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Sales and operations planning based on a modularized view of supply chains

**Supporting process industries and discrete manufacturing
industries**

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Division of Production Economics

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Abstract

The purpose of this dissertation is to propose a framework for sales and operations planning (S&OP), which is based on a modularized view of supply chains. The framework should support both process industries and discrete manufacturing industries in their quest for performance. S&OP has been highlighted in this framework due to its essential role in integrating different functions within a company and integrating a company with its supply chain partners (referred to as horizontal integration), and linking different planning levels in a company (referred to as vertical integration). As an integrator, S&OP influences companies' performance.

Originally, S&OP was developed as a generic process but still in line with the requirements of discrete manufacturing industries. The specific requirements of process industries have not been emphasized in this process to the same extent. In order to suggest a modularized S&OP framework for both process industries and discrete manufacturing industries, a systematic literature review is performed to understand the specific characteristics of S&OP in process industries. As a result, the importance of continuity/discontinuity of materials and its influence on the required production processes are highlighted. This indicates that the production process in process industries is actually a hybrid of continuous production and discrete production, whereas the discrete manufacturing industries often only deploy discrete production. Continuous production has specific characteristics that would be beneficial to include in the S&OP process; nonetheless, this is in contrast to the view in the literature that considers S&OP a generic process. Generic here means that S&OP is independent of the context in terms of, for example, the industry in which it is implemented. This issue is investigated in this dissertation by identifying the requirements, which can be considered in the S&OP of process industries as add-ons to the generic S&OP. In addition to this, two other concepts addressing the properties of the production process are identified as important in planning and control, including S&OP. One addresses the level of repetitiveness of the production process in response to the market demand, and the other concerns the trigger of the production flow. The three concepts are related to three different types of decoupling points and are the basis for a typology developed herein that provides a modularized view of supply chains. The application of the typology to S&OP leads to a modularized S&OP framework applicable to both process industries and discrete

manufacturing industries. The modularized view of supply chains has been long emphasized as an effective and efficient way to support companies' performance and their competitive position. The typology and the S&OP framework are developed through conceptual research methods.

To study how the modularized S&OP framework is related to companies' performance measures, different performance measures (including sustainable performance measures) at the S&OP level are extracted from the literature. The performance measures are then classified according to the typology, and linked to strategic performance attributes. Aligning performance measures at S&OP levels and strategic performance attributes would help in enhancing companies' performance. Sustainable performance measures are included in this classification to provide additional support for companies' performance. Finally, this approach in classification of performance measures is studied in four case companies, and the empirical performance measures are linked to the companies' strategic performance attributes and competitive strategies. The results of this empirical study have, to some extent, verified the results from the classification of performance measures based on the literature.

This dissertation contributes to the development of knowledge in S&OP. First, it identifies three key concepts in planning and control of manufacturing companies. Second, it investigates how S&OP should be tailored to the specific characteristics of companies and their supply chains. The modularized S&OP framework developed in this dissertation is based on the three identified concepts. This framework provides a foundation for fulfilling the supply chains needs by suggesting decision-making processes, planning techniques, and performance measures for different modules. More specifically, this work investigates how S&OP should be designed and implemented in process industries, which has not been extensively studied before. Third, this dissertation shows how S&OP level performance measures can be selected in line with the specific characteristics of supply chains. Finally, by integrating the sustainable performance measures in the S&OP process, this dissertation expands the scope of S&OP and its potential in supporting companies' performance.

Keywords: Sales and operations planning, Decoupling point, Performance measure, Process industry, Discrete manufacturing industry

Sammanfattning

Syftet med den här avhandlingen är att utveckla ett ramverk för sälj- och verksamhetsplanering (SVP) baserat på ett modulariserat perspektiv på försörjningskedjor. Ramverket är avsett att ge stöd åt både processindustri och diskret tillverkningsindustri i deras strävan mot bättre prestation. SVP lyfts fram i ramverket på grund av dess viktiga roll för integration av olika funktioner inom ett företag och integration av ett företag med andra parter i försörjningskedjan (horisontell integration), koppling mellan olika planeringsnivåer i ett företag (vertikal integration) samt dess påverkan på företags prestation.

Ursprungligen utvecklades SVP som en generisk process även om det var inom ramen för behoven hos diskret tillverkningsindustri. De specifika behoven hos processindustrin har inte betonats i samma utsträckning. För att utveckla ett modulariserat SVP-ramverk för både processindustri och diskret tillverkningsindustri har en systematisk litteraturstudie genomförts för att förstå de specifika kännetecknen för SVP i processindustrin. Ett resultat från den studien är betydelsen av om material är kontinuerliga eller ej och denna egenskaps betydelse för vilken typ av produktionsprocess som krävs. Den här klassificeringen visar att produktionsprocessen i processindustri faktiskt är en hybrid av kontinuerlig produktion och diskret produktion medan diskret tillverkningsindustri vanligen består enbart av diskret produktion. Kontinuerlig produktion har specifika egenskaper som med fördel kan beaktas i SVP-processen men det ligger inte i linje med litteraturen vilken behandlar SVP som en generisk process, d.v.s. som en process som är oberoende av sammanhanget i termer av t.ex. den industri inom vilken SVP implementeras. Detta begrepp behandlas i den här avhandlingen genom att identifiera de behov som kan ses som tillägg till den generiska SVP-processen. Utöver detta identifieras också två andra begrepp kopplade till egenskaper hos produktionsprocessen som är viktiga för planering och styrning, inklusive SVP. Det ena är kopplat till graden av repetitivitet i produktionsprocessen, som reaktion på marknadsbehoven, och det andra är kopplat till vad som initierar produktionsflödet. De tre begreppen är även kopplade till tre olika typer av frikopplingspunkter vilka är utgångspunkt för en typologi som utvecklats och som ger stöd för ett modulariserat perspektiv på försörjningskedjor. Genom att tillämpa typologin på SVP erhålls ett modulariserat SVP-ramverk som är användbart både för processindustri och diskret tillverkningsindustri. Det

modulariserade perspektivet på försörjningskedjor har sedan länge framhållits som ett effektivt sätt att ge stöd åt företags prestation och deras konkurrenskraft. Typologin och SVP-ramverket har båda utvecklats med konceptuella forskningsmetoder.

För att studera hur det modulariserade SVP-ramverket är kopplat till företags prestationsmått är olika prestationsmått (inklusive prestationsmått för hållbarhet) på SVP-nivån inhämtade från litteraturen, klassificerade enligt typologin samt kopplade till strategiska prestationsfaktorer. Genom att samordna prestationsmått på SVP-nivån med strategiska prestationsfaktorer ges stöd för att förbättra ett företags prestation. Prestationsmått för hållbarhet ingår i den här klassificeringen för att ge ytterligare stöd för företags prestation. Slutligen studeras den här klassificeringen av prestationsmått i fyra fallföretag och de empiriska prestationsmåtten kopplas till företagens strategiska prestationsfaktorer och konkurrensstrategier. Resultaten från denna empiriska studie har, i viss utsträckning, verifierat resultaten från klassificeringen av prestationsmått med utgångspunkt i litteraturen.

Den här avhandlingen bidrar till utvecklingen av kunskap inom SVP. Först identifieras tre centrala begrepp inom planering och styrning av tillverkande företag. Därefter undersöks hur SVP bör skräddarsys för de specifika egenskaperna hos företag och deras försörjningskedjor. Det modulariserade SVP-ramverket i den här avhandlingen baseras på de tre identifierade begreppen ovan och ger basen för att uppfylla försörjningskedjors behov genom att bidra med stöd för beslutsfattande, planering samt prestationsmätning för olika moduler. Mer specifikt så undersöker det här arbetet hur SVP bör utformas och implementeras i processindustri vilket inte har studerats i någon större utsträckning tidigare. Den här avhandlingen visar även hur prestationsmått på SVP-nivån kan väljas i linje med egenskaper som är specifika för försörjningskedjor. Slutligen, genom att integrera prestationsmått för hållbarhet, utökas SVP och dess potential för att stödja företags prestation.

Nyckelord: Sälj- och verksamhetsplanering, frikopplingspunkt, prestationsmått, processindustri, diskret tillverkningsindustri

Foreword

I can hardly believe that five years have passed, and I am close to the end of this journey. I would like to express my gratitude to a lot of people who helped me during this process.

First and foremost, I would like to thank my supervisors, Professor Joakim Wikner and Professor Ou Tang, for giving me this opportunity to perform research in my favorite field, and for all of the fruitful discussions and thoughtful comments. Joakim has also been a coauthor in most of my papers, and I am grateful for his endless support and patience.

My dear colleagues in the division of Production Economics, both you who are still here and those who have already graduated and left, thank you for providing a friendly environment and for interesting discussions. I enjoyed my days here with you.

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Olof, thank you for all your help and support during the past year and a half, for always telling me that everything is going to be fine, and cheering me up. Your presence made this time much more enjoyable and exciting.

Finally, I would like to thank my dear family—my parents, and Soheil, Sahar, and Atra—for their endless love and support the whole time. Mom and Dad, thank you for supporting me all my life, trusting me, and believing in me. Regardless of the distances, I always felt your support and presence, and it is the power that makes me go on. This book is dedicated to you.

Sayeh Noroozi

November 2016 – Linköping

List of publications

Dissertation outline

The dissertation, entitled “Sales and operations planning based on a modularized view of supply chains: Supporting process industries and discrete manufacturing industries,” is a summary of the author’s studies in the doctoral research program in the Division of Production Economics, Department of Management and Engineering at Linköping University. The dissertation is divided into two parts: the introductory part and a collection of five papers. The status of the appended papers is presented below.

Paper 1

Noroozi, S. & Wikner, J. 2016b. Sales and operations planning in the process industry: A literature review. Resubmitted for peer review to a scientific journal after a major revision.

An early version of this paper was presented at the EurOMA conference, Dublin, Ireland, June 7–12, 2013.

Paper 2

Wikner, J. & Noroozi, S. 2016. A modularised typology for flow design based on decoupling points – A holistic view on process industries and discrete manufacturing industries. *Production Planning & Control*, 27(16), 1344–1355.

An early version of this paper was presented at the International Conference on Sustainable Design and Manufacturing, Cardiff, Wales, United Kingdom, April 28–30, 2014.

Paper 3

Noroozi, S. & Wikner, J. 2016a. A modularized framework for sales and operations planning with focus on process industries. *Production & Manufacturing Research*, 4(1), 65–89.

An early version of this paper was presented at the 18th International Working Seminar on Production Economics, Innsbruck, Austria, February 24–28, 2014.

Paper 4

Noroozi, S. & Wikner, J. 2017. S&OP related key performance measures with integration of sustainability: A decoupling point based and modularized view on supply chains. In: Brennan, L. & Vecchi, A. (eds.), *International Manufacturing Strategy in a Time of Great Flux* (series: Measuring Operations Performance) (pp. 197–233). Switzerland: Springer International Publishing. ISBN 978-3-319-25350-3.

An early version of this paper was presented at the EurOMA conference, Neuchâtel, Switzerland, June 26 – July 1, 2015.

Paper 5

Noroozi, S. 2016. S&OP related key performance measures with integration of sustainability and decoupling points: A case study approach. Working paper.

An early version of this paper was presented at the 5th World Conference on Production and Operations Management, Havana, Cuba, September 6–10, 2016.

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1. Introduction

Tough competitive environments, globalization, and increased supply chain complexity have highlighted the role of business processes such as sales and operations planning (S&OP) in both academia and industry (Thome et al., 2012a, Tuomikangas and Kaipia, 2014). In general, S&OP is a tactical planning process with the aim of balancing market demands and supply capabilities at an aggregate level (Jonsson, 2011, Tuomikangas and Kaipia, 2014), which supports companies in their efforts to maximize the return on investments (Thome et al., 2012a). Traditionally, S&OP has been considered independent from the context of the industry in which it is implemented. However, to improve performance, it is crucial for the S&OP process to reflect the specific requirements of companies and their supply chains in terms of products, processes, and markets. This dissertation addresses this issue by adapting S&OP for process industries and discrete manufacturing industries based on the characteristics of their supply chains.

1.1. Background

In recent years, tough economic situations (Atkinson, 2009), market uncertainty (Tuomikangas and Kaipia, 2014), the ongoing trend of outsourcing (Klappich, 2012), and globalization (Jonsson, 2011) have put more emphasis on the management of supply chains. These trends have led to longer supply lead-times, shorter delivery lead-times, and shorter product and market life cycles, which, in line with Olhager (2013), demand more complex planning and control systems. Traditionally, the focus of planning and control has been on lower (operational) planning levels. However, during the past 50 years, the focal point has shifted to higher (strategic and tactical) levels due to increased supply chain complexity (Olhager, 2013). A planning process within this context, which has received increased attention during the recent years, is S&OP.

S&OP is the key business process to balance customer demand with supply capabilities (Feng et al., 2013, Tuomikangas and Kaipia, 2014). S&OP is defined as “a process to develop tactical plans that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain” (Blackstone Jr., 2010). S&OP is known as a supply chain integrator (Basu and Wright, 2008) and plays a crucial role in both horizontal and vertical

integration. The role of S&OP in horizontal integration covers coordination among the company's functions as well as their relation with supply chain partners (see e.g. Affonso et al., 2008, Wallace and Stahl, 2008, Thome et al., 2012b, Kjellsdotter Ivert and Jonsson, 2014, Tuomikangas and Kaipia, 2014, Goh and Eldridge, 2015). In this dissertation, however, horizontal integration is mainly considered as the integration of business functions, which is referred to as the internal supply chain by Harland (1996). S&OP also links the strategic plans to the operational plans and provides vertical integration within a company (see e.g. Affonso et al., 2008, Wallace and Stahl, 2008, Thome et al., 2012b, Kjellsdotter Ivert and Jonsson, 2014, Tuomikangas and Kaipia, 2014, Goh and Eldridge, 2015). Due to its role as a supply chain integrator, S&OP usually affects supply chain performance through the management of resources (referring to costs), output (customer responsiveness), and flexibility (responsiveness to changes and uncertainties), which are all vital components of supply chain success (see e.g. Beamon, 1999, Thome et al., 2012a). Therefore, S&OP has an essential role in realizing the supply chain management's goals to fulfill customers' demands with the aim of improving competitiveness (Tuomikangas and Kaipia, 2014) and maximizing profits (Grimson and Pyke, 2007, Wagner et al., 2014).

To increase profits and improve competitiveness, it is important to match the company's supply chains with its products, markets, and processes (see e.g. Fisher, 1997, Childerhouse et al., 2002, Aitken et al., 2003, Towill, 2005, Godsell et al., 2011, Dreyer et al., 2016) and take a segmented (see e.g. Godsell et al., 2011) or modularized view of supply chains. This view emphasizes that a company might need more than one supply chain to support its various products, which are sold in different markets. These different supply chains are viewed as a set of modules in this dissertation. The need for a modularized view of supply chains has been emphasized in the literature. This view implies that companies can modify the management of their supply chains based on, for example, the product and market characteristics (Pagh and Cooper, 1998, Childerhouse et al., 2002, Godsell et al., 2011), and the position of the customer order decoupling point, CODP (Hoekstra and Romme, 1992, Mason-Jones et al., 2000, Wikner and Rudberg, 2005, Wikner, 2014, van Donk and van Doorne, 2016). A modularized view would provide the possibility of configuring a company's supply chains based on standard modules, benchmarking, and information sharing between companies with similar modules. It might not provide unique customized solutions for the companies but largely fits their specific requirements and is cost-efficient. A modularized view of supply chains,

therefore, helps with decreased cost, increased profit, improved competitive positions, and increased efficiency (see e.g. Fisher, 1997, Godsell et al., 2011, Piran et al., 2016), which in turn implies effective and efficient management of supply chains. Considering the crucial role and influence of S&OP in supply chain success, a logical conclusion would be that S&OP should also reflect the specific needs of supply chains. However, S&OP has mainly been considered a generic (Proud, 1999), one-size-fits-all process and, therefore, independent from the context of the industry in which it is implemented. This view of S&OP highlights a conflict: if S&OP's ultimate goal to improve companies' performance and competitiveness is to be met, then it is important for S&OP to reflect the specific needs of companies' supply chains. However, this issue has not been given due attention in the academic debates.

Thome et al. (2012b) have raised this issue and suggest that contextual factors, such as industry type and the position of the industry in the product-process matrix, can be influential at the S&OP level. However, one of the first papers to address this issue indicates that there is no meaningful relation between the product-process matrix and S&OP (Grimson and Pyke, 2007). In recent years, this issue has regained interest due to the need for increased flexibility and responsiveness, as well as the complexity of supply chain networks (Thome et al., 2014a, Kjellsdotter Ivert et al., 2015b). In response to these needs and complexity, different contingency theories have been suggested in relation to S&OP. Examples are manufacturing strategy (see e.g. Wallace and Stahl, 2008, Burrows III, 2012), process complexity (Thome et al., 2014a), and planning environment (Olhager et al., 2001, Olhager and Rudberg, 2002, Kjellsdotter Ivert et al., 2015a). This stream of research suggests that in contrast to the traditional literature, S&OP should not be considered a generic process because it is dependent on the context of the industry within which it is implemented. However, a large part of the literature in this field is still based on the assumption of a generic S&OP process, which was initially developed with the needs of discrete manufacturing industries in mind. The question raised here, therefore, is whether S&OP should be modified when being deployed in other types of industries, for example, in process industries, based on their specific needs and characteristics, in order to support companies' performance and competitiveness. Quite few papers have addressed the implementation of the S&OP process in food industries (see e.g. Kjellsdotter Ivert et al., 2015a, 2015b, O'Reilly et al., 2015). Nonetheless, these papers are focused only on the specific requirements of S&OP in food industries, and their results might not be

fully generalizable and applicable in other types of process industries such as chemical and steel industries. But what differentiates process industries from discrete manufacturing industries, and how should these differences be reflected in the S&OP process?

Discrete manufacturing industries are producers of distinct items, whereas process industries are traditionally defined as “the group of manufacturers that produce products by mixing, separating, forming, and/or performing chemical reactions” (Blackstone Jr., 2010) such as steel, chemical, textile, and food industries. These two types of industries are usually considered mutually exclusive. In general, while developing planning techniques, the focus has been mostly on discrete manufacturing industries. Process industries were lagging behind the discrete manufacturing industries in implementing the planning processes and techniques that match their specific characteristics and needs (Dennis and Meredith, 2000b, van Donk and Fransoo, 2006), specifically at the strategic/tactical planning level (Finch and Luebbe, 1995, Proud, 1999), including S&OP. However, some properties are similar between process industries and discrete manufacturing industries. Abdulmalek et al. (2006) suggest that in the production process of process industries, there is a point at which continuous production turns into discrete production. This point is referred to as the discretization decoupling point (DDP) in this dissertation and emphasizes that process industries actually deploy both continuous production and discrete production. Discrete manufacturing industries, on the other hand, only deploy discrete production. Thus, while continuous production is only applicable to process industries and should be distinguished in the planning processes, discrete production is applicable to both process industries and discrete manufacturing industries and can be used as a common part between these two industries, as illustrated in Figure 1.

	Process industry	Discrete manufacturing industry	
Continuous production	√	—	DDP
Discrete production	√	√	

Figure 1 The distinction between process industries and discrete manufacturing industries

It should be noted that in the APICS dictionary, “continuous production” is used in relation to the continuous flow of material; however, in this dissertation, continuous production is used instead of the term “process manufacturing” to represent an analogy to the phrase “discrete production.” APICS defines process manufacturing as “production that adds value by mixing, separating, forming, and/or performing chemical reactions” (Blackstone Jr., 2010). The term “process manufacturing” thus is more focused on the continuity of materials than just the flow. The concept of DDP can be used as a point of reference in the planning and control of process industries (Pool et al., 2011). This dissertation follows this line of argument and suggests a new approach in the design and implementation of the S&OP process by integrating contextual criteria into S&OP. It also applies the notion of DDP in order to include the specific requirements of both continuous production and discrete production in a combined framework for S&OP, which supports both process industries and discrete manufacturing industries. “Framework” here refers to a combination of two or more concepts for explaining an event and providing understanding (Meredith, 1993). This approach enables S&OP to reflect the specific needs of companies’ supply chains and manage them in an effective and efficient way.

1.2. Purpose and research objectives

As discussed previously, S&OP has mainly been considered as a generic process. Several papers have been published about the generic S&OP process (Grimson and Pyke, 2007, Thome et al., 2012b), S&OP performance measures (Thome et al., 2012a, Thome et al., 2014b, Wagner et al., 2014), and S&OP integration issues (Tuomikangas and Kaipia, 2014). Nevertheless, recent arguments state that S&OP is not a one-size-fits-all process and therefore needs to manage the specific requirements of supply chains in line with the company’s strategic goals; however, this subject has seldom been discussed in the literature. To address these issues, the purpose is defined as follows:

The purpose of this dissertation is to propose a framework for sales and operations planning (S&OP), which is based on a modularized view of supply chains. The framework should support both process industries and discrete manufacturing industries in their quest for performance.

To cover the purpose, three research objectives (ROs) are defined. The ROs are connected to each other logically, and the succeeding ROs build on the results of the preceding ones. Together, the ROs help fulfill the purpose.

One issue barely touched in the literature concerns the implementation of S&OP in process industries. In general, planning and control of process industries has been under focus during the past 30 years (Kallrath, 2002, van Donk and Fransoo, 2006) due to the interest in flexible processing, responsiveness to global markets, and continuation of business competitiveness and sustainable growth (Kopanos et al., 2012). These issues have led to increased emphasis on the importance of tailored planning processes for process industries as well as supply chain integration (Papageorgiou, 2009, Oliva and Watson, 2011). However, the focus has mainly been on lower planning levels (see e.g. Kallrath, 2002), and, except for a few papers that recently addressed the implementation of S&OP in food industries, this subject has not been thoroughly studied in the literature. Thus, the first step to fulfill the purpose of this dissertation is to examine the process industries' operational characteristics and whether they influence the design and implementation of the S&OP process. This issue is addressed in R01.

R01. Identify key characteristics of process industries with implications for S&OP.

R01 is fulfilled through a systematic literature review.

R01 is expected to lead to distinguishing characteristics of continuous production that can influence S&OP in process industries because they are considered hybrids of continuous production and discrete production, separated by DDP. The common discrete production in process industries and discrete manufacturing industries highlights the possible synergies between these two types of industries. However, the literature lacks classifications that take a holistic view and consider the characteristics of both process industries and discrete manufacturing industries. The DDP can be used to integrate both continuous production and discrete production in order to provide a holistic view of planning and control supporting both process industries and discrete manufacturing industries. This approach enables not only the recognition of the differentiating characteristics of the continuous and discrete production in planning and control systems but also the importance of the common discrete production in both process industries and discrete manufacturing industries, which can help in identifying similarities between these two types of industries. Within this context, DDP decouples the materials flow and, through its nature as a decoupling point, indicates the need for different planning techniques and decision-making processes before and after DDP.

However, to suggest a framework for S&OP, DDP alone is not sufficient because it does not provide information on the process and market interaction. Therefore, DDP should be combined with other criteria that are considered important in the planning and control context and can support the modularized view of supply chains. In combination, therefore, they form an S&OP framework that is general enough to apply to different industries, yet flexible enough to be tailored to the specific characteristics of each company based on the specific needs of their supply chains as formulated in R02.

R02. Identify the key criteria in planning and control, which, in combination with the key characteristics of process industries, provide a modularized view of supply chains, and investigate the applicability of these criteria in S&OP of process industries and discrete manufacturing industries.

R02 is fulfilled through conceptual research methods.

R02 is expected to result in a modularized S&OP framework that reflects the specific needs of supply chains. The final step to cover the purpose is to study how this modularized S&OP framework can help effectively and efficiently support the company's performance. The relation between S&OP, with regards to its role as a horizontal and vertical integrator, and the company's performance has been under focus recently. Nonetheless, further research is required to investigate how the supply chain requirements should be reflected in S&OP to support performance (see e.g. Feng et al., 2008, Thome et al., 2012a, Thome et al., 2014b, Tuomikangas and Kaipia, 2014, Wagner et al., 2014) and how the modularized S&OP can be used to identify performance measures for different companies based on the needs of their supply chains. This issue is addressed in R03.

R03. Investigate how the modularized S&OP framework can be used in relation to companies' performance measures.

R03 is fulfilled through conceptual research and case study methods and is expected to result in a classification of performance measures based on a modularized view of supply chains.

Table 1 shows the relation between the ROs and the constructs of purpose, namely S&OP, modularized supply chains, process industries, discrete manufacturing industries, and performance.

Table 1 Relation between the purpose and research objectives

Research objectives	Constructs of purpose				
	S&OP	Modularized supply chains	Process industries	Discrete manufacturing industries	Performance
R01	√	√	√	√	
R02	√	√	√	√	
R03	√	√	√	√	√

Figure 2 The relation between the research objectives and the papers

Figure 2 illustrates the relation between the ROs and the appended papers. In Figure 2, boxes show the papers’ numbers and their main results, which are used as an input to the succeeding papers. The arrows represent the information flow between the papers, and the dashed lines around the papers indicate the relation between the papers and the ROs.

The rest of the dissertation is as follows. It starts with the methodology chapter describing the research process and the methods used to conduct this research. It then continues with the frame of references to discuss the applied concepts and ends with the summary of research results, conclusion, and further research ideas. The five papers are attached as an appendix.

2. Methodology

The relation between the ROs, papers, and methods used for each paper to fulfill the ROs are presented in Table 2 and further explained in the continuation of this chapter.

Table 2 Methods applied in each paper in relation to the research objectives

Research objectives	Papers	Methods
RO1	Paper 1	Systematic literature review
RO2	Paper 2	Conceptual model: Typology
	Paper 3	Conceptual framework: Conceptual deduction
RO3	Paper 4	Conceptual framework: Conceptual deduction
	Paper 5	Multiple case study

The next section discusses the specific research process followed during this study. This chapter then continues with the research methods applied in this dissertation, namely theory building and case study. This is followed by a discussion of the data collection methods related to these research methods. The chapter ends with a discussion on the research quality.

2.1. Research process

This section discusses a phased approach of how the research in this dissertation was conducted and ends with the author's contribution in the appended papers.

2.1.1. A phased approach

This study has been performed in two successive phases as shown in Figure 3. The first phase includes the pre-study and the conference version of the first three papers, which led to the licentiate thesis. During this time, the study was mainly focused on S&OP in process industries. The research during this time was performed within the Process Industry Center (PIC), which was a research and competence development center funded by the Swedish Foundation for Strategic Research (SSF). PIC had two centers: PIC-LI at Linköping University, which was focused on operations management, optimization

theory, and automatic control, and PIC-LU at Lund University, which worked on automatic control and chemical engineering issues. These two centers also cooperated in a joint research project called PIC-opic. The first phase of this research was part of the PIC-opic project in PIC at Linköping University. PIC formally ended in spring 2014.

Conf.: Conference version, Jour.: Journal version

Figure 3 Research process

Phase 1 started with a pre-study covering the manufacturing planning and control system in a food manufacturer. The results of the pre-study highlighted the importance of S&OP with regard to its role in linking different planning levels. During this time, an initial literature search was also performed to find models or frameworks regarding the implementation of S&OP in process industries, but the search did not achieve any results, which implied the gap in the literature within this subject. The conclusion was that S&OP has been developed based mainly on the characteristics of discrete manufacturing industries, and a model that integrates both process industries and discrete manufacturing industries was missing. To address this gap, the first step was to study the characteristics of S&OP in process industries and then take the next step to find synergies between process industries and discrete manufacturing industries to act as a basis for an S&OP framework as highlighted in the purpose, RO1, and RO2 in section 1.2.

As shown in Figure 3, after the pre-study, a literature review was conducted in Paper 1 to provide a firm foundation for future research and to identify the gaps in the field. As a result, DDP and S&OP characteristics with regard to the specific properties of continuous production in process industries have been identified. DDP is related to object type, that

is the physical properties of the flow object which is transformed in the production process. In addition to DDP, two other concepts have also been identified as important in suggesting an S&OP framework: control mode, which is concerned with the repetitiveness of the production process in response to the market demand, and flow driver, which defines the trigger of the material flow. These three aspects (object type, control mode, and flow driver) constitute the core of the suggested modularized typology in Paper 2. To define the modularized S&OP framework for both process industries and discrete manufacturing industries, the typology has been applied to S&OP in Paper 3.

In the second phase, the intention was to study how the suggested S&OP framework is related to the performance of companies. To fulfill this part of the purpose and in line with RO3, the focus was on the key performance measures (including sustainable performance measures) at the S&OP level with regard to the modularized S&OP framework and the relation between the performance measures and the strategic performance attributes and therefore, competitive strategies that companies might follow. This subject was first studied based on the available literature in Paper 4, where a classification of performance measures for process industries and discrete manufacturing industries is suggested. Then, an empirical study in the form of a multiple case study was performed in Paper 5 to gather the performance measures practically used in both process industries and discrete manufacturing industries performing in Sweden as well as to examine the results of Paper 4. The second phase of the research was part of the strategic innovation program Process Industrial IT and Automation (PiiA) funded by VINNOVA, the Swedish Energy Agency, Formas, and the Swedish industry, in relation to a project about key performance measures in the Swedish process industries. In this phase, the first three papers were developed into journal papers as well.

2.1.2. Author's contribution

The author's contribution in different papers is as follows. Papers 1, 3, and 4 were coauthored with Professor Joakim Wikner. The author of this dissertation had the leading role in all these papers in data collection, data analysis, and writing process. The coauthor supported the process via structuring the papers and analyzing the results. In Paper 2, which provides input to all the succeeding papers and is partly based on Paper 1, Professor Joakim Wikner had the leading role in conducting the research and writing process. The author of this dissertation contributed by positioning the paper in the body

of literature. All these papers are interrelated, and the authors had extensive discussions together while developing them. In Paper 5, the author of this dissertation was the sole author. Professor Joakim Wikner attended the interviews, but all other parts of the research, that is, data collection (except interviews), data analysis, and writing process, were performed by the author of this dissertation.

2.2. Research strategy

Three different sets of logic have been suggested to define the relations between theory and research in terms of building arguments: deduction, induction, and abduction (Karlsson, 2009, Brayman and Bell, 2011). The deductive approach suggests hypotheses based on present theories and examines them through empirical observations to conclude whether they are verified (Karlsson, 2009, Brayman and Bell, 2011). The inductive approach, on the other hand, starts with the empirical observations and tries to build the theories (Karlsson, 2009, Brayman and Bell, 2011). The abductive approach is a combination of induction and deduction and enables the researcher to move back and forth between empirical observations and existing theories in order to suggest new theories (Kovács and Spens, 2005). All these approaches aim to suggest theories and create knowledge.

Another widely used classification of research strategy is focused on qualitative and quantitative methods (Brayman and Bell, 2011). According to Karlsson (2009), a qualitative approach is concerned with interpretation, perception, and interaction in data collection and analysis, whereas a quantitative approach is mainly based on mathematical and statistical tools in data gathering and analysis.

Considering the research in this dissertation, it suggests a typology and frameworks based on the available theories in the literature with the intention to verify these suggestions based on empirical data from a multiple case study; thus, it is in line with the deductive approach. While building the typology and frameworks, this dissertation is focused mainly on definitions, interpretation, and interaction between different terms and concepts, which indicates its qualitative nature. The data collection and analysis of the gathered data from the case companies have followed a qualitative approach as well.

2.3. Theory building

The two general objectives of research are theory-building and fact-finding (Wacker, 1998). While the purpose of theory-building research is to suggest an integrated body of knowledge applicable to many instances, the fact-finding research aims to gather facts under specified conditions and then build a lexicon upon them (Wacker, 1998). Comparing the dissertation's approach with these definitions reveals a theory-building nature because it aims to suggest an S&OP framework that is applicable to many instances, that is, process industries and discrete manufacturing industries.

Numerous references have been published on the subject of theory building (see e.g. Bacharach, 1989, Eisenhardt, 1989, Weick, 1989, Meredith, 1993, Weick, 1995, Wacker, 1998, Meredith, 2001, Wacker, 2004, 2008, Schroeder, 2008). Among these, the papers by Meredith (1993) and Wacker (1998) are quite compatible and have been widely referred to by other researchers (see e.g. Forza, 2002, Voss et al., 2002, Shah and Ward, 2007, Carter and Rogers, 2008, Schroeder, 2008, Seuring and Müller, 2008); therefore, they are used as guidelines in this dissertation.

Theory-building has been the main method to cover RO2 and RO3. This dissertation does not claim to build a theory but to suggest a framework. The difference between the two lies in the fact that a framework is considered as a pre-theory, which may substitute for a theory in many ways but does not cover all the requirements for a theory (Meredith, 1993). This issue is explained further in section 2.3.2.

2.3.1. Theory-building research

Theory is defined as “an explained set of conceptual relationships” (Wacker, 2008), “a coherent group of interrelated concepts and propositions used as principles of explanation and understanding” (Meredith, 1993), and “a statement of relations among concepts within a set of boundary assumptions and constraints” (Bacharach, 1989). According to Wacker (1998) and Meredith (2001), a theory should include four parts:

- i. Description/definition: Definition of terms, which is related to who and what research questions;
- ii. Domain: Related to when and where research questions;
- iii. Explanation/understanding of relationships: The relationships between the terms, which is related to how and why research questions;

- iv. Predictions: Related to what would, should, and could happen as the result of the theory.

Note that, in this dissertation, instead of research questions that are more applicable in empirical studies (see e.g. Yin, 2009), research objectives have been used in line with the theory-building conceptual research. The research objectives cover the same scope with regard to the definition of theory—about what, who, when, where, how, and why—but only with different phrasing.

Different types of theory-building research are shown in Figure 4. The methods used in this dissertation are highlighted in the figures in this chapter. This dissertation is based on an analytical conceptual research, which, in line with MacInnis (2011), means that it uses deductive arguments and aims to provide new insights on the theories already existing in the body of literature. In other words, the concepts of flow design, S&OP in process industries and discrete manufacturing industries, and performance measures used as bases in this study have already been covered in the literature to some extent, and this dissertation integrates these concepts and suggests a new insight about them. Note that even though the final paper in this dissertation uses the case study method, because this method is not used to build a theory inductively, the related boxes (i.e., empirical and case studies) are not highlighted in Figure 4.

Figure 4 Theory-building types of research (based on Wacker, 1998)

2.3.2. Conceptual research methods

Meredith (1993) has introduced seven methods for conceptual research ranked in explanatory power as illustrated in Figure 5. The first three, classified under conceptual

models, are the most basic regarding the explanatory power (Meredith, 1993). The second three, classified under conceptual frameworks, are a collection of several interrelated concepts that attempt to provide explanation and understanding. The last one, classified as theories, is the final stage where theories are built (Meredith, 1993).

Figure 5 Conceptual research methods (based on Meredith, 1993)

As mentioned earlier, frameworks are considered as pre-theories and may well substitute for theories in many ways, but they do not cover all the requirements a theory should have (Meredith, 1993). For example, a framework might have defined attributes or variables but have not fully explained the interrelations between them (Weick, 1989). As shown in Figure 5, this dissertation suggests a framework and not a theory in that it does not provide a full explanation of interrelations between the variables, and it has not been implemented in the real world, which might lead to its falsification (Wacker, 2008). For more information about the requirements of a theory, readers are referred to Weick (1989, 1995), Meredith (1993), and Wacker (1998, 2004, 2008).

As highlighted in Figure 5, the conceptual research methodologies used in this dissertation are taxonomies and typologies, and conceptual deduction, in relation to R02 (Paper 2 and Paper 3) and partly R03 (Paper 4). According to Meredith (1993), taxonomies are defined as “listings of items along a continuous scale.” Typologies then include two or more taxonomies on different dimensions (Meredith, 1993). The result of the first part of R02 (presented in Paper 2) is a modularized typology based on flow design, including the three dimensions of object type, control mode, and flow driver.

Conceptual deduction, on the other hand, suggests a framework, provides detailed predictions that can be used for comparison with reality, and provides managerial insights and guidelines (Meredith, 1993). The second part of R02 (covered in Paper 3) is a conceptual deduction because it provides a modularized framework combining the object type, the control mode, and the flow driver with S&OP and describes the relationships between them. It also includes managerial insights on the implementation of the framework, which covers the design phase before the implementation of S&OP. R03 (covered in Paper 4) is also a conceptual framework for performance measures because it combines the modularized S&OP framework from R02 with the performance measures and competitive strategy literature and suggests a new classification for the performance measures at the S&OP level. The analysis of the combined influences of these concepts on strategic performance attributes and competitive strategies provides managerial implications about how to choose the performance measures based on the specific needs of a company's supply chains and in line with its competitive strategy in order to support the performance.

2.4. Case study

Case studies can be used for research when the phenomenon is studied in its natural setting to gain knowledge about the how, what, and why of the phenomenon; when the control of the researcher on events is restricted; and when the events are contemporary in the actual circumstances (Voss et al., 2002, Yin, 2009). The case study is defined as an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Yin, 2009), and can be used for exploration, theory building, theory testing, and theory extension/refinement (Voss et al., 2002). In line with Voss et al. (2002) and Eisenhardt (1989), the following steps have been suggested for conducting a case study:

- Defining the research framework;
- Selecting cases: single or multiple cases, number of cases;
- Defining data collection methods and research protocol: single or multiple interviewees, protocol piloting;
- Conducting the field research: the role of interviewees in a company, field data collection, interviews, data storing, seeking clarification;

- Documenting the gathered data;
- Performing analysis: within-case analysis, cross-case analysis.

Case study design is not limited to the study of only one case, and “multiple case study” is very common in business and management research (Brayman and Bell, 2011) and recommended when enough case companies and resources are available. This is due to the benefits that can be gained when performing the case study as well as in the analysis phase (Yin, 2009). Analytic conclusions are more powerful because the probability of unique or exceptional case conditions is lower in multiple case studies (Yin, 2009). It also helps in decreasing the researcher’s bias (Voss et al., 2002). More information about the case study can be found in Paper 5.

This method has been used in this dissertation in relation to R03 (presented in Paper 5), which aims to gain what, why, and how information in relation to practical performance measures being used in companies and their links to companies’ performance attributes and competitive advantages. This is in line with Paper 4 in which a framework has been suggested for classification of performance measures by using conceptual methods and based on the literature. As the next step, this framework is examined through a multiple case study to analyze whether the results from the empirical data match the results from the conceptualization. This approach is in line with theory testing (Voss et al., 2002).

2.5. Data collection methods

The data collection methods frequently used in this work, in relation to conceptualization and case study, are literature review and interview, which are discussed below.

2.5.1. Literature review

Literature review is a fundamental part of all types of research (Tranfield et al., 2003, Croom, 2009) and is defined as “a process of reading, analyzing, evaluating, and summarizing scholarly materials about a specific topic” (Fink, 2013). Literature review is a commonly used data collection method in conceptual research because providing new insights and guidance into the conventional problems in the literature is one of the main aims in this type of research (Wacker, 1998). In addition, literature review helps in identifying the gaps in the literature, in authenticating and authorizing the research, and in justifying the potential contributions of the research with regard to the previous

literature (Croom, 2009). Therefore, literature review provides a firm foundation for performing research.

Two types of literature review are systematic literature review and narrative review. The systematic literature review is distinguished from the narrative review in that the former aims to take a scientific, transparent, and replicable process through an extensive literature search in order to minimize the bias inherent in the narrative reviews (Tranfield et al., 2003, Thome et al., 2016). The systematic literature review has been used in this dissertation to fulfill RO1 (presented in Paper 1), and the results of this paper have been used in Paper 2 and Paper 3. Less formal literature reviews have also been performed to gather additional information related to Paper 2 and Paper 3. For the systematic literature review, the process suggested by Tranfield et al. (2003) was practiced as follows:

- Planning the review
 - Identify the need for a review.
 - Prepare a proposal for a review.
 - Develop a review protocol.
- Conducting a review
 - Identify the research.
 - Select the studies.
 - Assess the quality.
 - Take notes and extract data.
 - Synthesize the data.
- Reporting and dissemination
 - Report the results of the review.

The synthesizing process used in relation to RO1 is “meta-ethnography”, which is used in qualitative research (Tranfield et al., 2003, Thome et al., 2016). In this process, a synthesis is defined, and then the reviewed references are compared to the synthesis as well as to each other (Brayman and Bell, 2011). Three synthesizing methods are defined in relation to meta-ethnography: “refutational synthesis which can be used when reports give conflicting representations of the same phenomenon, reciprocal synthesis which can be used when reports address similar issues, and lines of argument synthesis which can be

used if different reports examine different aspects of the same phenomenon” (Tranfield et al., 2003). To cover RO1, reciprocal synthesis has been used because the reviewed references address similar issues, that is, S&OP.

A narrative review, on the other hand, is defined as a “comprehensive narrative synthesis of previously published information,” which often discusses different concepts and is suitable for providing new insights (Green et al., 2006). A paper based on narrative literature review should provide sources of information, search terms, selection criteria, and results (Green et al., 2006). This review method has been used with regard to RO3 (presented in Paper 4) because this paper deals with integrating different concepts in the literature, and, therefore, systematic literature review is challenging to perform due to its complexity (Baumeister and Leary, 1997).

2.5.2. Interview

Interviews are considered a primary data collection method and a very important source of data in case studies (Eisenhardt, 1989). Three approaches can be followed in interviews: in-depth interviews, focused interviews, and surveys (Yin, 2009). In the in-depth interview, the interviewee might be asked about facts as well as his or her point of view about the topic of the study. In this type, the interview is similar to a guided conversation, and the interviewee can suggest new people or introduce related documents (Yin, 2009). On the other hand, the focused interview more likely follows a structured and rigid set of questions within a limited time frame (Yin, 2009). Surveys can also be used as part of a case study to produce quantitative data. They usually contain a more rigid set of questions in comparison to the focused interview.

In this study, focused interviews were used to gather data for RO3 (presented in Paper 5). A structured document with questions and instructions was prepared and discussed with the interviewees in a limited amount of time. Of course, the interviewees could discuss their opinion about the subject and introduce documents, but this was limited, and most of the results presented in Paper 5 are based on the direct answers to the questions. When uncertain about an answer, the interviewees were contacted again to seek clarification.

2.6. Research quality

The research quality is discussed in terms of validity and reliability, both of which are critical factors in scientific research. In line with Voss (2009), Yin (2009), and Brayman

and Bell (2011), different types of validity (internal, external, and construct) and reliability (internal and external) are defined for qualitative research. Internal validity shows whether or not the observations and the developed theories are in line, while external validity discusses the generalizability of developed theories (Brayman and Bell, 2011). Construct validity refers to “identifying correct operational measures for the concept being studied” (Voss, 2009, Yin, 2009). Internal reliability is concerned with the level of agreement between the researchers when more than one researcher is involved in the process, and external reliability discusses whether the research is reproducible (Brayman and Bell, 2011). The quality of research for the methods used in this dissertation (i.e., conceptual research and case study) is discussed below.

2.6.1. Conceptual research

Conceptual research in general is credited for its high external validity (Meredith, 1993); however, the degree of generalizability differs between different theories (Wacker, 2004) and is dependent on whether a theory holds true “in a broad range of specific instances” (Weick, 1989). The typology and frameworks suggested in this dissertation are designed to be applicable to process industries and discrete manufacturing industries and, therefore, cover a broad range. However, as mentioned earlier, this dissertation does not claim to build/suggest a theory. The construct validity in relation to conceptual research is concerned with the empirical test of the concepts, which, in this dissertation, is partly realized through the case study by observing whether predictions made about relationships between different concepts and variables are confirmed by the cases. Due to the deductive approach followed in the conceptualization process, the internal validity is not applicable in this research.

Internal reliability is applicable because the papers dealing with conceptual methods (Papers 2, 3, and 4) were written by two authors. To improve the internal reliability, the authors had extensive discussions and information sharing sessions in different phases of idea generation, research, and reporting the results. Regarding the external reliability, the research process is replicable through conducting the reviews and analysis. It can be argued that logical reasoning and the deductive approach provide the possibility to replicate the research; however, if theory building is considered a creative process or, as Weick (1989) suggests, a “disciplined imagination”, it is possible that different

researchers follow different mind maps and end up with differentiated ideas and frameworks.

2.6.2. Case study

In line with Voss (2009) and Yin (2009), construct validity for the case study is realized through confirmation of the paper draft by the interviewees and use of multiple sources of data, such as theses and documents, during the data gathering. In line with Yin (2009), the internal validity is realized through comparison of the results with predictions and the explanation of how and why. Case studies are usually considered to provide generalizable results, which is referred to as external validity by Yin (2009). Case studies usually deal with analytic generalization, thus it is possible to generalize some results of the case study to a broader context. A multiple case study is preferred to a single case study within this context because it provides better external validity. In this dissertation, a multiple case study was performed; however, due to the limited number of cases, the results can be generalized to some extent by considering the background.

The two other aspects are external and internal reliability. Regarding external reliability, Yin (2009) suggests that by following the same case study protocol as used in this study, the same results might be achieved. Internal reliability in the case study performed in this dissertation is realized through having two interviewers perform the interviews and subsequently consensus-building, which is in line with Voss (2009).

Note that this part of the methodology is only related to Paper 5; therefore, there might be some similarities between the paragraphs above and Paper 5.

3. Frame of references

This chapter describes the concepts that build the foundation of this dissertation. It starts with a general discussion about supply chain and then continues with the flow design criteria that provide the basis for a modularized view of supply chains. The chapter then focuses on issues related to planning and control of supply chain activities through S&OP and closes the loop by discussing the performance measures.

Table 3 The relation between the frame of references and the purpose

Concepts		Constructs of purpose				
		S&OP	Modularized supply chains	Process industries	Discrete manufacturing industries	Performance
Supply chain Section 3.1	Supply chain management		√			
	Planning and control	√		√	√	
Flow design Section 3.2	Object type		√	√	√	
	Control mode		√	√	√	
	Flow driver		√	√	√	
S&OP Section 3.3	Definition and process steps	√				
	Benefits and measures	√				√
Performance measures Section 3.4	Measuring competitive advantage					√
	Performance measurement frameworks					√
	Sustainable performance measures					√

As shown in Table 3, these concepts are in line with the constructs of the purpose. In Table 3, the relations between the concepts covered in this chapter with the purpose of this study are illustrated with $\sqrt{}$. Some relations are obvious; for example, S&OP as a construct of purpose is discussed in a section with the same heading. In defining the terms, the APICS dictionary is used as one of the main sources in this dissertation because its definitions are based on accumulated knowledge from a worldwide acknowledged community and are used by many researchers to provide comprehensive and clear definitions (see e.g. Feng et al., 2008, Thome et al., 2012b, Kjellsdotter Ivert and Jonsson, 2014, Kjellsdotter Ivert et al., 2015b).

3.1. Supply chain

The APICS dictionary defines supply chain as “the global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash” (Blackstone Jr., 2010). This definition emphasizes three different flows, namely, material flow, information flow, and cash flow, among which the material flow is the focus of this study. The supply chain includes a focal actor collaborating with its group of partners, such as supplier actors upstream, customer actors downstream, and competitors. These actors might belong to the same or different legal, physical, and logical entities, but they have one characteristic in common—they create value in the supply chain through provision of products or service (Wikner, 2014). Because service industries are not included in this study, the focus here is on manufacturing companies. Early references on this subject divide the manufacturing companies into two groups of continuous/bulk/non-discrete producers and discrete item producers (see e.g. Wild, 1971, Constable and New, 1976, Finch and Luebbe, 1995), which today are recognized as process industries and discrete manufacturing industries, respectively. In this part, the general concepts about supply chain management and the relevant planning approaches are discussed.

3.1.1. Supply chain management

The management of the supply chain addresses “the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally” (Blackstone Jr., 2010) with the ultimate

goal of creating value for the customers in the form of products and services (Stadtler, 2008).

According to Harland (1996), supply chain management can vary in scope and refer to the management of the following: a) an internal supply chain focused on integrating business functions; b) a dyadic supply chain covering the relation between a focal actor and its immediate supplier actors; c) an external chain covering the relation between a focal actor and its tiers of supplier actors and customer actors (a simpler version is referred to as a triad supply chain, which only considers one supplier actor and one customer actor in relation to the focal actor; see Choi and Wu, 2009); and d) a network of interconnected partners, that is, several external chains. In this dissertation, and in line with Harland (1996), mainly the internal supply chain and in one paper the external supply chain are under focus. The management of supply chains is built on two main building blocks: integration and coordination (Stadtler, 2008). The integration aspect deals with leadership, partners' selection, and collaboration with partners and has been emphasized in the literature by, for example, van Donk and van der Vaart (2005) and Feng, et al. (2008). The collaboration with partners, as used in this dissertation, is further discussed in section 3.3. The coordination aspect is concerned with the use of information technology, orientation, and planning (Stadtler, 2008). The planning function, which is the building block of this dissertation, is further discussed in section 3.1.2.

It has been long known that the competitive power is within the supply chains and not the companies (Christopher, 1998); thus, companies compete not only on internal efficiency but also the efficiency of their supply chains (Olhager and Selldin, 2004). However, in their networks, companies deal with more than one supply chain, and some researchers have emphasized that companies should tailor their supply chains based on, for example, delivery lead-time, demand uncertainty and variability, demand volume, product life cycle stage, product variety, product and market characteristics (Fisher, 1997, Pagh and Cooper, 1998, Childerhouse et al., 2002, Aitken et al., 2003, Godsell et al., 2011), and position of the CODP (Hoekstra and Romme, 1992, Mason-Jones et al., 2000, Wikner and Rudberg, 2005, Wikner, 2014, van Donk and van Doorne, 2016). This point of view is stressed in this dissertation as a modularized view of the supply chains. The ability of a company to distinguish and manage its supply chains is key to competitiveness (Olhager, 2013). This dissertation follows this point of view and studies how the modularized view

of supply chains can be embedded in different planning processes, specifically in the S&OP process to support the performance of companies in an effective and efficient way. The modularized view of supply chains is emphasized through the concept of flow design in this work and is further discussed in section 3.2.

3.1.2. Planning and control

Planning supports the numerous decision-making activities that must be dealt with for a supply chain to function properly (Fleischmann et al., 2008). The planning activities can be studied based on control and time perspectives. From the control perspective, the three levels of strategic, tactical, and operational are distinguished. The strategic level addresses activities in relation to the company's objectives, which affect its position in the business environment (Gorry and Morton, 1971, Finch and Luebbe, 1995, Jonsson and Mattsson, 2009, Blackstone Jr., 2010). The tactical level activities aim to provide the tactical plans such as sales, production, distribution, and so on, along with balancing different functions in the company to achieve the intermediate objectives and support the strategic level goals, while the operational level is concerned with breaking down the tactical plans to the detailed schedules of day-to-day activities (Gorry and Morton, 1971, Finch and Luebbe, 1995, Jonsson and Mattsson, 2009, Blackstone Jr., 2010). The strategic, tactical, and operational levels cover different time horizons: long-term, medium-term, and short-term, respectively. Long-term planning is responsible for providing resources to meet the future needs of the business in line with the desired position of the company in the market (Taylor and Bolander, 1994, Finch and Luebbe, 1995). In addition, long-term planning is involved in the design of the company's supply chains based on future market needs (Fleischmann et al., 2008). Medium-term planning aims to balance demand and supply in a way to support the main operations, and the short-term planning addresses the detailed instructions for all the activities on a daily basis (Fleischmann et al., 2008). In a hierarchical structure, the higher planning levels provide instructions and limitations to the lower planning levels, and the lower planning levels provide feedback to the higher planning levels (Fransoo, 1993, Kallrath, 2002, Feng et al., 2008, 2010, O'Reilly et al., 2015). In line with the discussion above, the dissertation is about S&OP and thus mainly deals with the tactical planning level with a medium-term horizon (see section 3.3), but it also includes the links between the tactical and the strategic levels (see section 3.4) as part of the S&OP process and to support performance and competitiveness.

Considering planning and control of the process industries and discrete manufacturing industries, which are under study in this dissertation, it should be mentioned that operations management research has been focused on discrete manufacturing industries to a large extent and had not paid much attention to process industries until the 1980s (Kallrath, 2002, van Donk and Fransoo, 2006). As a result, most of the planning processes have been designed with the needs of discrete manufacturing industries in mind. This fact has caused process industries to lag behind the discrete manufacturing industries in the implementation of manufacturing planning processes that match their specific characteristics and requirements (Dennis and Meredith, 2000b), specifically at the strategic/tactical planning level (Finch and Luebbe, 1995, Proud, 1999), including S&OP. This issue is the focal point in this dissertation.

3.2. Flow design

Globalization, shortened product life cycles, and the increasing cost of manufacturing have put more emphasis on the design, management, and analysis of supply chains (Beamon, 1998, Garcia and You, 2015). In this context, design is a key activity because it sets the baseline for the execution of activities in the supply chain. The design of supply chains has mainly been based on geographical aspects (see e.g. Mello et al., 2012), which reflects the location of sites, the locations of customer and supplier actors, layouts, available transportation modes, and so on. One issue that has not been highlighted enough in this context is the flow design (based on the flow logic), which addresses the transformation process. The flow design provides the information about the key decision categories that are essential in decision-making in flow management and, consequently, in the planning of supply chains (Wikner, 2014). In line with the APICS dictionary, flow management, that is, the actual transformation of materials during the production process through decoupling points, implies the recognition of discontinuities in terms of decoupling points between processes (Blackstone Jr., 2010, Noroozi and Wikner, 2017). Wikner (2014) suggests that a decoupling point is related to a particular decision category. A decision category deals with a certain aspect of decision-making, meaning that it is based on a specific criterion that might have different characteristics in different parts of the flow, and the point where the properties change is referred to as a decoupling point (Noroozi and Wikner, 2017, Wikner, 2014). Consequently, different managerial

approaches and planning decisions are required at each side of the decoupling points (see e.g. Giesberts and Tang, 1992, van Donk, 2001, Soman et al., 2004).

In this dissertation, three decision categories, also referred to as flow dimensions, of particular interest for flow design and management are stressed. These three flow dimensions, first introduced by Constable and New (1976) and later emphasized by other researchers, are object type, which is related to the physical properties of the product (see e.g. Finch and Luebbe, 1995, Wild, 1971, Abdulmalek et al., 2006); control mode, which studies the flow of material from the time perspective or repetitivity (see e.g. Wild, 1971, McCarthy, 1995, Arnold et al., 1998, MacCarthy and Fernandes, 2000); and flow driver, which is related to the trigger of flow (see e.g. Constable and New, 1976, Hoekstra and Romme, 1992, Porter et al., 1999, Olhager and Rudberg, 2002). These dimensions are related to DDP, control mode decoupling point (CMDP), and CODP, respectively. The three dimensions are explained further below. These three flow dimensions and their respective decoupling points are used in this dissertation to conceptualize a modularized view of supply chains in order to distinguish the specific needs of each module and reflect their related managerial implications.

3.2.1. Object type

The objects transformed in the flow can be of different types. The transformed material (here referred to as object) can be discrete or continuous/bulk/non-discrete (Finch and Luebbe, 1995, Wild, 1971). Discrete manufacturing industries are defined as the producers “of distinct items such as automobiles, appliances, or computers”, and process industries are defined as the “manufacturers that produce products by mixing, separating, forming, and/or performing chemical reactions” (Blackstone Jr., 2010). The discrete manufacturing industries only deal with discrete objects during the transformation processes and thus deploy only discrete production. In contrast to discrete manufacturing industries, the process industry is not defined by the complete transformation process but rather by the fact that some parts of the transformation are based on the continuous production of continuous objects, while other parts can be based on discrete production (Wikner and Noroozi, 2016). In this dissertation, the term “continuous production” is used instead of “process manufacturing” to provide an analogy with discrete production. Process manufacturing is defined in the literature as adding “value by mixing, separating, forming, and/or performing chemical reactions” (Blackstone Jr., 2010). This means that

process industries are hybrids and deploy both continuous and discrete production, whereas discrete manufacturing industries deploy only discrete production. Consequently, an object being transformed in the flow can be either continuous or discrete (Abdulmalek et al., 2006). Therefore, there is a point in the production process of process industries where continuous objects turn into discrete objects, and discrete products are produced (Woodward, 1965, Finch and Luebbe, 1995, Dennis and Meredith, 2000a, Abdulmalek et al., 2006, Abdulmalek and Rajgopal, 2007, Lyons et al., 2013). This point is referred to as the point of discretization by Pool et al. (2011), but in this dissertation, it is termed DDP to emphasize its nature as a decoupling point. DDP emphasizes the transformation of the physical attribute of the product from uncountable continuous to countable discrete (Abdulmalek et al., 2006). The discrete objects are the output of a transformation process, which implies that DDP is related to a resource that performs transformation (and not a stock point). DDP also implies that continuous production and discrete production are deployed before and after DDP, respectively. Thus, while discussing the differentiating characteristics of continuous production and discrete production, the continuity of the object plays an important role because it affects the choice of the production processes and consequently the choice of resources (Fransoo and Rutten, 1994, Noroozi and Wikner, 2013).

This concept is used in this dissertation as a point of reference in the planning and control approach and in order to distinguish the differences between process industries and discrete manufacturing industries through the specific requirements of continuous and discrete production. In addition, the discrete production in both these industries is used as a common part to integrate concepts from discrete manufacturing industries with concepts from process industries in the suggested S&OP framework.

3.2.2. Control mode

To control the flow of objects, not only the demand pattern but also the way the company responds to the demand in terms of frequency of production are influential (Finch and Luebbe, 1995, Arnold et al., 1998). The company's response depends on different factors, such as volumes required, frequency of requirements, and the set-up time needed to change between different products on a resource. Thus, the control mode is related to the planning and control of transformation processes on flow objects. In line with Wild (1971), and based on the repetitiveness (MacCarthy and Fernandes, 2000) of the

transformation process, three modes are identified: onetime, intermittent, and continuous.

Onetime mode is used when the demand is non-recurring and irregular, the product is complex, and the lead-time is long (Jacobs et al., 2011). It defines the performance of a unique transformation at a time such as production of a bridge or a building. Usually, the project management techniques are applicable in onetime mode (MacCarthy and Fernandes, 2000), and this mode is mainly applicable in discrete manufacturing industries. The intermittent mode is applicable when the demand is recurring, the object flows at time intervals, and the transformation is done in batches, lots (Arnold et al., 1998), or, as applicable in process industries, campaigns (Taylor and Bolander, 1994). The main reason for deploying intermittent mode is set-up time, which inhibits the use of continuous mode (Olhager and Rudberg, 2002). Planning techniques, such as process flow scheduling for the continuous production part of process industries (Taylor and Bolander, 1994), and time-phased techniques, such as MRP for discrete production (MacCarthy and Fernandes, 2000), are suitable for intermittent mode. Continuous mode is applicable when the demand is high and homogenous, the products flow continuously through the processes, and the time gap between successive units is negligible (Jacobs et al., 2011). In this mode, the set-up time can be neglected if there is only one object or if no set-up is required between the successive objects (e.g., within a product family). The rate-based planning techniques are applicable in continuous mode (MacCarthy and Fernandes, 2000), and this mode is applicable in both process industries and discrete manufacturing industries. Different control modes (if applicable) in a transformation process are separated by CMDP.

3.2.3. Flow driver

So far, the flow object, that is, the object that transformation is performed on, and the planning and control of the transformation process have been covered through the concepts of object type and control mode. However, what actually activates the flow of objects through the transformation processes is covered by the flow driver. The activation is directly related to the customer demand and can be speculation/forecast driven, commitment/customer order driven (Giesberts and Tang, 1992, Hoekstra and Romme, 1992, Pagh and Cooper, 1998), and hybrid driven, which is a mixture of both (Wikner, 2014).

The forecast driven part is based on the anticipation of customers' needs, the customer order driven part deals with the known/confirmed requests of the customers, and the hybrid driven part is a combination of both from a resource perspective, that is, when a resource is used by both speculation and commitment driven flows (Wikner, 2014). The point in the flow where speculation driven and commitment driven transformation are separated is referred to as CODP (Giesberts and Tang, 1992). CODP is also known as the order penetration point (Sharman, 1984), delayed differentiation (Akkerman et al., 2010), and postponement (Towill, 2005), and it is usually related to a stock point (Hoekstra and Romme, 1992, Wikner and Rudberg, 2005). Note that all three types of drivers are applicable in both process industries and discrete manufacturing industries.

Positioning the CODP is a strategic decision (Blackstone Jr., 2010) based on the length of delivery lead-time and production lead-time (Shingo, 1989) and is directly related to the manufacturing strategy deployed by the companies (Giesberts and Tang, 1992). The four most common manufacturing strategies are make-to-stock (MTS), assemble-to-order (ATO) or finish-to-order (FTO) in process industries, make-to-order (MTO), and engineer-to-order (ETO). The position of CODP changes from the finished goods inventory in MTS to sometimes raw material inventory at suppliers in ETO; therefore, CODP can potentially be located at any stock point in the supply chain (van Hoek, 2001).

3.3. Sales and operations planning (S&OP)

This section describes the core concept of this dissertation, that is, S&OP, and is described in detail in Noroozi and Wikner (2016b).

There are three streams of thought regarding the evolvement of S&OP (Noroozi and Wikner, 2016b). One stream suggests that S&OP was initiated by the work of Holt, Modigliani, Muth, and Simon on aggregate production planning and forecasting in the 1950s (Holt et al., 1955, Singhal and Singhal, 2007, Feng et al., 2011). The other stream suggests that S&OP has emerged from manufacturing resource planning (MRP II) and been improved since the 1970s (Wight, 1984, Ling and Goddard, 1988, Basu and Wright, 2008). Still, a third stream puts the first two streams together and suggests that S&OP evolved from aggregate production planning in 1950s to MRP II in 1970s and then to S&OP as a business process (see e.g. Thome et al., 2012b). The advancement of information and communication technology has enabled the rapid growth of S&OP (Olhager, 2013) in response to globalization complexities (Jonsson, 2011, Lim et al., 2014), the outsourcing

trend (Klappich, 2012), and market uncertainty and increasing supply chain complexity (Tuomikangas and Kaipia, 2014).

S&OP has been referred to as the supply chain pillar (Affonso et al., 2008) and the integrator of total supply chain management (Basu and Wright, 2008). S&OP covers cross-functional intra-company and supply chain inter-company coordination, as well as coordination of material, financial, and information flows. Therefore, S&OP has an essential role in realizing supply chain management in order to fulfill customer demands with the aim of improving competitiveness (Tuomikangas and Kaipia, 2014) and maximizing profit (Grimson and Pyke, 2007).

S&OP has traditionally been treated as a generic process (Proud, 1999), meaning that it is not dependent on the specific characteristics of a particular industry. Recent research, however, suggests that S&OP is not a one-size-fits-all process and should be tailored based on its implementation environment (Thome et al., 2014a, Kjellsdotter Ivert et al., 2015a, Kjellsdotter Ivert et al., 2015b, O'Reilly et al., 2015). This dissertation is in line with the second stance on S&OP and suggests that S&OP should reflect the specific needs of the companies' supply chains if it aims to support the performance and competitiveness of companies. This issue is addressed in this dissertation through the integration of flow dimensions (see section 3.2) into the S&OP process in order to embed the modularized view of supply chains in this planning process. Below, the traditional view of S&OP is represented, and the gaps are highlighted.

3.3.1. Definition and process steps

S&OP has a role to create balance between demand and supply plans at an aggregate level (Wallace and Stahl, 2008, Jacobs et al., 2011, Jonsson, 2011), and it is a combination of people, process, and technology (Lapide, 2005). Different terms have been used to describe this process, including enterprise S&OP; executive S&OP; integrated business management (IBM); sales, inventory and operations planning; and sales, operations, and financial planning (see e.g. Maskell and Baggaley, 2004). In line with Ling and Goddard (1988), the term "S&OP" in this dissertation refers to all of these expressions.

Traditionally, S&OP is defined as "a dynamic process in which the company operating plan is updated on a regular monthly or more frequent basis" (Ling and Goddard, 1988), a proactive process "for continually revising the strategic business plan and coordinating

plans of various departments” (Arnold et al., 1998), “a senior management review process of establishing the operational plan and other key activities of the business to best satisfy the current level of sales forecast according to the delivery capacity of business” (Basu and Wright, 2008), and “a set of business processes that helps companies keep demand and supply in balance” (Wallace and Stahl, 2008). Finally, the APICS dictionary provides a comprehensive definition of S&OP as:

“a process to develop tactical plans that provide management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing, and financial) into one integrated set of plans. It is performed at least once a month and is reviewed by management at an aggregate (product family) level. The process must reconcile all supply, demand, and new product plans at both the detail and aggregate levels and tie to the business plan. It is the definitive statement of the company’s plans for the near to intermediate term, covering a horizon sufficient to plan for resources and to support the annual business planning process. Executed properly, the S&OP process links the strategic plans for the business with its execution and reviews performance measurements for continuous improvement.” (Blackstone Jr., 2010)

S&OP is mainly considered as a monthly process (Wallace and Stahl, 2008, Jonsson, 2011). The suggested planning horizon for this process covers a wide range between three months and three years (Noroozi and Wikner, 2013), while more emphasis is on a horizon between 12 and 18 months (Wallace and Stahl, 2008), especially for companies with a seasonal profile, in order to cover the whole marketing cycle (Grimson and Pyke, 2007, Jonsson and Mattsson, 2009). To achieve the balance between demand and supply plans, the role of S&OP in horizontal integration, i.e., integration of people from different areas both within a company (Ling and Goddard, 1988) and between a company and its supply chain partners, is essential (Affonso et al., 2008, Oliva and Watson, 2011, Thome et al., 2012b, Lim et al., 2014, Thome et al., 2014b, Tuomikangas and Kaipia, 2014, Goh and Eldridge, 2015). The role of S&OP in vertical integration is to connect strategic and

operational plans (Thome et al., 2012b, Thome et al., 2014b). It should be noted that S&OP is mainly located at the tactical level in the hierarchy of planning. However, when this process deals with capacity expansion and new investments (Olhager et al., 2001, Olhager and Selldin, 2007, Thome et al., 2012b) or scenario management and risk assessment (Wallace and Stahl, 2008), it has extensions toward the strategic level (Olhager and Rudberg, 2002, Wallace and Stahl, 2008, Alexander, 2013, Noroozi and Wikner, 2013). This emphasizes the benefits of a strong connection between S&OP and the strategic planning level, which is also stressed in this dissertation.

Most authors follow a five-step procedure for S&OP process (Wallace, 1999, Jacobs et al., 2011). The process starts with gathering the historical data for demand and supply planning. In the second step, a demand plan is generated that is mainly focused on forecasting the demand for present and new products based on the inputs to the forecasting process, such as historical data and strategic directives. This plan is then sent to the supply planning step where the capacity planning is performed based on the demand plan (or required capacity), available capacity, and inventory/backlog levels (Noroozi and Wikner, 2013). The two final steps are designed to discuss and solve the probable conflicts and achieve balance between demand and supply plans (Wallace, 1999, Wallace and Stahl, 2008, Jacobs et al., 2011). Considering that data gathering is used as a basis for all the succeeding steps, and the two final steps deal with balancing the demand and supply plans, it can be concluded that the S&OP process has three main attributes: demand planning, supply planning, and balancing (Noroozi and Wikner, 2016a). These attributes are used in this dissertation to unify the presentation of the results in relation to S&OP.

The S&OP process steps as defined above are mainly focused on the intra-company relations; however, companies today have extended their scope toward the supply chain and their external partners such as supplier actors, customer actors, competitors, and distributors. Thus, the scope of S&OP is widened to cover the supply chain partners as well (see e.g. Lapide, 2005, Grimson and Pyke, 2007, Thome et al., 2012b, Tuomikangas and Kaipia, 2014, Goh and Eldridge, 2015). The advancement of companies' S&OP process, for example, the extent to which they integrate supply chain partners or use technology, can be identified through maturity models. Maturity models are diagnostic tools used by companies to realize their present S&OP process status and to identify in which areas the

process should be improved (Lapide, 2005). For more information about the S&OP maturity models, refer to Grimson and Pyke (2007) and Thome et al. (2012b).

3.3.2. Benefits and measures

Implemented correctly, companies gain different types of benefits from the S&OP process. However, as Wallace & Stahl (2008) emphasize, S&OP implementation is mainly about the people involved in this process; therefore, a company's culture plays an important role in realizing the benefits of S&OP (Shobrys and White, 2002, Grimson and Pyke, 2007), which can be divided into soft and hard benefits (Wallace, 2006).

In line with Noroozi and Wikner (2013), the soft benefits are difficult to measure (Wallace, 2006) and include, for example, better cooperation between different functions in a company (Gianesi, 1998, Wallace, 2006), improved organizational behavior (Shobrys and White, 2002), and enhanced visibility (Kjellsdotter Ivert and Jonsson, 2010). The hard benefits include payoffs such as customer satisfaction (Thome et al., 2012b), improved inventory turns (Basu and Wright, 2008), enhanced forecast accuracy (Grimson and Pyke, 2007), and improved operational performance (Gianesi, 1998, Thome et al., 2012b).

The performance measures play an important role in providing information and identifying improvement areas for S&OP. Some examples of generic S&OP measures are on-time delivery and inventory level for end products, work-in-process and raw material (Thome et al., 2012b), line fill (Grimson and Pyke, 2007), forecast volatility (Chae, 2009), new product introduction lead-time (Goh and Eldridge, 2015), and financial metrics such as gross margin, return on investments and profitability (Thome et al., 2012a, 2012b, Tuomikangas and Kaipia, 2014). The measures have usually been classified based on the Supply Chain Operations Reference (SCOR) model, demand and supply aspects, and financial, operations, and process performance (Noroozi and Wikner, 2017).

In line with the discussion in sections 3.1.1 and 3.2 regarding the modularized view of supply chains, different industries require different measures based on the specific needs of their supply chains. This issue represents a gap in the literature (Neely et al., 1995, van der Veeken and Rutten, 1998, Thome et al., 2014a) and is in line with the call for a tailored S&OP process based on a modularized view of supply chains. In addition, according to authors such as Tuomikangas and Kaipia (2014) and Ivert et al. (2015a), more conceptual and empirical studies are required to study the S&OP process and its effect on

performance. These issues are discussed further in the next section and in line with the aim of supporting companies' performance through a modularized S&OP framework.

3.4. Performance measures

Performance measures assess the performance of a company and provide opportunities for continuous improvement; therefore, they have an important role in the management of supply chains (Beamon, 1998, Chae, 2009). As mentioned earlier, the planning system is part of the coordination aspect of supply chain management, and in line with Chae (2009), the planning system metrics can be used as measures of supply chain performance. By providing feedback on performance, the performance measures provide the opportunity for companies to compare themselves with yardsticks and to fine-tune their activities to achieve their intended goals. Below, the relationships among the competitive advantages and performance measures, performance measures frameworks, and sustainable performance measures are discussed. Sustainable performance measures are considered a subset of performance measures and are included due to their role in supporting companies' performance. This subject is described in detail in Noroozi and Wikner (2017).

3.4.1. Measuring competitive advantage

Competitive advantage grows out of the value a company is able to create by its supply chains for its customer actors that exceeds the company's costs of creating it (Porter, 1985). A competitive supply chain for a company, therefore, is defined as the supply chain that is aligned with its competitive strategy (Lapide, 2015), where competitive strategy is defined as "organizational attempts to reconcile goals with the realities of their environment and a way for companies to actively choose their route to competitiveness" (Porter, 1985). According to Hallgren and Olhager (2009), "competitive strategy discusses how an organization choose to compete on market, particularly the issue of positioning the company relative to competitors with the aim to establish a profitable and sustainable position." Therefore, competitive strategy concerns the specifics of management's game plan for competing successfully and securing a competitive advantage over rivals (Thompson et al., 2007). The competitive advantage is defined as "the advantage a company has over its rivals in attracting customers and defending against competitors. Sources of the advantage include characteristics such as a manufacturing technique,

brand name, human skill set, etc., that a competitor cannot duplicate without substantial cost and risk” (Blackstone Jr., 2010).

As emphasized in the literature, companies might follow cost-leadership, differentiation, or focused competitive strategy to compete in the market (see e.g. Wheelwright, 1984, Porter, 1985, Hallgren and Olhager, 2009). In a cost-leadership strategy, the companies serve a broad range of customer actors and try to be the low-cost provider of the products through, for example, an efficient supply chain (Porter, 1985). Companies that follow the differentiation strategy aim to be unique along some dimensions that are widely valued by the customer actors and earn profit through charging premium prices (Porter, 1985). Finally, companies with focus strategy usually have a narrower competitive scope in comparison to the two other competitive strategies and might focus on cost-leadership or differentiation (Porter, 1985). In line with authors such as Porter (1991) and Hallgren and Olhager (2009), the competitive strategy of a company has a direct effect on its performance measures and performance management system because the measures should be aligned with the competitive priorities and reflect the decision criteria, which supports the competitive strategy. This view is followed in this dissertation through linking the performance measures at the S&OP level to the strategic performance attributes and competitive strategies, which is in line with the vertical integration role of S&OP. The performance measures are further discussed in the next section.

3.4.2. Performance measurement frameworks

According to Blackstone Jr. (2010), a performance measure is “the actual value measured for the criterion” where criterion refers to “the characteristic to be measured”. A performance management system then is “a system for collecting, measuring, and comparing a measure to a standard for a specific criterion for an operation, item, good, service, business, etc.” (Blackstone Jr., 2010). Neely et al. (1995) suggest that a performance measure is a “metric used to quantify the efficiency and/or effectiveness of an action”. In this definition, efficiency means how economically a company can meet its customers’ requirements, and effectiveness addresses how well a company can satisfy these requirements (Neely et al., 1995). They then define performance measurement system as “a set of metrics used to quantify both the efficiency and effectiveness of actions” (Neely et al., 1995). Neely (2002) suggests another definition of performance measurement system as “a balanced and dynamic system that is able to support the

decision-making process by gathering, elaborating, and analyzing information”, and this is the definition followed in this dissertation because it is in line with consideration of different performance measures in different supply chain modules.

Because this dissertation studies the relation between the S&OP framework and the performance measures and suggests a new classification of performance measures based on the modularized framework, the previous classifications suggested in the literature for performance measure are briefly discussed here. Leong et al. (1990) classify the performance measures based on five dimensions: cost, quality, delivery performance, flexibility, and product and process innovativeness. Fitzgerald et al. (1991) divide the performance measures in companies into two groups. One group measures the results of performance and is related to competitiveness and financial performance, and the second group measures the determinants of the results, which is related to quality, flexibility, resource utilization, and innovation (Fitzgerald et al., 1991). Kaplan and Norton (1992) introduce the balanced scorecard and suggest the four perspectives of financial, customer, internal processes, and innovation and learning. Kaplan and Norton (1996) put forward a strong argument that the realization of full potential of a performance measurement system is dependent on its clear relation to the drivers (i.e., the related strategies) of the measures, which is considered one of the strength points of the balanced scorecard. The drawback of the balanced scorecard is that the competitor’s perspective is less obvious in this framework (Neely et al., 1995). A widely used approach for classification of performance measures, which shares the benefits of the balanced scorecard while overcoming its drawback, is the SCOR model. SCOR was initially developed by the Supply-Chain Council (SCC), which is now merged with APICS and known as APICS SCC.

The SCOR model is a reference model that provides the opportunity for companies to benchmark their processes with best practices (Sürie and Wagner, 2008). The SCOR model has five performance attributes related to strategy: reliability, responsiveness, agility, cost, and asset management efficiency (assets). Performance attributes are different from performance measures in that performance attributes cannot be measured per se but are representatives of groups of metrics that are used to express a strategy; therefore, performance attributes are used to set the strategic directions (Supply Chain Council, 2012). The SCOR model has a hierarchical structure and includes three process levels: Level 1 is process type, which includes plan, source, make, deliver, and return;

Level 2 is process categories; and Level 3 is process elements (Supply Chain Council, 2012). Performance measures are assigned to these three process levels and form a hierarchical structure that can be used to trace poor performance at higher levels to its main causes (Sürrie and Wagner, 2008). The hierarchical structure of key performance measures as deployed in the SCOR model is applied in this dissertation to provide the link between the key performance measures at the S&OP level and the strategic goals as well as the competitive strategies of companies. This is done through connecting the performance measures to SCOR's performance attributes and later to the competitive priorities relevant to the performance attributes.

3.4.3. Sustainable performance measures

As mentioned earlier, companies strive to establish a sustainable position in their competitive environment (Hallgren and Olhager, 2009), where sustainability traditionally refers to economic survival. Recently, the globalization of supply chains has put emphasis on the flow of material, information, and capital among the supply chain partners. This, in turn, has highlighted the importance of supply chain sustainability due to the effects of production and transportation of products among supplier actors, the focal actor, and customer actors on environment and social systems (Seuring and Müller, 2008). The management of a sustainable supply chain is defined as “the management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three categories of sustainable development, i.e., economic, environmental, and social, into account which are derived from customer and stakeholder requirements” (Seuring and Müller, 2008). A sustainable supply chain should be distinguished from a green supply chain because a green supply chain covers only the environmental category of sustainability and, therefore, is a subset of a sustainable supply chain. A green supply chain is defined as “integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end of life management of the product after its useful life” (Ahi and Searcy, 2013). In line with Seuring and Müller (2008), in comparison to supply chain management, a sustainable supply chain management looks at a longer part of the supply chain than required just for economic purposes, requires stronger cooperation among the supply chain partners, and deals with a wider set of performance objectives and consequently measures. The sustainable performance measures can be generic and wide in application and thus

applicable to different industries and locations, or they can be specific to a region or country based on local policies (Labuschagne et al., 2005).

Several classifications have been suggested for the sustainable performance measures. The Global Reporting Initiative (GRI) provides a well-known and practical classification of sustainable performance measures that is widely recognized and used by manufacturing companies. The GRI covers all three categories of sustainability, that is, economic, environmental, and social (Global Reporting Initiative, 2015a). The three categories are further divided into aspects with different measures suggested for each aspect (Global Reporting Initiative, 2015b). Using the GRI structure, IChemE (2002) suggests sustainability metrics that are specifically recommended for process industries. Considering the literature with focus on two categories of sustainability, Bai et al. (2012) categorize the economic and green performance measures based on the SCOR model, and Reefke and Trocchi (2013) use the balanced scorecard as the basis for environmental and social performance measures. Considering only the environmental category, a well-established practical classification of environmental performance measures is ISO 14031 (ISO, 1999).

Some gaps in the literature are identifiable from the above discussion. First, the sustainable measures have usually not been classified based on the managerial levels, that is, strategic, tactical, and operational (see e.g. Ahi and Searcy, 2015), or they are mainly focused on the strategic level. Second, the main focus has been on environmental issues, and the social aspect of sustainability has been neglected in the field of operations management to a large extent (see e.g. Hutchins and Sutherland, 2008, Seuring and Müller, 2008, Ahi and Searcy, 2015). This is also the case in the practice of sustainability (Cuthbertson and Piotrowicz, 2008) because some companies see the sustainable integration as a cost, not a competitive advantage (Carter and Rogers, 2008); therefore, they are not eager to invest in improving their sustainable performance. This is despite the fact that the literature suggests the activities at the intersection of the three categories of sustainability can actually improve the companies' environmental and social performance while also resulting in long-term economic benefits (Carter and Rogers, 2008). It is also suggested that the sustainable practices should be integrated within all planning levels of the company if the benefits are to be realized (Husgafvel et al., 2015). However, as mentioned above, the sustainable performance measures have been mainly

considered at the strategic level, and their practice in the tactical and operational levels have been largely neglected.

The economic category of sustainability has previously been included in S&OP to some extent (see e.g. Thome et al., 2012b), but the environmental and social categories have not been directly reflected on except in energy issues (see e.g. Mohanty and Singh, 1992, Kiranoudis et al., 1995, Arnold et al., 1998, Yin et al., 2003, Corsano et al., 2007, Shabani et al., 2014). It is, therefore, interesting to include the other aspects of environmental as well as social categories in S&OP. This issue represents a gap in the literature, which is aimed to be filled in this dissertation.

The next chapter covers how the above highlighted gaps in the literature are addressed in this dissertation.

4. Summary of research results

In this chapter, the research results are discussed from two perspectives: first, the results are discussed in relation to each paper, and then, how they fulfill the research objectives is explained. Because the same content is discussed from two perspectives, some overlaps are inevitable in this chapter.

4.1. Summary of papers

The purpose and research objectives are fulfilled through the five appended papers. Note that as mentioned in section 3.1.1 with regard to the supply chain scope, the first paper in this dissertation covers both the external and internal supply chains, whereas the other papers deal mainly with the internal supply chain.

4.1.1. Paper 1: Sales and operations planning in the process industry: A literature review

The paper aims to study S&OP in process industries through a systematic literature review. Three research objectives are defined for this paper. The first is to investigate how advanced the implementation of S&OP processes have been in process industries in comparison to discrete manufacturing industries based on the literature. The second is to study which parts of the supply chain this process covers from an integration point of view, and the third is to identify the operations characteristics of process industries, which may substantially affect the design and functionality of S&OP in process industries.

This paper addresses the gap in the literature regarding the lack of aggregate planning processes, such as S&OP, which are specifically designed or modified for process industries. In the beginning of this study, the need for a systematic literature review was identified because research about S&OP in process industries has not gained much attention in the literature until recent years. Thus, the review was planned and conducted, and, as a result, 145 papers, including peer-reviewed full-text papers from scientific journals, from 1980–2016, and papers from gray literature (Thome et al., 2016) from 2000–2016, were reviewed. These papers are about S&OP in both process industries and discrete manufacturing industries in order to provide a basis for comparison. An integrative S&OP framework (based on both internal and external supply chains) is suggested as the synthesis, and the papers in both groups of process industries and discrete manufacturing industries are classified according to this framework.

To get a better understanding about the context of available papers in this field, the papers are also classified based on their research strategy. In this paper, the definition of process industries is investigated through the concept of DDP. The aim is to find out whether or not the reviewed papers considered different characteristics for continuous object/production and discrete object/production at each side of the DDP. This part of the paper is mainly focused on the internal supply chain.

The results from this paper highlight the lack of conceptual models to define the needs and the boundaries of process industries. In general, S&OP in process industries has been more limited to the internal activities of a focal actor rather than the external supply chain, and not many integration issues have been covered, such as involvement of supply chain partners, risk and scenario management, and financial integration. The difference between process industries and discrete manufacturing industries identified as the result of the review is that process industries deploy both continuous and discrete production (decoupled by DDP), whereas discrete manufacturing industries only deploy discrete production.

Table 4 Continuous object characteristics affecting S&OP (Based on Noroozi and Wikner, 2016b)

Important characteristics	CO characteristics affecting S&OP
Resources	Energy provision and consumption
	Variable yield
	Uncertainty in raw material supply
Capacity utilization	Maintenance integration
	Inventory capacity restriction
	Perishability of inventory
	Set-up/Changeover time (related to cleaning and sterilization)
Material	Seasonality of raw material and dependency on nature, Perishability of semi-finished and finished goods

DDP can be used as a point of reference in planning and control issues to distinguish the needs of process industries and discrete manufacturing industries through continuous production and discrete production while considering the similarities of discrete production applied in both these industries. This approach is used in this paper to identify

the differentiating characteristics of continuous production and discrete production and, thus, process industries and discrete manufacturing industries, which can affect the S&OP process. Paper 1 gathers the continuous object/continuous production characteristics that affect the S&OP process as shown in Table 4 and presented in both Noroozi and Wikner (2013) and Noroozi and Wikner (2016b). Paper 1 is in line with R01.

4.1.2. Paper 2: A modularised typology for flow design based on decoupling points – A holistic view on process industries and discrete manufacturing industries

This paper aims to define a typology based on the flow logic that provides a generic approach to flow design to support, for example, planning and control in different industries. This paper addresses the gap in the literature concerning the neglected importance of flow design with regards to transformation process rather than the physical and geographical aspects. The paper focuses on identifying influential decision categories in flow design that affect the planning and control in both process industries and discrete manufacturing industries. To do this, the paper integrates the concepts from process industries, identified in Paper 1, with the concepts from discrete manufacturing industries and combines them in a three-dimensional typology (see Figure 6).

Figure 6 Modularized typology for flow design based on decoupling points (Based on Wikner and Noroozi, 2016)

The typology is developed through conceptual research methods. The three dimensions (decision categories) are available separately in the literature; however, modified definitions are assigned to them so that they support the modularized view of supply chains, which helps to fulfill R02. The three dimensions are object type, control mode, and flow driver, which are linked to DDP, CMDP, and CODP, respectively (see section 3.2). The typology in Figure 6 covers both continuous production and discrete production through

continuous and discrete object types. The white boxes are not prone to be relevant because onetime mode is mainly applicable to discrete objects and customer order driven flows. For more information about the typology, please see Paper 2 in the appendix.

Through the decoupling points, the typology provides a modularized view of supply chains, with each box presenting a module of the supply chain. The modularized view emphasizes the need for different planning techniques, managerial decisions, and performance measures on different sides of the decoupling points and represents a gap in the literature. This paper also contributes through studying the effects of hybridities within each dimension and cross hybridities between different dimensions, and investigating the combined influences of the three dimensions. Hybridities and cross hybridities play an important role in choosing planning techniques and performance measures in each module, and, in some cases, they introduce conflicts of interest. The typology can also be used to configure a model of a company’s supply chains based on the predefined modules shown in Figure 7. The predefined modules provide the opportunity of benchmarking and information sharing between companies with similar modules.

Figure 7 Supply chain configuration for a steel company (Wikner and Noroozi, 2016)

Comparing this figure in Paper 2 with a similar one in Paper 3, it can be noticed that the location of SD/CD and OM/IM/CM on the boxes (modules) have been switched. This change was made in Paper 2 in order to emphasize the position of control mode in the management of boxes. However, since Paper 3 was already published, it was not possible to apply these changes in it.

4.1.3. Paper 3: A modularized framework for sales and operations planning with focus on process industries

This paper aims to outline a framework for S&OP that is applicable to process industries as well as discrete manufacturing industries. The framework covers both the content (presented in Table 5), that is, the constructs of the framework, and the process used for the implementation of the framework (presented in Figure 8), thus including both the design phase and the actual performance of the monthly S&OP. The framework is based on a modularized approach that provides the opportunity for the modules of S&OP to be standardized and used for benchmarking. The framework's content is based on the typology presented in Paper 2 and studies the effect of decoupling points on the decision variables in S&OP. The framework's process addresses the importance of the design phase prior to the operational use of S&OP's content for different production contexts. The framework supports both process industries and discrete manufacturing industries, recognizes their specific requirements, and reflects them in the S&OP. The framework suggested in this paper is a conceptual deduction, which covers the description and definition of the terms and, to some extent, the explanation and understanding of the relationships between them.

Although the main body of the literature on S&OP suggests S&OP is a one-size-fits-all process that is independent of the context of the industry it is implemented in, this paper suggests a modularized framework for S&OP that recognizes and highlights the specific requirements of continuous production and discrete production, and thus process industries and discrete manufacturing industries. These requirements are considered as additional decision variables added to the generic S&OP's decision variables. The generic S&OP decision variables are, for example, sales and production volumes at the aggregate level, inventory and backlog levels, and capacity allocation. The generic decision variables are applicable to all types of industries. Examples of additional decision variables based on the S&OP modules are energy cost for the continuous objects, production rate for the continuous mode, cycle time for campaigns in process industries and related to the intermittent mode, safety stock level for the speculation driven flow, and safety capacity level for the commitment driven flow, which are presented as the framework's content in Table 5. The issues presented in Table 5 should be given further consideration and be integrated into the five steps of the S&OP process in addition to the generic S&OP decision variables.

Table 5 The S&OP framework's content in terms of the eight modules of the typology (Based on Noroozi and Wikner, 2016a)

Properties of object type, control mode, and flow driver affecting S&OP		Speculation driven (SD) <i>Demand planning: forecast-based</i> <i>Supply planning: lag strategy, inventory and safety stock level</i> <i>Balancing: level production</i>	Commitment driven (CD) <i>Demand planning: customer order-based</i> <i>Supply planning: lead strategy, safety capacity, and backlog level</i> <i>Balancing: chase production</i>
Continuous object (CO) <i>Demand planning: New product introduction (higher frequency of new product development and demand uncertainty)</i> <i>Supply planning: Energy cost</i> <i>Variable yield's effect on the throughput</i> <i>Bottlenecks (inventory capacity restriction, laboratory capacity restriction)</i> <i>Supply uncertainty (seasonality of raw material and dependence on nature)</i> <i>Perishability of semi-finished and finished goods (affecting inventory level target)</i> <i>Balancing: Not applicable</i>	Continuous mode (CM) <i>Demand planning: -</i> <i>Supply planning: production rate</i> <i>Balancing: level production</i>	CO-CM-SD Match	CO-CM-CD Mismatch
	Intermittent mode (IM) <i>Demand planning: -</i> <i>Supply planning: cycle and set-up time</i> <i>Balancing: chase production</i>	CO-IM-SD Mismatch	CO-IM-CD Match
Discrete object (DO) <i>Not applicable because it is generic</i>	Continuous mode (CM) <i>Demand planning: -</i> <i>Supply planning: Production rate</i> <i>Balancing: level production</i>	DO-CM-SD Match	DO-CM-CD Mismatch
	Intermittent mode (IM) <i>Demand planning: -</i> <i>Supply planning: cycle and set-up time</i> <i>Balancing: chase production</i>	DO-IM-SD Mismatch	DO-IM-CD Match

The hybridities and cross hybridities have also been studied in this paper. Based on the discussions in Paper 3, mismatches happen in the modules where a mixture of continuous mode-commitment driven or intermittent mode-speculation driven exists because continuous mode and speculation driven imply level production, and intermittent mode and commitment driven imply chase production. Level production is associated with lower cost of production in comparison to chase production, which is mainly focused on flexibility; therefore, the presence of both production strategies in one module represents a mismatch. The match/mismatch situations are further discussed in Paper 3 in relation to process industries and discrete manufacturing industries. Note that a mismatch implies the need for further investigation. In such cases, the companies decide on the appropriate production type based on additional information, for example, companies' strategic goals and competitive strategies. Therefore, the suggested S&OP framework helps companies recognize the probable mismatches (based on the modules of the framework they are associated with) and provides support for decision-making at the S&OP level. Note that, in this paper, a simplified version of the typology is used, meaning that onetime mode and hybrid driven are excluded from this paper because the focus is on process industries.

The framework's process for implementation is illustrated in Figure 8 and starts with identification and segmentation of product families and continues with positioning the decoupling points per product family, assigning the product families to the modules, performing S&OP, and ends with a follow-up step for evaluation and improvement.

Figure 8 The S&OP framework's process for implementation (Noroozi and Wikner, 2016a)

Notice that the design of S&OP is also covered in these steps. As indicated with a frame in Figure 8, the first three steps belong to the strategic design phase in which different product families, based on the positions of decoupling points, are allocated to the appropriate modules of the typology. There might be several iterations in the strategic

design phase until a practical design is achieved. After the design phase is complete, the monthly S&OP is performed in step 4, and the results are evaluated. In step 5, the feedback is provided to the previous steps. Note that the S&OP process steps explained in section 3.3.1 are part of the monthly S&OP performed in step 4 in the framework's process suggested in Paper 3. This paper is in line with RO2.

4.1.4. Paper 4: S&OP related key performance measures with integration of sustainability: A decoupling point based and modularized view on supply chains

This paper aims to develop a classification of the performance measures related to S&OP according to a typology of decision categories based on decoupling points in order to provide supports for a modularized supply chain design. The paper also emphasizes the link between the performance measures and strategic goals of companies. The focus is on the performance measures reported in the literature, which are relevant to manufacturing companies, covering both process industries and discrete manufacturing industries. The paper uses conceptualization to represent the mental presentation of an idea through the deductive approach with the goal to relate different concepts through integration and with a holistic approach. The narrative literature review method was used to extract the performance measures from the literature in different contexts and integrate them as illustrated in Table 6.

This paper addresses the gap in the literature concerning the need to reflect the specific characteristics of different supply chains with regard to product, process and market characteristics. This approach would help the companies choose performance measures based on the configuration of their supply chains according to the modularized typology, among many measures available in the literature. The classification of performance measures in this paper is according to the typology presented in Paper 2 because it provides a modularized view of supply chains and emphasizes the need for different performance measures at each side of the decoupling points. The sustainable performance measures, including economic, environmental, and social categories, are considered a subset of performance measures. They are integrated in this paper as well to emphasize the importance of integrating sustainable measures in all levels of the planning hierarchy and decision-making processes to support performance, which might

lead to long-term benefits for the companies. The importance of S&OP is emphasized in this context due to its role as a vertical and horizontal integrator of the supply chain.

Table 6 Key performance measures for decision categories related to the SCOR performance attributes at the S&OP level (Noroozi and Wikner, 2017)

Performance attributes	Decision categories						
	Object type		Control mode			Flow driver	
	Discrete object	Continuous object	Onetime mode	Intermittent mode	Continuous mode	Speculation driven	Commitment driven
Reliability	<p style="text-align: center;">Key performance measures for sales and operations planning (S&OP)</p>						
Responsiveness							
Agility							
Cost							
Assets							

To support the performance of the companies, linking the performance measures to the strategic directions and competitive strategies of the companies is crucial. To fulfill this goal, the five performance attributes of the SCOR model, that is, reliability, responsiveness, agility, cost, and assets, are used. The performance measures are first linked to these performance attributes, and then the relation between these attributes and the competitive advantages is studied. Table 6 illustrates the framework for classification of performance measures based on the typology and in relation to the performance attributes.

The results of Paper 3 show that some mismatches appear when the cross hybridities are studied. This issue is investigated in Paper 4 through studying the strategic characteristics of each module of the typology with regard to the competitive advantages. Note that in Paper 4, the term “conflict” is used instead of “mismatch” in order to emphasize the importance of strategic alignment for companies to support their long-term survival in the competitive environment. As highlighted in Table 7, the conflicts are present when one or two of the decision criteria in a module are strategically focused on reliability, cost, and assets, which are in line with the cost-leadership competitive advantage, while the other criteria in the same module are related to responsiveness and agility, which are in line with the differentiation competitive advantage. The framework for classification of performance measures helps companies recognize whether the performance measures

they choose, based on the modules their supply chains are associated with, are in conflict from a strategic point of view. A conflict represents a potentially problematic area and indicates that more information is required to analyze the situation and make a decision based on, for example, the competitive strategy a company follows.

Table 7 Analysis of the typology modules based on decision categories and the SCOR performance attributes (Noroozi and Wikner, 2017)

Decision categories		Speculation driven (SD)	Commitment driven (CD)
Onetime mode (OM)	Continuous object (CO)	-	-
	Discrete object (DO)	-	OM and CD (Reliability, Responsiveness, and Agility)
Intermittent mode (IM)	Continuous object (CO)	CO, SD (Reliability, Cost, and Assets) icw. IM (Responsiveness and Agility)	CO (Reliability, Cost, and Assets) icw. IM, CD (Responsiveness and Agility)
	Discrete object (DO)	SD (Reliability, Cost, and Assets) icw. IM (Responsiveness and Agility)	IM and CD (Reliability, Responsiveness, and Agility)
Continuous mode (CM)	Continuous object (CO)	CO, CM, and SD (Reliability, Cost, and Assets)	CO and CM (Reliability, Cost, and Assets) icw. CD (Responsiveness and Agility)
	Discrete object (DO)	CM and SD (Reliability, Cost, and Assets)	CM (Reliability, Cost, and Assets) icw. CD (Responsiveness and Agility)

* icw: in conflict with

Some sustainable performance measures are suggested in the paper in relation to different decision categories and where available in the literature, as presented in Table 8. The results about the sustainable performance measures are not linked to the performance attributes in this paper because the links between sustainable measures and the performance attributes and, in general, the effect of sustainability practices on companies' performance are not fully covered in the literature. This paper is in line with R03.

Table 8 Examples of sustainable performance measures with regard to decision categories at the S&OP level (Based on the results of Noroozi and Wikner, 2017)

Sustainability categories	Decision categories						
	Object type		Control mode			Flow driver	
	Discrete object	Continuous object	Onetime mode	Intermittent mode	Continuous mode	Speculation driven	Commitment driven
Economic	New product introduction	Sales amount of by-/co-products	-	-	-	-	-
Environmental	Weight of waste, Gas emissions	Energy consumption	-	-	Quantity of hazardous, recyclable, or reusable waste	Quantity of hazardous, recyclable, or reusable waste	-
Social	Average hours of training, Injury rate	Expenditure on illness and accident prevention	-	-	Employees' health and safety with regard to improved ergonomics	Employees' health and safety with regard to improved ergonomics	-

4.1.5. Paper 5: S&OP related key performance measures with integration of sustainability and decoupling points: A case study approach

This paper aims to classify the empirical key performance measures (including sustainable measures) used at the S&OP level in manufacturing companies, based on a modularized view of supply chains. It also aims to link the key performance measures to companies' strategic objectives. This paper is the continuation of Paper 4, but instead of using literature to gather the performance measures, it is based on empirical data from

four case companies. The paper addresses the gap in the literature regarding the need for more conceptual and empirical studies to study the S&OP process and its effect on companies’ performance through case studies.

The four case companies were selected with the goal to cover different modules of the typology; therefore, two of them belong to process industries, two are discrete manufacturing industries, and the unit of analysis is a product family in each company. The two companies related to process industries are a specialty chemical company (company A) and a tooling company (company C). The two discrete manufacturing industries used in this multiple case study are a company in motion and control technologies (company B) and a technology company with core activities in the fields of electrification, automation, and digitalization (company D). Data was collected through focused interviews with the S&OP owners of these companies, by review of the companies’ documents, and through follow-up interviews. The performance measures gathered through the case studies are classified based on the modularized typology as illustrated in Table 9.

Table 9 S&OP related key performance measures classification (Noroozi, 2016)

			SCOR model performance attributes	S&OP attributes
Generic S&OP decision (decision category independent)			Empirical generic key performance measures for S&OP	Demand planning/supply planning/balancing
Decision categories	Object type	Discrete object (DO)	Empirical typology-dependent key performance measures for S&OP	Demand planning/supply planning/balancing
		Continuous object (CO)		
	Control mode	Onetime mode (OM)		
		Intermittent mode (IM)		
		Continuous mode (CM)		
	Flow driver	Speculation driven (SD)		
		Commitment driven (CD)		

In this paper, the performance measures that are independent from the typology’s decision categories are classified as generic S&OP performance measures. In addition, the

performance measures are linked to the S&OP attributes, that is, demand planning, supply planning, and balancing, in order to study whether these three attributes gain similar attention in the practice of S&OP in case companies. These attributes are in line with the S&OP process steps as described in section 3.3.1.

The case companies in this study cover five modules of the typology, which are CO-CM-SD and DO-CM-SD (company A), DO-IM-SD (companies B, C, and D), CO-IM-SD (company C), and DO-IM-CD (company D), see Figure 6. These modules are related to both continuous and discrete objects on the object type dimension, intermittent and continuous mode on the control mode, and speculation and commitment driven on the flow driver. Almost all the product families under study are speculation driven. Regarding the relation between the modules, performance attributes, and competitive advantages, the results from this paper confirm the results from Paper 4. However, the results from this case study show that the selection of performance measures based on specific characteristics of the modules, which the companies are related to, is not broadly practiced. For example, distinguishing between continuous and discrete objects is discussed in the literature. However, the results show that process industries still implement the generic S&OP process, which does not explicitly consider the specific characteristics of continuous object/production. The situation is different for the control mode because some authors believe that the control mode is not an influential factor in the S&OP level, while the results from this case study show that some companies take this issue into account in their S&OP process. Regarding the flow driver, because almost all the product families are speculation driven, it is not possible to make any conclusions based on the results from the case study. Before conducting the case study, the assumption was that all three decision categories are influential in selection of performance measures. The results from the case study show that this assumption is partly supported.

Regarding the S&OP attributes, most case companies are mainly focused on supply planning issues, which is reflected in their selection of performance measures. Considering the literature, the expectation is that all three S&OP attributes are considered equally important because one of the main goals of S&OP is to balance the demand and supply. The results from this case study, however, shows that the main focus in the case companies is on supply planning and that demand planning and balancing have not

received enough attention. The results of Paper 5 in this regard are in line with the previous findings in the literature.

Considering the integration of sustainable measures, all case companies include economic performance measures at the S&OP level, and some of these measures can potentially contribute to the company's economic sustainability. The results from this paper are in line with the previous findings in the literature in that economic performance measures have been the main focus of companies for a long time. Environmental and social performance measures at the S&OP level have only been used in company B. These measures are generic, meaning that they are not classified based on the decision categories. In addition, these sustainable measures have not been linked to the performance attributes of company B. The low-level integration of sustainable measures in S&OP is in line with the findings from the literature in that sustainability has been considered mainly as a strategic issue, and its integration in other planning processes, such as S&OP, is usually not practiced.

4.2. Summary of research objectives

In this part, the research results are discussed in relation to the research objectives.

R01. Identify key characteristics of process industries with implications for S&OP.

R01 is fulfilled through scrutinizing the concept of object type and DDP. The way the process industries are represented in this dissertation is based on the fact that they deal with continuous objects such as liquid, powder, and gas, which affects their production processes (implementation of continuous production) and the type of resources they use for transformation of materials in terms of form and place. These differences from discrete manufacturing industries emphasize the need for tailored planning processes in process industries, also at higher planning levels such as S&OP. To find the key characteristics of process industries that can affect S&OP, a systematic literature review was conducted, and the key characteristics of process industries that deserve further notice at the S&OP level in process industries are presented in Paper 1 and illustrated in Table 4. According to the findings, characteristics such as variable yield, inventory capacity constraints, and uncertainty in raw material supply are aspects that affect the decisions at the S&OP level and can be reflected as additional decision variables in this

process. Most of these characteristics are related to the supply planning part of S&OP and highlight the importance of resource management in process industries.

RO2. Identify the key criteria in planning and control, which, in combination with the key characteristics of process industries, provide a modularized view of supply chains, and investigate the applicability of these criteria in S&OP of process industries and discrete manufacturing industries.

The focus in this part is on flow design and consideration of the actual transformation process, including the factors that affect it in terms of the flow object being transformed, the management of the flow repetitivity and the activation of the flow. The three decision categories identified in this dissertation are therefore the object type, which helps in distinguishing the specific characteristics of process industries and discrete manufacturing industries and assisting the use of synergies between them; the control mode, which defines the level of repetitivity of the production processes in response to the market demand and manages it in an efficient way; and the flow driver, which indicates if the transformation flow is activated by speculation or based on real orders from the customers. The decision categories are in line with product, process, and market characteristics. These three criteria are interrelated, and, therefore, a typology of three decision categories is introduced in Paper 2 and illustrated in Figure 6 to study the effects of hybridities (within each decision category) and cross hybridities (between the decision categories) on planning and decision-making processes. Each decision category is related to a decoupling point, which represents a discontinuity in the flow. The three types of decoupling points used in this work are DDP, CMDP, and CODP. Through the decoupling points, the typology suggests a modularized view of supply chains, which is the key in defining the planning techniques and decision-making processes of each module. The typology can be used to configure companies' supply chains into several modules and provides the possibility for information sharing and benchmarking through standardization of the modules.

To cover the second part of the RO2, namely, the applicability of key criteria in S&OP of process industries and discrete manufacturing industries, the typology is further applied to the S&OP process as a generic planning process in order to distinguish the specific needs of these industries at the S&OP level with regards to their supply chains, and the modularized S&OP framework is shaped. In this context, the specific decision variables

that can influence the implementation of the S&OP process in both process industries and discrete manufacturing industries are presented in Paper 3 and illustrated in Table 5. The decision variables related to the object type are already mentioned in relation to RO1. The decision variables related to the control mode are, for example, production rate in continuous mode and cycle and set-up time in intermittent mode. For the flow driver, the decision variables are, for example, inventory and safety stock levels for the speculation driven part and safety capacity and backlog levels for the commitment driven part. In addition, the need for the design of the S&OP process before the implementation phase is emphasized in this part of RO2. The design of the S&OP process should be in line and reflect the needs of the company's supply chains as well. To address this issue, the implementation steps for the S&OP process are suggested in Paper 3 and illustrated in Figure 8. These steps help the companies realize which modules of the S&OP framework are applicable to them based on the configuration of their supply chains.

RO3. Investigate how the modularized S&OP framework can be used in relation to companies' performance measures.

The focus of this RO is on how a modularized S&OP can influence the performance measures used at the S&OP level and how these measures are linked to the strategic objectives of a company. This focus emphasizes the need for a hierarchical structure of performance measures at different levels in the planning hierarchy, which is covered in this dissertation through identifying the related performance measures for each module from both a theoretical (Paper 4) and an empirical (Paper 5) perspective, and linking them to the strategic goals. The classification of performance measures in both papers is conducted based on the typology in Paper 2. This classification helps the companies select the performance measures based on the specific needs of their supply chains in order to support their performance. This approach also helps in managing their supply chains effectively and efficiently, in line with their strategic goals. The study of cross hybridities between the dimensions of the typology with regard to the performance attributes present in each module reveals some strategic conflicts in relation to the competitive strategies as presented in Paper 4 and illustrated in Table 7. This is due to the fact that different performance attributes in each module, related to each decision criterion, might be suitable for different competitive strategies, and this sometimes represents a trade-off between the practiced performance attributes. Presence of a conflict in a module indicates

that more information is required to analyze the situation in order to make a decision. In such a case, the main competitive strategy of a company can be used as a guideline for how to manage a conflict in a module. Therefore, through the suggested framework for performance measures, the companies can investigate if the modules their supply chains are associated with represent conflicts, indicating that careful analysis is required in order to select the performance measures that are in line with the companies' strategies.

Empirically, the performance measures used in four case companies are gathered and classified based on the typology, and their relation to the performance attributes is studied as presented in Paper 5. The results from the empirical study to some extent verify the analysis and results of the theoretical study in Paper 4. The results show that companies consider the control mode as an influential factor in choosing their performance measures. Regarding the object type, the results show that process industries are not aware of how they can use this concept in their planning and decision-making processes. In line with the literature, this implies that the process industries in this study use S&OP as a generic process and still do not reflect the specific requirements and needs of process industries with regards to continuous production in the S&OP process and its performance measures. The studied product families in the case companies have mainly been speculation driven; therefore, it is not possible to make any conclusions regarding whether this aspect affects companies' choice of performance measures. The modules representing conflicts in the companies are handled through the alignment with the company's competitive strategy, which is in line with the provided discussions in Paper 4. The sustainable performance measures are also included in both Paper 4 and Paper 5. Because S&OP, as an integrator, has an essential role in companies' success, and the integration of sustainable measures at different planning levels is considered a means of enhanced performance and competitiveness, it can be expected that the combination of sustainable performance measures in S&OP could be beneficial for the companies and support their performance. This dissertation addresses this issue and suggests some sustainable performance measures that can be used at the S&OP level in different modules. However, the empirical results from this study show that this issue is not widely practiced in the case companies. The reasons can be lower maturity of the S&OP process at the case companies, especially in process industries, or simply that sustainability might not be as important at the S&OP level as at the strategic level.

However, considering the limited number of case companies, this study cannot make a final conclusion on this subject.

5. Conclusion and further research

This chapter discusses the research findings in relation to the purpose of the study and ends with further research ideas.

5.1. Discussion and conclusion

The purpose of this dissertation is to propose a framework for sales and operations planning (S&OP), which is based on a modularized view of supply chains. The framework should support both process industries and discrete manufacturing industries in their quest for performance.

Traditionally, S&OP has been considered a generic process, meaning that it is a one-size-fits-all process, applicable with the same conditions in all industries and situations. This view has been challenged in recent years by suggesting that S&OP is actually contingency dependent based on, for example, the industry type and the product-process matrix. This dissertation follows this point of view and studies how S&OP should be designed and implemented based on the context of the industry to which it is applied. In this study, the characteristics of products, processes, and markets are used in order to include the supply chain requirements in the S&OP process. This is realized through the three types of decoupling points, namely, DDP, CMDP, and CODP, in order to provide a modularized view of supply chains. These three decoupling points are related to object type, control mode, and flow driver decision categories, respectively. The S&OP framework based on these three types of decoupling points benefits from a modularized structure, which can help to tailor the S&OP process for different companies based on the specific characteristics of their supply chains. The importance of a modularized view of supply chains as an effective and efficient way to support companies' performance has already been emphasized in the literature, and the modularized S&OP framework provides the possibility of benchmarking and data sharing between companies with similar modules. The S&OP framework suggested in this study covers both process industries and discrete manufacturing industries through the concept of DDP because this concept provides the possibility to include the characteristics of both continuous production (applicable to process industries) and discrete production (applicable to both process industries and discrete manufacturing industries).

The modularized structure can also be used as a tool to assist companies in selecting the performance measures based on the specific characteristics of their supply chains. This issue represents a gap in the literature and has been a challenge for companies because the appropriate measures can vary between different companies and situations. Well-aligned performance measures with strategic objectives/competitive strategies are considered in the literature to support companies' performance. This alignment is covered in this work through linking the performance measures to the performance attributes and their relations to different competitive strategies. Within this context, sustainable performance measures are also included to provide support for the performance of companies. The argument provided in this dissertation is that because both S&OP and sustainability usually are considered to have positive effects on companies' performance, their combination could also support the performance. This argument is supported by the literature in that the integration of sustainability in different planning levels has been considered beneficial. The empirical results, however, show that the case companies usually do not integrate sustainable measures in their S&OP processes. The reason can be that the S&OP processes in some of the case companies are not mature enough to support the integration of sustainable measures. Another interpretation can be that these companies deal with sustainability at other planning levels but do not consider it relevant at the S&OP level.

Altogether, the S&OP framework and the performance measures classification presented in this dissertation can help companies gain a better understanding of how to benefit from a modularized S&OP that reflects the specific needs of supply chains in the decision-making processes. It also helps companies effectively and efficiently manage their supply chain activities through measuring their performance in line with their performance attributes and competitive strategies.

5.2. Further research ideas

The ideas for further research address different areas with focus on S&OP, process industries, performance measures, and typology.

The S&OP framework suggested in this dissertation is based mainly on the literature, and although it has been developed based on some discussions with companies, it has not been directly implemented in practice. The limited case study in Paper 5 verifies the framework to some extent, but it is important to conduct in-depth case studies in both

process industries and discrete manufacturing industries with a specific focus on the framework for verification. The implementation of the S&OP framework in the real world would result in further refinement and improvement of the proposed framework. It could also help in quantifying the results of the implementation of the S&OP framework in terms of different performance measures. The same argument is valid for the typology and classification of performance measures.

Concerning the S&OP process, some other issues have raised interest for further research as well. In relation to the role of S&OP in the supply chain integration and dealing with new trends such as globalization, new areas have been included in this process. Some examples are the integration of supply chain partners, financial integration, new product introduction, portfolio management, and risk/scenario management. Nonetheless, how these issues should be implemented in the real world has not been thoroughly dealt with in the literature yet. In addition to the implementation, the way issues such as integration of key supplier and customer actors and new products introduction in S&OP influence the companies' performance and competitiveness are crucial and provide interesting opportunities for further research.

Regarding the process industries, the approach suggested in this dissertation provides a different view of the production processes of these companies through the concept of DDP and the way it affects S&OP. However, more conceptual and empirical research is required to address this issue. Some examples of additional decision variables, such as seasonality of raw material and dependency on nature, have been suggested in this study for the continuous object/production part of process industries. The ways these decision variables can be dealt with in the S&OP process in order to maximize the profit in these industries have not received due attention in the literature. The specific requirements of S&OP in different types of process industries, such as chemical and pharmaceutical industries, provide an interesting opportunity for further studies.

Another direct continuation of this dissertation would be to create a database of key performance measures for each module of the typology at the S&OP level as well as at other planning levels because the typology offers approaches for developing benchmarking between companies. The next step in this line would be to link different measures at different managerial levels to build a hierarchy of performance measures where each performance measure at the lower level is connected and so affects the

measures at the higher levels and vice versa. Within this context, the competitive strategy of the company and its related strategic performance attributes define which performance measures are required and should be focused on at the lower planning levels. The results from this dissertation show that sustainability is not integrated at the S&OP level in practice. Further research is required to investigate the reasons for the low level of sustainability integration in S&OP and the potential benefits of this integration. In relation to sustainability, the effect of product life cycle on the S&OP process provides an interesting path for further studies. The S&OP literature has not dug into this issue despite the fact that fierce competition has led to shorter product life cycles, which influence the companies' competitiveness (Iyengar and Gupta, 2013). Because various performance attributes and competitive strategies are suitable for different life cycle stages, this issue affects the implementation of S&OP as well as the suitable performance measures at each stage (Aitken et al., 2003). This issue might be of greater importance for discrete manufacturing industries, for example, in the electronic industry, than process industries. However, process industries are also facing shorter product life cycles compared to the past; therefore, this issue is crucial for them (Shah, 2005).

Finally, the typology introduced in this dissertation has three dimensions. The number of dimensions can be extended in order to provide additional information for managing a company with regard to, for example, customization, due to increasing customer expectations and requirements (Pine, 1993), or purchasing, which has gained increased importance as a result of outsourcing (Lankford and Parsa, 1999). It can also take a broader perspective and include the reverse flow of material or the service provision, which is integrated in the businesses of economically sustainable companies today. The assignment of proper planning and control methods to each module is another area for further research. The typology can provide support for the application of both qualitative and quantitative methods based on standardized modules, resulting in a modularized approach for supply chain optimization. In addition, the effect of hybridities and cross-hybridities on decision criteria, planning techniques, and performance measures is not thoroughly covered in the literature and can be further investigated.

6. Bibliography

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Glossary

Acronyms

CD (commitment driven): A flow driver that is triggered by the known/confirmed requests of the customers.

CM (continuous mode): A mode type that is applicable when the demand is high and homogenous, the products flow continuously through the processes, and the time gap between successive units is negligible.

CO (continuous object): An object that cannot be counted in pieces but must be measured in terms of volume or weight.

CMDP (control mode decoupling point): One or more points in the production process where different control modes in a transformation process are separated from each other.

CODP (customer order decoupling point): The point in the flow where speculation driven and commitment driven transformation are separated.

DDP (discretization decoupling point): A point in the production process of process industries where continuous objects turn into discrete objects, and discrete products are produced. DDP decouples continuous production and discrete production.

DO (discrete object): An object that can be counted in pieces.

HD (hybrid driven): A flow driver that is a combination of speculation driven and commitment driven in the sense that, from a resources perspective, there is a mix of forecasts and customer orders.

IM (intermittent mode): A mode type that is applicable when the demand is recurring, the object flows at time intervals, and the transformation is done in batches, lots, or, as applicable in process industries, campaigns.

OM (onetime mode): A mode type that is applicable when the demand is non-recurring and irregular, the product is complex, and the lead-time is long.

S&OP (Sales and Operations Planning): A process to develop tactical plans that provides management the ability to strategically direct its businesses to achieve competitive

advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain.

SD (speculation driven): A flow driver that is triggered by a forecast that estimates future customer orders.

Definitions

Continuous production: production that adds value by mixing, separating, forming, and/or performing chemical reactions. Therefore, it is related to the transformation process on continuous objects.

Discrete manufacturing industries: Producers of distinct items.

Discrete production: Transformation process on discrete objects.

Flow (in flow design and flow management): The actual transformation of materials during the production process.

Performance management system: A system for collecting, measuring, and comparing a measure to a standard for a specific criterion for an operation, item, good, service, business, and so on.

Performance measure: The actual value measured for the criterion.

Process industries: Types of firms that produce products by mixing, separating, forming, and/or performing chemical reactions.

Supply chain: The global network used to deliver products and services from raw materials to end customers through an engineered flow of information, physical distribution, and cash.

Supply chain management: The design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally with the ultimate goal of creating value for the customers in the form of products and services.

Sustainable supply chain management: The management of material, information, and capital flows as well as cooperation among companies along the supply chain while taking goals from all three categories of sustainable development (i.e., economic, environmental, and social) into account, which are derived from customer and stakeholder requirements.

Appendix