed that supply chain performance can be improved through a better utilisation of the different parts of the supply chain, accomplished through a sourcing strategy of sourcing stable demand in China and handling the uncertainty in Sweden.

Research Question 3 describes the materials planning environment during production transfer and start-up and shows how the choice and application of the materials planning process during production transfer and start-up affects supply chain performance. The materials planning environment was studied in four cases and it was seen that by evaluating the materials planning environment in the specific case it is possible to make an estimation of the supply chain uncertainty during production transfer and start-up. The materials planning process during production transfer and start-up was also applied to four cases, which demonstrated how the materials planning process before and during production transfer and start-up affects materials availability during production transfer and start-up.

In the discussion the results from the research questions were brought together and a framework of how to ensure materials supply during the whole outsourcing process was outlined (Figure 5.1). To make good strategic decisions like the outsourcing decision, the operational implications like materials availability have to be considered. A process like the one presented in Figure 5.1 helps companies assess the operational effects of their outsourcing options in the strategic decision making. The outsourcing framework is a managerial contribution because it presents a structured approach of how to consider and ensure materials supply during the whole outsourcing process. It makes it possible for companies to go from a reactive approach to a proactive approach towards materials supply when outsourcing. The results of the thesis contribute to the materials supply research area by identifying how existing processes and methods within the materials supply area have to be adapted to fit with the specific conditions of outsourcing and to the outsourcing research area by showing that to ensure materials supply the whole outsourcing process (before physical transfer, during production transfer and start-up, and during steady state with continuous supply) has to be in focus.

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