THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Use of Advanced Planning and Scheduling (APS) systems to support manufacturing planning and control processes

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Abstract

An Advanced Planning and Scheduling (APS) system is defined as any computer program that uses advanced mathematical algorithms or logic to perform optimization and/or simulation on finite capacity scheduling, sourcing, capacity planning, resource planning, forecasting, demand planning and others. Relative the massive interest, both from academia and industry in the subject area of manufacturing planning and control, there has not been much written about the use of APS systems in practice. For academia, this means a lost opportunity of understanding benefits and problems of implementing and using advanced planning and scheduling approaches. Seeing the many algorithms developed by academia during the years that never have been put into practice this should be valuable knowledge. For practitioners, the many failed implementations should make it important to understand what could be expected when implementing an APS system and what is required to effectively use it. This thesis studies how APS systems can support manufacturing planning and control (MPC) processes in adding value to the company by focusing on the consequences of using APS system and the variables influencing the consequences of using APS systems. It is different from previous studies concerned with APS systems as special focus is given to the *use*, i.e. when the APS system is operated in the MPC process instead of the *implementation*, the phase between the software selection and going live. Four case studies and one survey have been conducted to aid in fulfilling the overall aim.

The thesis found that the use of an APS system can support MPC processes by improving the decision support, simplifying planning activities, and reducing planning time and by generating feasible plans and schedules that are possible to follow. Still, the use of an APS system might make the planning activities more difficult to conduct and result in plans and schedules that are difficult to retrace or which are incorrect. It was identified that not only the use or non use of APS functionalities, but also the way the functionalities are used and the extent to which the functionalities are used influences the MPC process. The planning environment complexity, identified as the number of/and dependencies between entities and uncertainties in demand, supply and the production system of a manufacturing company, was found to influence how the APS system 'should' be used. Variables connected to the implementation of the APS system and to the MPC process, on the other hand, influence how the APS system is actually used. This thesis should be of interest to the subject area manufacturing planning and control. Researchers may benefit from definitions and conceptualisations of a number of constructs. For managerial usage, a number of benefits from using APS system in different MPC processes have been identified. Those may be used as a tool to assess whether the potential benefits of APS systems support the overall business objectives. Alternatively, it can be employed as an evaluation mechanism to access whether anticipated benefits were realized. A number of variables of importance in order to use an APS system in such a way so that benefits could be achieved have been identified. Those should be important when considering an APS system implementation. The thesis also contributes with a number of case descriptions in how APS systems are used in different companies and the users perceptions of using APS systems. This could be interesting knowledge for consultants and system vendors.

List of publication

This thesis is based on the research presented in six appended papers. Table 1 describes the author's different roles in the papers.

Paper I

Jonsson, P., Kjellsdotter, L., and Rudberg, M. (2007). "Applying advanced planning systems for supply chain planning: Three case studies". *International Journal of Physical Distribution and Logistics Management*, Vol. 37. No. 10, pp. 816-834.

Paper II

Ivert Kjellsdotter, L. and Jonsson, P. (2010). "The potential benefits of APS systems in the sales and operations planning process". *Industrial Management & Data Systems*, Vol. 110. No. 5, pp. 659-681.

Paper III

Ivert Kjellsdotter, L. and Jonsson, P. (2011). "When to use APS systems in sales and operations planning processes".

(Submitted to *International Journal of Operations and Production Management*)

Paper IV

Ivert Kjellsdotter, L. (2012). "Shop floor characteristics influencing the use of advanced planning and scheduling systems". *Production Planning & Control,* Vol. 23, No. 6, pp. 452-467.

Paper V

Ivert Kjellsdotter, L. and Jonsson, P. (2011)."Problems in the onward and upward phase of APS system implementation: Why do they occur?". *International Journal of Physical Distribution and Logistics Management*, Vol. 41, No. 4, pp. 343-363.

Paper VI

Ivert Kjellsdotter, L. and Jonsson, P. (2012). "Linking planning methods for capacity balancing to master production scheduling performance".

(Submitted to *International Journal of Production Economics*)

Table 1: Authors' responsibility for the appended papers

Paper	First author	Second author	Responsibilities
I	Patrik Jonsson and Martin Rudberg	Linea Kjellsdotter Ivert	The first authors stood for the largest part of the data collection, analysis and writing. The second author participated in data collection at one case company and participated in the paper planning and some of the writing
II	Linea Kjellsdotter Ivert	Patrik Jonsson	The paper's planning and analysis were equally shared among the authors while the data collection and writing have been the first author´s responsibility
III	Linea Kjellsdotter Ivert	Patrik Jonsson	The paper´s planning and analysis were equally shared among the authors. The first author took the largest part in the data collection and writing
IV	Linea Kjellsdotter Ivert	Sole author	
V	Linea Kjellsdotter Ivert	Patrik Jonsson	The first author stood for the largest part in the paper planning, data collection and writing. The second author participated at one case company and some of the writing. The analysis was equally shared among the authors.
VI	Linea Kjellsdotter Ivert	Patrik Jonsson	The first author stood for the largest part in the paper planning, data collection and writing. The second author stood for the data analysis.

Acknowledgement

A thesis does not write itself. First, you need a subject to write about. In my case, the topic area “APS systems” was indicated from the start – but I needed substantial help on the learning curve from the initial string of three letters, to a better knowledge of the subject. Second, a thesis must be of interest to people, preferably the people active within its subject area. To find an interesting angle, I needed help to get access to interesting case studies, and support as I learned how to collect the relevant data. Third, in order to sit down and write you need inspiration, motivation and discipline – none of which are automatic. A wise man once told me that a well-balanced person needs three legs: his or her personal life, family, and work. During my time as a PhD student one of those supports suffered a serious blow, and I have needed a great deal of help and encouragement to be able to walk again.

I would like to start by expressing my heartfelt gratitude to my supervisor Patrik Jonsson: Thank you for encouraging and supporting me throughout my research process. Your excellent knowledge in the field of manufacturing planning and control, and your exceptional research skills, have helped me to develop deeper understanding and insight in my own specific area. Your sensible advice and enormous patience have made it possible to turn difficulties into challenges. Most of all, thank you for making me feel prioritized, and for believing in me!

Secondly, I would like to express my gratitude to my assistant supervisor, Stig-Arne Mattsson: Your thorough knowledge and experience of information systems in manufacturing planning and control has been invaluable to my own understanding of the subject. All of your excellent ideas, and your flair for research, have enhanced my work and made my task very inspiring. I am grateful for our discussions, and for your special ability to see the speck of gold in everything!

I am grateful to my colleagues Martin Rudberg and Ola Cederborg, on the research project “Integrating the supply chain through advanced planning and scheduling systems” (ISCAPS). Together we have clarified many little-understood aspects of our research area. I am thankful for our valuable discussions on research in general, and research into advanced planning and scheduling systems in particular.

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Isak and Oliver, my beautiful sons. There were times when I thought I had lost you, Isak. Times when I thought you would never come back to us. Now I know that I can never lose you: you live in my heart forever. Oliver, my ray of sunshine. Everyday with you is a day in heaven. Thank you for helping me to learn the most difficult lesson in the world – how to be here, right now. I love you both with all my heart.

Göteborg, August, 2012.
Linea Kjellsdotter Ivert

1 Table of Contents

1 Introduction

This thesis deals with the use of advanced planning and scheduling (APS) systems as support for manufacturing planning and control (MPC) processes. It is a compilation thesis meaning that it consists of a cover essay and a number of appended papers. The introduction chapter defines key concepts and provides a historical perspective of computer based information systems (IS) and its evolution, ending in the development of APS systems. Further on, the problem area of APS systems in MPC processes is described and the thesis' overall aim, research questions, and scope are presented. Lastly, an outline of the thesis is presented.

1.1 Background

Effective planning and control of material flows and production resources, i.e. manufacturing planning and control (MPC) are usually seen as a key to success of a manufacturing company (Jacobs et al, 2011). In simple terms, planning means making decisions about future activities and events. In terms of manufacturing, planning can be identified as a number of MPC processes carried out at three different planning levels; long-term, midterm, short-term (ibid). The MPC processes should answer four general questions (Jonsson and Mattsson, 2009): (1) how large are the quantities demanded, and for when, (2) how much is there available to deliver, (3) how large are the quantities that must be manufactured or purchased and for when, (4) what capacity is required to manufacture these quantities. MPC processes take place within a planning environment, i.e. the conditions that characterize demand, products, manufacturing processes constituting the manufacturing company and which form the basic prerequisites for planning (ibid).

The theory and professional area around MPC began to seriously emerge in 1950s and since then significant contributions have been taken to the development and advancements of MPC (Mabert, 2006). One contribution that has played, plays and most likely will play an important role in MPC is computer based information systems (IS).

In retrospect, one can see that the evolution of IS correlates highly with the continual change of the planning environment. In the 1960s, the primary competitive thrust was costs, resulting in product-focused manufacturing strategies based on high-volume production, cost minimization, assuming stable economic conditions (Rondeau and Litterdal, 2001). Computerized reorder point (ROP) systems satisfied the basic needs of manufacturing firms (Jacobs and Weston, 2007). As the primary competitive thrust was shifting toward marketing in 1970s, more powerful methods were needed (Jacobs and Westron, 2007). Material requirements planning (MRP) was developed to better cope with the target-market strategies that emphasized production integration (Rondeau and Litterdal, 2001). MRP is a set of techniques that uses bill of material data, inventory data and the master production schedule to calculate requirements for materials (APICS, 2011). MRP application software soon became the state of the art tool for planning and scheduling material for complex products (Mabert, 2006).

The developments in hardware and software allowed for expansion of MRP systems. Simultaneously, there was a change in the primary competitive focus on quality; the manufacturing strategy emphasized greater process control, world-class manufacturing, and a focus on reducing overhead costs (Jacobs and Weston, 2006). A new generation systems, manufacturing resource planning (MRP II) systems, were developed in the 1980s to support these new initiatives (Jonsson and Mattsson, 2009). MRP II systems built on the required based material management capabilities of MRP systems, adding capacity requirement planning (CRP) capabilities to create an integrated or closed-loop MRP system (Rondeau and Litteral, 2001). This meant that it became possible to integrate both material and production capacity requirement and constraints into the calculation of the overall production capabilities. The concept was further developed and in the early 1990s the analytical firm Gartner Group minted the term enterprise resource planning (ERP), marking the start of a new era of enterprise systems (Chen, 2001). ERP is a comprehensive system meant to integrate all processes within a company by using one database which contains all the data for software modules such as manufacturing, distribution, finance, human resources, purchasing, warehouse management and project management (Chen, 2001; Berechet and Habchi, 2005). ERP systems have meant a lot for the trend in 1990s of organizing companies on the basis of business processes and aligning the aspects of an organization with the wants and needs of the customer (Rajagopal, 2002; Weske, 2007). This trend was an answer to the increased level of global competition combined with the changing markets and technologies (Rondeau and Litterdal, 2001). As a planning and scheduling system ERP has been criticized for having many limitations (Hamilton 2003; Stadtler and Kilger, 2005; David et al, 2006).

The evolvement so far has mainly been driven by practical people and by computer companies with IBM as a leading player (Jacobs and Weston, 2006). This might open up the question for where academia has been all this time. When discussing the development of MPC, it is not far-fetched to view it as the involvement of two different worlds: the world of the practitioners and the world of academia (Jonsson and Mattsson, 2009). Researchers have put a lot of effort into describing mathematical methods and algorithms for solving planning and scheduling problems (Wiers, 2002; de Kok and Graves, 2003; Lin et al., 2007). A negligible amount of this theoretical development has however been put in practice for different reasons (Lin et al., 2007; Henning, 2009). Still, operation research based methods have played an important role in individual cases where software is custom built for a specific situation (e.g. Brown et al, 2001; Gupta et al., 2002; Fleischmann et al., 2006). During the 1970s and 1980s operations research applications lead to the implementation of tailor-made decision support system (DSS) which supported production planning, inventory planning and transportation planning (de Kok and Graves, 2003).

In the late 1990s it was recognized that the ERP system was not a sufficient tool for the increased complexity in form of geographical dispersion and increased variety of material, capacity and capability requirements that the internationalization and push for individualization, accurate deliveries, and short lead-times created (Stadtler and Kilger, 2005; Henning, 2009; Kristianto et al, 2011). A new type of systems with the ability to integrate multi-site production systems, the capability to simulate different scenarios, and taking into account several constraints at the same time was needed (David et al., 2006; Kristianto et al., 2011). Developments in operations research and advances in computer programming languages and powerful hardware made it possible to create an answer to those needs: the APS system was born (de Kok and Graves, 2003; Hvolby and Steger-Jensen, 2010).

In general, APS systems are used in conjunction with ERP systems, either as add-ons or direct integral components of ERP systems, creating the support mechanism for planning and decision-making (Kreipl and Dickersbach, 2008). APS system is defined as: *"Techniques that deal with analysis and planning or logistics and manufacturing during short, intermediate and long-term time periods. APS system describes any computer program that uses advanced mathematical algorithms and/or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios."* (APICS, 2011)

APS systems have been implemented with good results in many different types of industries of different sizes e.g. steel processing companies (Wiers, 2002), food and beverage (Cederborg, 2010), farming and food industry (Rudberg and Thulin, 2009), electronic industry (Setia et al., 2008), consumer goods industry (Setia et al., 2008). Gartner estimates that the 2011 market of APS systems will grow 13.7% and exceed 8.5 billion dollar in 2012 (Kappich et al., 2011).

1.2 Problem area

The expectations of APS systems have been high from both academia and the industry active in the area of MPC. Turbide (1998) for example stresses that "*APS systems represent the most relevant innovation in the world of manufacturing since the introduction of MRP systems*", and Bermudez (1999) concludes that "*APS systems are a superb example of innovative software developers using advanced technologies to respond to the requirement of a new business paradigm*". Gayialis and Tatiopolous (2004) argue that "*APS systems have shown that operations research algorithms can be applied in practice…*" Studies also indicate that implementation of APS functionalities is top priority in industry (Straube, 2006) and many companies have started to invest in APS systems (Stadtler and Kilger, 2005). A survey of ERP systems implementation in Swedish manufacturing firms found that most companies that had implemented an ERP system were planning or considering an APS system (Olhager and Selldin, 2003).

For a considerable time there has been much discussion on the value of IS support in planning and controlling material flows and production resources (Renkema and Berghout, 1997; Zhu and Kreamer, 2005). The "IS value paradox" i.e. the gap between substantial firm spending on IS and the widespread perception about the lack of value, has been discussed in articles, magazines and journals and at conferences and seminaries, all around the world

(Lin and Pervan, 2003; Chau et al, 2007). Managers have found it increasingly difficult to justify rising IS expenditures and are often under immense pressure to find reliable ways to ensure that the expected benefits from the IS investments are realized (Setia et al., 2008). Additionally, researchers within IS face strong pressure to answer the question of whether and how IS investment creates value to the company (Zhue and Kraemer, 2005). APS systems are no exception, and far from everyone is convinced that APS systems are the solution to outstanding planning and control (de Kok and Graves, 2003; Jonsson and Mattsson, 2009). Although early adopters of APS systems reported significant reductions in cycle time, resources, and inventory levels, recent studies shows that the promises of APS systems are not realized in many cases (Fontanella, 2001; Hvolby and Steger-Jensen, 2010). Studies also indicate that there are several problems involved in successfully using planning systems, e.g. high complexity of the system, lack of knowledge among managers and personnel, low data accuracy, and a lack of support from the software vendors (Petroni, 2002; Jonsson, 2008).

In relation to the massive interest in and the high expectations of APS systems, there has not been much written about the use of APS systems in practice (Rudberg and Thulin, 2009; Gruat La Forme, 2009). Instead most of the literature concerning APS systems have focused on development of mathematical models (e.g. Nuemann et al., 2002; Moon et al., 2004; Pibernik and Sucky, 2007; Chen and Ji, 2007; Bakhrankova, 2010). This is a problematic situation and a number of researcher call for a much more active role of the academic community in studying the real added value of APS systems in practice (e.g. Gruat La Forme et al., 2005; Lin et al., 2007; Setia et al., 2008). Considering the high number of mathematical methods and algorithms developed by academia during the years that never has been put into practice there seems to be a great need for exploiting the opportunities that could come out from utilization advanced planning and scheduling approaches (Lin et al., 2007; Henning, 2009). Beside, seeing that several APS implementations fail or does not meet the initial expectations (McKay and Wiers, 2003; Stadtler and Kilger, 2005; Günter, 2005) there is a need also for manufacturing companies to better understand what to expect when implementing APS systems and how to achieve expected benefits.

Having those needs in mind, a review of the literature dealing with the aspects of APS systems in practice is in place. Zoryk-Schalla et al. (2004) focuses on the modelling issues in a longitudinal study of APS system implementation in an aluminium manufacturing company. By comparing the structure of an APS system with production control theory, Zoryk-Schalla et al. (2004) is able to explain why implementation problems occur in a specific case. Wiers (2002) describes the implementation of APS systems in a steel processing plant focusing on the integration between ERP systems and APS systems. The paper identifies and discusses typical issues to be solved when ERP and APS systems are integrated. Stadtler and Kilger (2005) put a special emphasis on implementing APS systems successfully by describing six case studies implementing APS systems. David et al. (2006) study the relevance of APS systems in the specific area of the aluminium conversion industry (ACI). They identify potential benefits and limitations of using APS functionalities in ACI. Lin et al. (2007) set out to assess the effectiveness of APS systems by conducting a case study at a semiconducting manufacturing firm implementing an APS system to formulate a supply chain management strategy. In addition, they propose an approach for APS system implementation. Rudberg and Thulin (2009) present findings from a case study regarding supply chain redesign and supply chain planning with the aid of an APS system. They describe the methodology used when an APS system was used to develop a master production schedule and present the results obtained. Setia et al (2008) develop a framework for organizational value creation from agile IT applications where APS systems are used as example. Six propositions are generated and tested in two case studies. Wiers (2009) presents two cases where the relationship between autonomy and APS system implementation success is investigated. He concludes that it is important that there is an agreement in a company about what is scheduled by the APS system and what is scheduled locally on the shop floor before an APS system implementation is started.

The studies presented above have increased the understanding of APS systems in practice. A number of important variables when implementing APS systems have been identified. Examples of such variables are: strong integration of APS systems and ERP systems (Wiers 2002; Stadter and Kilger, 2005), consistent modelling (Zoryk-Schalla et al., 2004), empowered human planners, (Lin et al., 2007), and a good fit between the APS system, the planning task and the organisation (Setia et al., 2008). Some understanding for what to expect when implementing an APS system has also been gained. Rudberg and Thulin (2009) for example report on decreased inventory levels and total costs, reduced total planning time, and increased control of material flows when APS system was installed in combination with a centralised planning function and structural changes in a particular case. Previous studies have, however, focused on the implementation aspect of the APS system and the understanding for the actual use of the APS system, and its role in value creation has been neglected in the majority of the studies. Being aware of the many definitions of implementation, it is here seen as the phase between the software selection and going live, whereas use is seen as the phase from when the APS system is operated in the MPC processes. The dominated focus on the implementation process in APS system literature has resulted in a rather low knowledge of what variables influence the use of APS system and how the use of APS system influences the MPC processes. Although some benefits of implementing APS systems have been reported in literature, most studies have studied benefits of implementing APS system indirectly and a general understanding for what to expect of APS systems is missing. It is particularly difficult to grasp the role of the APS system in the identified benefits in previous literature. Finally, although studies have suggested that APS systems are not suitable in all processes and contexts (e.g. Gruat La Form et al., 2005; Setia et al., 2008) no studies have explicitly dealt with the question of when the APS system is an appropriate choice, i.e. in which situations it is appropriate to use APS systems. This thesis aims to fill some of those knowledge gaps.

1.3 Overall aim and research questions

Before formulating the overall aim, the way the MPC processes is looked upon, is described.

A process is usually seen as a collection of activities that takes one or more kinds of input and creates an output that is of value to a specific customer/s (Hammer and Champy, 2003). Using this definition on MPC processes, the following characteristics can be derived. The input to the MPC processes is in general terms policies, strategies, customer demand, available capacity, and goals on capacity utilization, service levels, and inventory levels. A number of activities using this input are performed to create an output, i.e. plans and schedules for what, when and how much to deliver/purchase/manufacture so that customer needs are met within the business goals. Seeing that a manufacturing company can be described as a number of business processes the customer of an MPC process is the business processes in which the MPC output is used e.g. other MPC processes, manufacturing, purchasing, sales and marketing. An MPC process is not a goal in itself; its purpose is always to create value to the company. Thus, an MPC process should develop plans and schedules that contribute to improving performance in the company and thereby achieving a positive impact on profits and competitiveness. There are several ways to accomplish such an MPC process, e.g. structured meetings, measurements, organizational changes and information technology (Grimson and Pyke, 2007). In this thesis focus is on the use of APS systems as a way to support the MPC processes in adding value to the company. Consequently…

The overall aim of this thesis is to study how the use of APS systems can support the MPC processes in adding value to the company

The overall aim implies that an APS system might have the capability to support MPC processes in such a way so that increased value can be added but that it is uncertain if and how this can be done. Two research questions have been formulated to aid in fulfilling the overall aim.

RQ1: What are the consequences of using APS systems in MPC processes?

Previous literature stresses that it is not clear whether an APS system creates value to the company and implies that there is a need to study the real added value of the APS system in practice (e.g. Gruat La Forme et al., 2005; Lin et al., 2007; Setia et al., 2008). So how can an APS system add value to a company? Is it at all possible for an APS system to add value to a company? In the model of IS success, DeLone and McLean (1992) suggest that system use is a direct antecedent of individual impact which has some organizational impact. In their updated version of the IS success model, individual and organizational impact are changed to net benefits to illustrate that an IS has impact on more levels than the individual and organizational levels, and that consequences are not only positive (DeLone and McLean, 2003). Taking this discussion further, an APS system can add value to a company if it is being used in such a way that the consequences of using the APS system have positive impact on the profit. There is, however, no direct link between APS system use and impact on profits. The APS system is used in the MPC processes activities, which brings positive and negative consequences to the MPC process. This has some impact on the MPC output, which in turn has some impact on the business processes in which the output is used, which has some impact on the profits of the company. At the level of the business process and the company the only negative about using APS systems is if the investment is not considered profitable. That is if 'expected benefits' is not generated or if the company has been putting too much effort into receiving those expected benefits. It is, however, difficult to capture benefits at the level of the business process and the company level, as it is difficult to isolate the contribution of IS from other contributions to their performance (Grover et al, 1996).

The point of departure in this thesis is that it is the MPC process that adds value to the company. The use of an APS system can *support* the MPC process, which then can add value to the company in terms of improving performance and achieving a positive impact on profits and competitiveness. The unit of analysis is therefore the MPC process. The consequences APS systems have on the realisation of the MPC process and for the MPC's output are significant. Figure 1 illustrates the consequences of using APS systems in the MPC process. The MPC process consists of several activities, which results in an output in form of plans and schedules. The APS system is used in the MPC process activities, which in turn brings on consequences in the realization of the MPC process and on the MPC output.

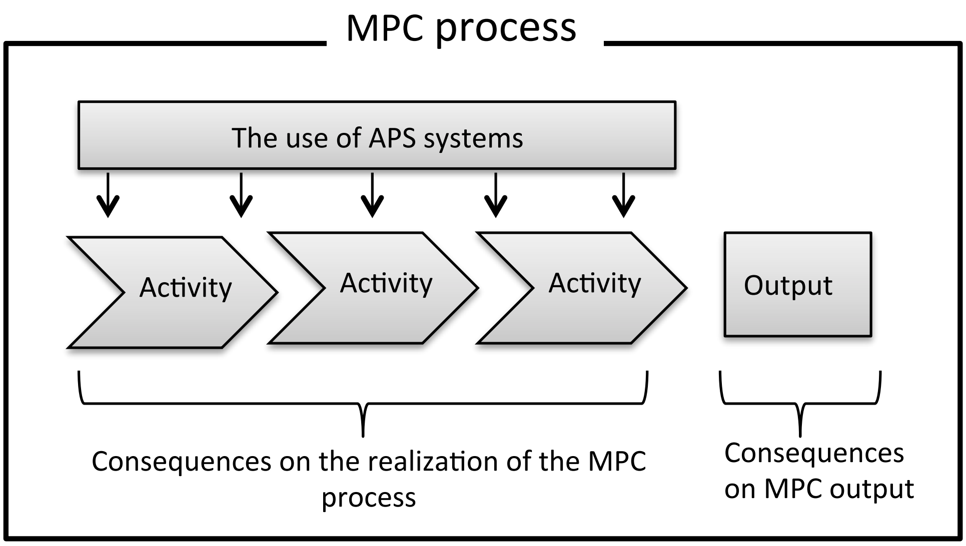

Figure 1: The consequences of using APS systems are on the realization of the MPC process and on the MPC output

RQ2: Which are the variables that influence the consequences of using APS systems in the MPC process?

Assuming that an APS system can bring certain benefits to the MPC process, it is of course interesting to know how to make this happen. Studies suggest that there are difficulties with implementing and using APS systems (Zoryk-Schalla et al., 2004, Lin et al., 2007) and many companies report on "failed" implementations and that expected benefits have not been achieved (de Kok and Graves, 2003; Günter, 2005). A number of theories and approaches have been developed in the IS literature to explain how benefits are achieved or why certain benefits are not achieved (Randolph and Zmud, 1990). The so called factor research aims at identifying variables, which are related to particular outcomes (Prescott and Conger, 1995) and is the approach used in this thesis. Focus is on identifying variables that influence consequences of using APS systems in MPC processes. Frame of references will be used to specify different types of variables.

As the overall aim and the two research questions suggest, the word "use" has an important meaning in this thesis. Most literature on APS systems has focused on the implementation aspects whereas little has been done to understand how and why the APS systems are used the way they are and what this means for the MPC process. Although the implementation is of high importance for the benefits to be achieved, there might be variables forgotten if the actual use of the system is not considered (Häkkinen and Hilmola, 2008). The low focus on system use does not seem as something unique in the APS system literature. Zhu and Kraemer (2005), for example, stress that although system use is an important link to achieving good values of IS, this link seems to be missing in the existing literature. Yu (2005) identifies that the dominant ERP system literature focuses on failure or success of ERP implementations in the same time as the market of post-implementation ERP service is growing. Therefor Yu (2005) stress that there is a need for a new research agenda in this field – giving focus to the phase when the ERP system is used in daily operations. The importance of studying the IS use in order to fully understand how to achieve benefits or why benefits are not achieved is motivated by Marcus et al. (2000). They found that although a company is very successful during the phase when an ERP system is configured and rolled out to the organisation it does not mean that the company is successful when the system is used in normal operations. The study also showed that it is possible for 'failed' ERP system projects to achieve expected benefits. Thus, a lot might happen on the way from that the decision on installing an IS is taken to the use of the IS in daily operations.

1.4 Scope

It is common that companies plan and control their material and production flows in a hierarchical structure with different time horizon and detailed information. A widely used model for illustrating this structure is through the MPC model originating from APICS (Olhager et al., 2001). In the model sales and operations planning (S&OP) has the longest planning horizon and the lowest level of detail. Next follows the master production scheduling (MPS). It is more detailed than the S&OP. There are several similarities between S&OP and MPS and in many companies these both planning levels are integrated into one planning process, typically called master planning or tactical planning (Jonsson and Mattsson, 2009). Next in the hierarchy comes order planning, which is the planning level related to materials supply, i.e. the method used to ensure that all raw material, purchased components, parts and other semi-finished items are purchased or internally manufactured so that the delivery and production plans draw up under the MPS process can be carried out (ibid). For internally manufactured items, more detailed planning of manufacturing orders created at the order planning level takes place. This level is called production activity control (PAC), which is the level with the shortest planning horizon and the largest level of detail.

Figure 2 shows the MPC model based on Jonsson and Mattsson (2009). In this thesis, focus is given to the processes sales and operations planning (S&OP), master production scheduling (MPS) and production activity control (PAC), all marked with circles in Figure 2. The reasoning behind this is that APS systems foremost are used in the PAC process (Wiers, 2009; Cederborg and Kjellsdotter, 2007) and that the potential many times are expected to be the highest in the S&OP and MPS processes.

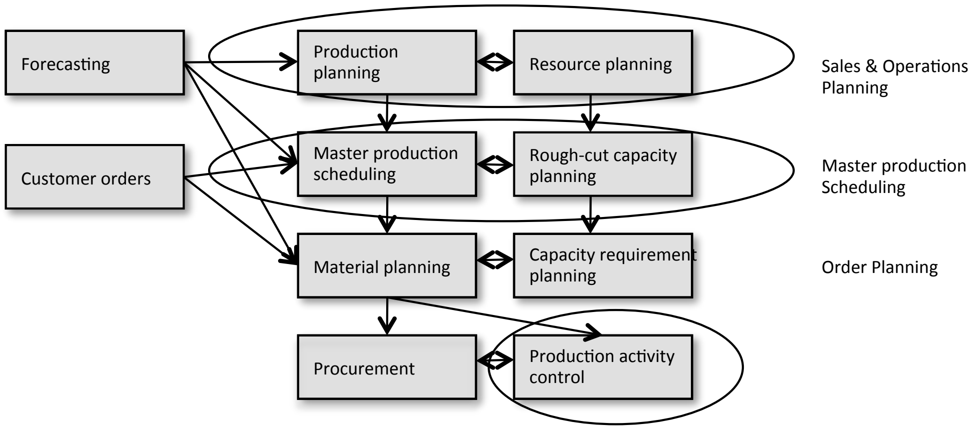

Figure 2: The focus is on S&OP, MPS and PAC (The MPC structure is based on Jonsson and Mattson, 2009)

This thesis concerns the functionalities available in commercial off-the-shelf APS systems, which support S&OP, MPS and PAC processes. APS systems in accordance with the definition of APS systems at page 13 have been studied. The definition is broad enough to cover the functionalities supporting MPC processes at the same time as it gives focus to some prominent characteristics of APS systems. In the respective study within each paper (which the cover essay is based on) focus is given to a particular planning process and the role of the APS functionality/system in this process. In some studies, focus is given to the use of the functionality supporting the planning process, in other studies focus is given to the use of an APS system in the light of a large information system and its meaning for the planning process.

The functionality in APS systems offered by different system vendors differ somewhat. The techniques or *algorithms* used to create a feasible (optimized) plan and/or schedule does for example vary widely. Some vendors attempt to achieve optimization by applying a single algorithm to a wide range of problems, other maintain a library of algorithms, which can be used in a trial fit approach. The algorithm used has influence on the solution quality and the activities during the implementation. For example, modelling, i.e. the process of customizing the APS system to a specific manufacturing environment, is largely dependent on the optimization technique used within the planning engine (Bermudez, 1996). This thesis does not go into detail in the different type of algorithms that is used in the planning engine of the studied APS systems. Even the most knowledgeable manufacturing experts many times feel ill-equipped to debate the relative merits of the competing algorithms in APS systems. Besides, it is difficult to receive information from APS vendors about the algorithms that they are using. The results of the thesis should be valid for similar APS systems as the studied ones. Besides the functionality, the user friendliness might vary between different APS systems, which in turn might have an influence on the use and its consequences. The studied APS systems have similar graphical user interfaces with well-designed panels for data entry, drag and drop graphical planning boards, and familiar display formats for results.

An organisation's experience with an IS can be described as moving through several phases (Marus and Tanis, 2000). Each IS experience is unique depending on several things, e.g. if it involves external consultants or is done in-house; if it follows a process of strategic business planning or business process reengineering, or does not follow such process. Marcus and Tanis (2000) suggest that an organisation goes through four phases during its experience with their ERP system: 1) the chartering phase, comprising decisions leading up to the funding of an ERP system, 2) the project phase, comprising activities intended to get the system up and running in the organisation, 3) the shakedown phase, during which the company makes the transition from "go live" to normal operations, 4) the onward and upward phase, which continues from normal operation until the system is replaced with an upgrade or a different system. It is during this last phase the company captures the majority of benefits (if any). Figure 3 illustrates the ERP experience cycle suggested by Marcus and Tanis (2000). A number of similar models describing the phases of an IS lifecyle has been proposed by several researcher (Forslund and Jonsson, 2010). An overall structure is to distinguish between the pre-implementation phase, the implementation phase and the post-implementing phase (ibid) representing phase 1, 2-3, and 4 respectively.

There are many differences between ERP systems and APS systems, which influence the four phases suggested by Marcus and Tanis (2000). The ERP system implementation is usually said to be a huge process that affects an entire company (Davenport, 1988) and which is more structured than the more add-hoc based and many times smaller APS system implementation process (Wiers, 2002). In general, ERP systems are built to process administrative transactions from many users to some extent in a batch-oriented manner whereas APS systems are built to support planning and scheduling decisions to few users in a continuous manner (ibid). Companies having implemented an ERP system are experiencing improved performance mainly from the information perspective, e.g. availability of information, process integration, and information quality (Olhager and Selldin, 2003) whereas common reported outcomes of the APS system concern decision support and MPC performance variables such as reduced inventory level, improved on time delivery, and increased customer service (e.g. Kilger, 2008). Still also an APS system goes though a number of phases during its lifetime, and the fundamental feature of the ERP experience cycle proposed by Marcus and Tanis (2000) should be similar to APS systems. Focus in this thesis is on the use of APS systems in MPC processes, representing the onward upward phase in the APS experience cycle in Figure 3. The APS system user, i.e. the person/s that are using the system typically use his/her APS system in the following ways: enter data and/or download data from an ERP system, manipulate data provided by the system, predefine how the APS system should generate plans/schedules, and interpret information generated by the system.

The definition and measurement of success are thorny matters (Marcus and Tanis, 2000). Success means different things depending on who one might ask but also on where in the IS lifecycle it is measured. Success in the project phase is many times seen as when the IS project is completed within time and budget (Al-Mashari et al., 2003). Success in the onward and upward phase is on the other hand more about achievement of business results expected for the IS project (Dezdar and Sulaiman, 2009). According to DeLone and McLean (2003) IS success is a multidimensional variable and as such "researchers should systematically combine individual measures from the IS success categories to create a comprehensive measurement instrument". It is important to understand that this thesis does not capture APS system success but concentrates on the use of APS systems. Focus is on how the use of APS systems can support the MPC processes in terms of consequences generated to the MPC process and variables of importance. 'Successful use' is seen as when the APS system is used in such a way so that it supports the MPC process in fulfilling its' goals and so that benefits could be achieved.

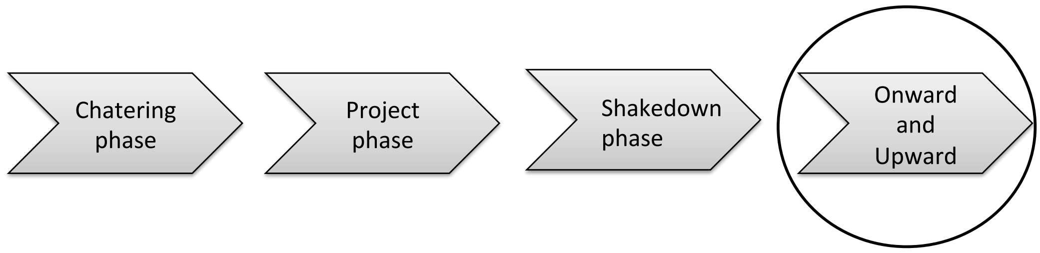

Figure 3: The focus is on the 'use' representing the onward and upward phase in the APS system experience cycle (based on the ERP system experience cycle by Marcus and Tanis, 2000)

1.5 Thesis outline

Chapter 1 (Introduction) introduces the background to and the problem area of advanced planning and scheduling (APS) systems in manufacturing planning and control (MPC) processes. The overall aim, research questions, and thesis scope are presented.

Chapter 2 (Frame of references) describes and defines the key concepts used in the thesis and lay the foundation for the theory used in the analysis and discussion. To start with the MPC processes of focus in the thesis are described, i.e. sales and operations planning (S&OP), master production scheduling (MPS), and production activity control (PAC). Next, the definitions and characteristics of an APS system is discussed and the use of the APS system in S&OP, MPS and PAC is described. Previous literature on consequences of using APS systems and variables influencing the consequences are reviewed and variables and consequences are categorized. Finally the conceptual framework used in the analysis and discussion is presented.

Chapter 3 (Methodology) presents the methodology used in the research. The research process of the thesis is presented followed by the research strategy used in the research. The methods used to approach each research questions in the papers are described and the case companies used in the case studies are presented. The section ends by discussing the validity and reliability of the research.

Chapter 4 (Summary of appended papers) presents a short summary of the six appended papers with focus on the papers' results and contributions.

Chapter 5 (Results) presents the results of the thesis. The chapter sets out to answer the two research questions generated in the introduction chapter. Each section ends by a short summary.

Chapter 6 (Discussion) discusses the paper findings by relating them to previous literature. The results from the research questions are compiled and the found relationships between variables and consequences of using APS systems are illustrated.

Chapter 7 (Conclusion and further research) presents the conclusions of the thesis, gives some managerial implications, discusses its contribution and gives suggestions for further research.

2 Frame of references

The frame of references aims at describing and defining key concepts and to lay the foundation for the theory used in the analysis and discussion. First the MPC processes of focus in the thesis are described, i.e. the S&OP process, the MPC process and the PAC process. In the second section APS systems are introduced and defined. Thereafter, it is described how APS systems can be used to support the S&OP, MPS and PAC processes. Previous literature is thereafter reviewed with the aim of identifying consequences of using APS systems and the variables influencing the consequences. Lastly, a conceptual framework including the categorization of variables and consequences that will be used in the analysis and discussion is presented.

2.1 The manufacturing planning and control processes

This section describes the S&OP, MPS, and PAC processes within the MPC system (Figure 2), which is a commonly used structure to depict the hierarchical planning structure of the MPC processes (Olhager et al, 2001; Jacobs et al, 2011).

2.1.1 Sales and operations planning

Sales and operations planning (S&OP) as a terminology originated in the articles concerning MRP II, where some authors used it interchangeably referring to the term aggregated production planning (Ling and Goddard, 1988; Olhager, 2001; Feng et al, 2008). Considering that S&OP has existed as a principle for at least 25 years, relatively little has been published about it up until recently. Some say that its recognition is on the rise (Feng et al, 2008; Tavares Thomé et al., 2012) and that S&OP will increase in importance as the complexity and rate of change increase across the industry (Wallace, 2006; Kappich et al., 2011).

According to the dictionary of APICS (2011) the definition of S&OP is *"…setting the overall level of manufacturing output and other activities to best satisfy the current planned levels of sales…while meeting general business objectivities of profitability, productivity etc., as expressed in the overall business plan"*. Just as the definition implies, S&OP sets the frame for the decisions at the lower levels based on the business plans, business goals and future visions (Proud, 1994 and Ling and Goddard, 1988). S&OP is the main link between the top management and the subordinated plans (Tavares and Thomé, 2012). It seeks to align various functions in a company and is sometimes seen as a tool that helps the managing team toward collective decision making (Wallace, 2006). Typically the S&OP is made on an "aggregated" or "family" level and covers a sufficient span of time to guarantee that necessary resources are available (Ling and Goddard, 1988). Roughly, S&OP can be divided into a delivery plan (demand plan), based on forecasted demand, and a production plan (supply plan), which determines the capacity requirements, inventory levels, and/or backlog level (Ling et Goddard, 1988; Wallace, 2004). The capacity planning at the S&OP level concerns the evaluation of capacity requirements, decisions about future capacity adjustments, and the issue with having sufficient capacity, which is of a financial nature (Jonsson and Mattsson, 2009). There are two basic strategies used to develop a production plan at the S&OP level; chase and level (Olhager and Selldin, 2007). A chase strategy means that production is changed to match demand, whereas a level strategy produces a quantity equal to the average demand (APICS, 2000). There are many cases when it is not possible (nor desirable) to maintain a pure S&OP planning strategy. Instead, a middle way with the aim of finding an efficient trade-off between the pure strategies is applied (Olhager et al, 2001). When managed in the appropriate way the S&OP process supposedly generates numerous benefits to the company in the form of improved customer service, reduced inventory levels, shortened customer lead times, stabilized production rates, better supplier cooperation, improved sales teamwork, operations development, financial development, product development, as well as possibilities to react to new business opportunities (Wallace, 2004; Jacobs et al, 2011; Bower, 2006).

S&OP typically consist of five main activities; 1) forecasting future demand, 2) generating a preliminary delivery plan, 3), generating a preliminary production plan, 4) adjusting the delivery plan and production plan and 5) settling the delivery plan and production plan (Jonsson and Mattsson, 2009). Activity 1 includes the generating of an unconstraint forecast using statistical analysis and/or management input (Grimson and Pyke, 2007). Activity 2 concerns the development of the delivery plan. In this step the target for inventory levels or customer backlogs is usually established (Jonsson and Mattsson, 2009). Whereas the forecast should only refer to what the market demand, the delivery plan refers to what the company wishes to sell and deliver in each period. The delivery plan might be decided upon during a pre meeting within the sales and marketing departments (Grimson and Pyke, 2007). In activity 3 the delivery plan is used as an input to plan the volumes to be produced and delivered for each period during the planning horizon. In order to evaluate the supply side’s ability to support the delivery plan, it is important to identify supply constraints and opportunities for capacity expansion (AMR Research, 2009). Activity 4 is many times conducted during a pre meeting with the operations team (Grimson and Pyke, 2007). The meeting aims at establishing valid production plans as well as recommendation actions to close identified gaps between delivery and production plans. Activity 5 concerns a reconciliation meeting where managers from all involved functions formally meet to develop the final plans (Jonsson and Mattsson, 2009; Grimson and Pyke, 2007). During the meeting the preliminary plans together with key scenarios should be presented and issues, consequences, risks, and opportunities should be discussed (AMR Research, 2009).

How often the S&OP process is conducted varies from case to case. It also depends on the type of business, current delivery lead times, how rapidly the market changes, and the frequency of product renewal. Another factor to take into consideration when conducting the S&OP process is how often it is necessary to synchronize different operations with their budgets and to make new budget forecasts (Grimson and Pyke, 2007). In most cases, sales and operations planning processes are carried out monthly (Jacobs et al, 2011). The overall aim of the S&OP process has traditionally been to create a platform for cross-functional cooperation between demand and supply, and to create consensus among one set of goals and generate feasible plans (Ling and Goddard, 1988; Proud, 1994; Feng et al., 2008). Recently more ambitious aims of the S&OP process has been proposed: (1) to generate optimum plans with optimal overall supply chain profit as the target function (Grimson and Pyke, 2007); (2) to identify and analyse future possible scenarios in order to evaluate and support mid- and long term decisions (Gallucci, 2008); (3) to be event-driven and be able to quickly respond to demand and supply fluctuations based on real-time techniques and exception based actions (Lapide, 2004); (4) to expand outside the intra-organisational boundaries and integrate external customers and suppliers in the process (Hahn et al., 2000).

According to Grimson and Pyke (2007), advanced software systems may be required in the S&OP process, but not when the S&OP process is immature. The reason is that it is more important to have a well understood S&OP process than it is to have elegant software. Grimson and Pyke (2007) further propose an S&OP integration framework to categorize the maturity level of different S&OP processes. The framework uses a one to five ranking scale across five dimensions: (1) meetings and collaboration, evaluates the effectiveness of the human component in the S&OP process, (2) organization, focuses on the corporate S&OP structure, (3) measurements, applies to company performance as well as the effectiveness of the S&OP process, (4) information technology, refers to the IT used to support the S&OP process, (5) S&OP plan integration, measures how effectively a company builds its delivery plans and production plans and how well the plans interface. This kind of integration is the goal of the meetings, measurements, organizational changes and information technology. A Stage 1 company does not have any S&OP process, whereas Stage 5 relates to a company with a proactive S&OP process characterized by event-driven meetings, real-time access to external data, seamless integration of plans, and profit-focused processes. At Stage 5, the company is also a company where S&OP is understood to be a tool for optimization. APS systems are most likely required to achieve a Stage 5 S&OP process. Genin et al. (2007), emphasize the great potential of APS systems as a support for the S&OP process since its capabilities of frequent rescheduling leads to several changes in the S&OP decisions, thus reducing the stability necessary for the plans at the operational level and throughout the supply chain. Michel (2007), stresses that it is important to use decision support in the S&OP process because it is difficult to reach consensus among the different departments and during meetings. The software most valued by the companies included in the study conducted by Michel (2007) for supporting the S&OP process were: what-if analysis tools, real time S&OP dashboards, and demand planning.

2.1.2 Master production scheduling

Master Production Scheduling (MPS) breaks down the aggregated plans in the S&OP into detailed programs, individually defined for each product and usually characterized in weeks (Proud, 1994; Jonsson and Mattsson, 2009). By doing so the MPS drives the operation in terms of what is assembled, manufactured and bought (Vieria and Favaretto, 2006). Creating a valid master production schedule where the material due dates equal the material need dates, and the planned capacity equalling the required capacity is one of the primary responsibilities of MPS (Proud, 1994). Besides, the master production schedule provides information to the sales function about what can be promised to customers and when delivery can be made, which makes the MPS a vital link between customer order management and production. MPS is also used to establish some degree of control and accountability (Proud, 1994).

MPS typically consist of five main activities (Jonsson and Mattsson, 2009): (1) forecast future demand, (2) generate a preliminary delivery plan, (3) generate a preliminary master production schedule, and (4) reconcile, realise, and adapt plans when necessary, and (5) settle the prepared plans. Activity 1 is basically the same in all types of companies and concerns the process of producing a forecast of the planning period's expected demand. Activity 2 and 3 differ depending on the manufacturing strategy (make to order, make to stock, or assemble to order). It includes the generation of a preliminary delivery plan based on produced forecasts and orders on hand, and of a master production schedule based on the preliminary delivery plan and targeted inventory levels and order stocks. In activity 4 and 5, adjustments are made until a final master production schedule that satisfies the company's goals is found. An effective MPS process provides the basis for good use of manufacturing resources, meeting customer delivery promises, and resolving trade-offs between sales and manufacturing (Jacobs et al., 2011).

Having an MPS process does not assure success, however, if the MPS process is improperly managed, many of the benefits may be lost (Proud, 1994). It is important to understand what to master schedule, the capacity needed, and where a company chooses to meet the customer (ibid). There are many restrictions to take into consideration in the master production schedule, for example, capacity restrictions, raw material availability, different setup times according to production sequence, and economic lot sizes. Besides, one should strive for minimizing inventory levels, production costs and changeover times and maximizing resource utilization and service levels in order to be competitive. Such objectives are often conflicting; for example, minimizing inventory levels may result in degradation of service levels, and having an inventory in order to meet customer demand is costly. In addition, production is generally a multi-task procedure, distributed in a multi-period discrete horizon, which means that MPS must consider many complicated questions such as; what is the most adequate resource to use when more than one can be picked? What is the best assignment of product quantities to resource so that changeover can be minimal? What if some products could only be scheduled after others? What if the lines have different processing rates? What if some products cannot be scheduled simultaneously because they have the same tools, pallets, or fixtures? MPS becomes more difficult to create as the number of products, number of periods, and number of resources (production lines, assembly lines, machines, and production cells) increase (Vieria and Favaretto, 2006).

In practice MPS is very often done by simple spread sheet calculations without considering capacity limitations (Fleischmann and Meyr, 2003). As this is not the real industry scenario for most companies (Vieria and Favetto, 2006), practitioners become more and more aware of the need for a simultaneous consideration of all major constraints of MPS (Fleischmann and Meyr, 2003). Vieria and Pavetto (2006) suggest computer algorithms, with heuristics or optimization techniques for the MPS process.

2.1.3 Production activity control

Production activity control (PAC), or shop floor control, or shop scheduling concerns execution of material plans (Jacobs et al., 2011) and has three main aims (Arnold, 1998); (1) To release orders at the rate that capacity conditions will allow them to be executed with reasonable throughput times, (2) to ensure that start-up materials are available when each order is planned to start, and (3) to ensure that orders released for manufacturing in the workshop are completed in a suitable sequence with respect to delivery precision and throughput times.

The PAC process consists of four main activities; (1) order release, (2) priority control, (3) dispatching, and (4) reporting. The relative importance of these activities will, to a large extent, depend on the manufacturing processes at the company (Arnold, 1998). The primary differences are between a product line and a job shop process (Jonsson and Mattsson, 2009). In a product line the control of order release and priority control take place almost simultaneously. In a job shop, on the other hand, all activities in PAC are roughly equal in importance and scope. In general the following applies: First the upper planning levels initiate a manufacturing order; the order normally contains information on start time, due date and quantities. Before the order is released to the workshop there must be capacity available to carry it out, material necessary for its manufacturing must be available, and information required for executing the manufacturing order must be communicated to the workshop. When the order is released to the workshop, its operations must be executed in an appropriate sequence. This activity is called sequencing (Stoop and Wiers, 1996) or priority control (Jonsson and Mattsson, 2009). The execution of the operations in the workshop is often referred to as dispatching (Stoop and Wiers, 1996). Finally, the fact that manufacturing orders and operations has start and finish times does not mean that they necessarily will start and complete at the times stated. Thus, information pertaining to the progress of orders in the workshop should be reported to the higher planning levels so that they can be aware of what is happening as well as intervene in order to correct possible problems. There are three different levels involving job reporting: to report the entire order, to report the operations, and to report materials withdrawn for the order or delivery when the order has been completed (Jonsson and Mattsson, 2009).

A large amount of the manufacturing companies today use MRP logic in ERP systems to plan material requirements and release manufacturing and purchasing orders (Jonsson and Mattsson, 2006). Nevertheless, there are several methods to ensure that the released orders to the workshop are executed in an appropriate sequence. Some companies pass the list of released orders to the supervisors or foremen, who in turn make local scheduling decisions, supported by experience or simple priority rules. Others make use of more or less sophisticated scheduling algorithms in computer systems. Since humans are not well equipped to control or optimize large and complex systems, practitioners in manufacturing planning and control are often convinced that much can be improved regarding manual scheduling (Kostas et al, 2003). The academic MPC field has for decades formulated various scheduling techniques in an attempt to render feasible production scheduling. Production scheduling problems are mostly categorized as single machine problems, flow shop problems, and job shop problems (Kreipl and Dickersbach, 2008). Different objective functions and additional criteria like priorities, sequence depended set-up times or parallel resources lead to a huge number of scheduling problem classes. For each class of scheduling problems, simple priority rules, and also sophisticated scheduling algorithms have been developed (ibid).

2.2 Advanced planning and scheduling (APS) systems

This section starts by scanning previous literature regarding APS systems and thereafter clarifies and discusses the definition used in the thesis.

2.2.1 APS system characteristics

There are many varying definitions of APS systems, which the below stated quotations indicate.

*"APS is a set of technologies, business processes and performance metrics that enable manufacturing companies to compete more effectively in the global market place. The technologies involved are computer software and hardware that enable organization to change the way they plan, schedule, forecast, distribute, and communicate with customer and suppliers". (*Naden, 2000*).*

"An APS is a system that suits like an umbrella over the entire chain, thus enabling it to extract real-time information from the chain, with which to calculate a feasible schedule, resulting in a fast, reliable response to the customer" (van Eck, 2003).

"Techniques that deal with analysis and planning or logistics and manufacturing during short, intermediate, and long-term time periods. APS system describes any computer program that uses advanced mathematical algorithms or logic to perform optimization or simulation on finite capacity scheduling, sourcing, capital planning, resource planning, forecasting, demand management, and others. These techniques simultaneously consider a range of constraints and business rules to provide real-time planning and scheduling, decision support, available-to-promise, and capable-to-promise capabilities. APS often generates and evaluates multiple scenarios. Management then select one scenario to use as the 'official plan', The five main components of APS system are demand planning, production planning, production scheduling, distribution planning and transportation planning" (APICS, 2011)

"An APS system is a software system designed to integrate with ERP and MRP systems to enhance the short term production planning and scheduling" (Bitepipe, 2012)

"APS is a type of system that tracks costs based on the activities that are responsible for driving costs in the production of manufacturing goods. An APS allocates raw materials and production capacity optimally to balance demand and plant capacity" (serachmanufacuringerp, 2012)

An APS system can refer both to commercial, off-the-shelf software and to bespoke software based on tailor-made algorithms solving a specific planning problem. It can be provided as a broad suite supporting planning processes at different planning levels or specialized components supporting one particular planning process. An explanation for this is that APS systems originate from different fields; it can be defined as an extension of ERP systems but it also stems from in-house developed decision support systems (DSS) (de Kok and Graves, 2003). Besides, APS systems are a relatively young technology that has only recently gained a lot of attention, which means that the term is not settled (Hvolby and Steger-Jensen, 2010). The term APS system was first introduced in the 1990s (Moon et al, 2004). Other terms are also used to describe the same thing creating confusion regarding the concept, e.g. advanced planning and optimization (APO), supply chain planning (SCP) (Chen, 2001) and advanced supply chain collaboration (Hvolby and Steger-Jensen, 2010). Besides, many concepts are overlapping each other, and it is difficult to obtain a clear picture about the functionalities and roles of each entity (Helo and Szekely, 2005). For instance, the modules of an APS system are often bundled together with the modules of an ERP system and it is not easy to determine which modules that belong to which system (Stadtler and Kilger, 2005). Another explanation for the ambiguousness concerning the definition of APS systems is that software vendors call their solution APS but the functionality of the solution differs between different vendors (Hamilton, 2003). The big ERP vendors have successfully achieved an adequate level of functional breadth, which has helped these vendors achieve market-leading positions. A few supply chain specialists have managed to keep pace with the ERP vendors and offer similar functional footprints. The rest of the market remains fragmented, with a range of smaller vendors that are either functionally oriented, industry oriented or geographically focused (Kappich et al., 2011).

So what is an APS system? Is it possible to define the APS system? Usually, APS systems are viewed in the light of well known deficiencies of its predecessors. Van Eck (2002) e.g. compares APS systems with MRP II (see Tables 2). According to van Eck (2002) there are a few assumptions underlying MRP II that do not apply for APS systems. Unlike the MRP approach, APS do not assume that all customers, products and materials are of equal importance and that certain parameters, such as lead times, can be fixed. APS systems make use of optimization techniques, which take into account such data as customers' requirements, resource capabilities, or process constraints, so as to provide improved plans at the different level of companies. An MRP II run is batch oriented and is a time consuming process whereas the APS system recalculates a plan or schedule relatively fast. The main capabilities for a real decision support are limited in MRP II systems. APS systems on the other hand are decision-support tools, based on models that allow companies to improve their forecast, planning and scheduling operations. APS systems have more user-friendly user interfaces which allows the user to drill down into the specification to identify where the problem occur. The material allocation in MRP II is done on a first-come-first-serve basis, which might result in suboptimal plans. An APS system deals with this problem in another way where material is allocated to the availability and the criterion specified.

Entrup (2005) compares APS systems with ERP systems (Table 3). He stresses that the main differentiating factor between APS systems and ERP systems is the shift in the planning philosophy. Constraints and bottleneck, which have previously been neglected, are taken into account in APS systems. The objective of production planning when generating feasible plans has in APS systems shifted to plans that are subject to company-specific optimization criteria. Therefore, all planning parameters of a specific planning problem are to be considered simultaneously. Ideally, production lead-times that are fixed in the MRP logic can be reduced in APS systems, which according to Entrup (2005) could result in the implementation of an order-based pull production. In contrast to the MRP logic, which is primarily appropriate in discrete industries, APS systems are suitable in all industries. Another important difference is the decision support function. APS systems focus entirely on the decision support whereas an ERP system is mainly a transactional system. An ERP system does, however, support some decision making processes, such as inventory management, production planning, forecasting, etc. (Fleishmann and Meyr, 2003). The real planning support of an ERP system is still provided for isolated activities such as algorithms for lot sizing (Entrup, 2005). Finally, an APS system delivers the results much faster than an ERP system due to the memory-resident data storage (ibid).

Table 2: A comparison APS systems and MRP II systems
(Adopted from van Eck, 2002)

APS system	**MRP II system**
Customer preference may be varied depending on the business importance of the customer	All customers are given equal preference in the system
Lead times can be dynamically entered by contacting the customers	Lead times are fixed and known a priori
APS applications dynamically calculate a plan and schedule within minutes of any change being made to them	MRP runs are usually batch time and have longer duration times
Support superior decision making by what-if analysis and simulations	Does not support any decision making aids
Smart and easy to drill down reporting based on the identification of exceptional conditions	Detailed reports, which are hard to read and decipher
Material allocation according to availability and according to the criterion specified	Material allocation done on a first come first service basis

Table 3: A comparison of APS systems and ERP systems
(Adopted from Entrup, 2005).

Areas	**ERP system**	**APS system**
Planning philosophy	• Planning without considering the limited availability of key resources required for executing the plans. • Goal: Feasible plans • Push • Sequential and top-down	• Planning provides feasible and reasonable plans based on the limited availability of key resources • Goal: Optimal plans • Pull • Integrated and simultaneous
Business driver	Manufacturing coordination	Satisfaction of customer demand
Industry scope	Primarily discrete manufacturing	All industries
Major business area supported	Transaction: Finance, Controlling, Manufacturing	Planning: Demand, Manufacturing, Logistics, Supply chain
Information flow	Top down	Bi-directional
Simulation capabilities	Low	High
Ability to optimize cost, price, profit	Not available	Available
Manufacturing lead times	Fixed	Flexible
Incremental planning	Not available	Available
Speed of replanning	Low	High
Data storage and calculations	Database	Memory-resident

Other researchers have tried to describe an APS system by identifying typical APS characteristics. Stadtler and Kilger (2005) have, for example, identified three main characteristics of APS systems; (1) integral planning of the entire supply chain, at least from the suppliers up to the customers of a single enterprise, (2) true optimization by properly defining alternatives, objectives, and constraints for the various planning problems and by using optimization planning methods; either exact ones or heuristics, and (3) a hierarchical planning system which is the only framework permitting the combination of the two preceding properties. According to Fleishmann and Meyr (2003), neither the hierarchical planning concept underlying the APS architecture nor the algorithms used in the single modules is particularly advanced. Instead, the real advance is the implementation of these concepts in standard software, enabling dissemination of reasonable planning concepts and OR based algorithms in practice. Helo and Szekely (2005) identify five main functionalities of APS systems; (1) supply chain inventory and lot size optimization, (2) available-to-promise/capable-to-promise calculations, (3) inventory and transportation optimization; order decoupling point definition, (4) reduced inventory points, and (5) material flow analysis. Wiers (2009) identifies three elements of APS systems; (1) it is based on a model of the system to be planned or scheduled, (2) it contains supporting or automating functionalities to generate plans or schedules, and (3) it provides a graphical user interface to present the plan or schedule to the user and to give the user the option to manipulate the plan or the schedule.

Yet a common way of explaining APS systems is by describing the functionalities of the software modules comprising an APS system (e.g. Fleishmann and Meyr, 2003; Stadler and Kilger, 2005; Kreipl and Dickersbach, 2008). Based on the so called supply chain planning (SCP) matrix Stadtler and Kilger (2005) suggest a common structure of commercial off-the-shelf APS systems. The SCP matrix identifies planning tasks according to two dimensions, the planning horizon (long-term/strategic, mid term/tactical, short-term/operational) and the supply chain process (procurement, production, distribution, sales). Figure 4 illustrates the common structure of APS system modules supporting planning processes in the SCP matrix. The following modules can be distinguished: *Strategic Network planning* covers the quantitative part of strategic planning. Questions of network design like plant location dimensions of stocking or production capabilities, and the choice of procurement and distribution channels are answered from a quantitative view (ibid). *Demand Planning* incorporate both strategic long term demand estimation and mid-term sales planning (Entrup, 2005). The results of the demand planning module are required as input figures for the other modules. *Master planning* coordinates the material flow of the supply chain as a whole for a mid-term planning horizon. *The production planning and scheduling* modules deal with lot sizing, machine assignment, scheduling and sequencing. APS usually designate one or two modules to the tasks production planning and scheduling (Stadtler and Kilger, 2005). *Distribution planning and transport planning* concerns the mid-term tactical constraints within the distribution system, such as the regular transport links, the delivery areas of warehouses, the allocation of customers to sources, and the use of service providers. *Demand fulfilment and Available to promise* takes care of the arriving customer orders. It comprises the tasks of order promising, which includes checking the availability of materials and due date settings, and of measures in case of shortage (Fleishmann and Meyr, 2003). *Purchasing* and *material requirements planning* (P&MRP) is connected to the mid- and short-term procurement processes. As many companies have these functions already available in their ERP systems, this module is only seldom provided in APS systems (Entrup, 2005).

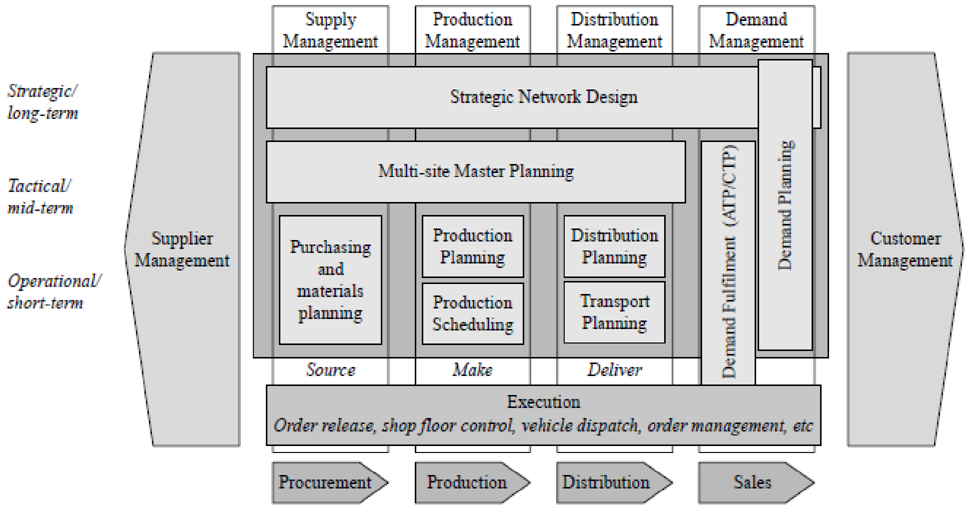

Figure 4: APS modules covered in the supply chain planning matrix (Stadtler and Kilger, 2005)

While a representation of the APS modules within the SCP matrix is favoured by many authors, some criticism has been placed against it. It is said that the representation is misleading and that some elements are missing (Entrup, 2005). It is, for example, argued that the modules demand planning and available to promise should not be included as those modules have nothing to do with planning, but instead with the generation of input data. It is also suggested that industry-specific planning solutions and collaboration between customers and suppliers should be integrated in the representation.

Stadtler (2005) identifies a number of areas of improvements of todays APS systems; (1) event based planning, i.e. updating the plan whenever new information comes in, (2) stochastic programming to deal with uncertainty, (3) agent technology to coordinate decentralised plans, and (4) linking APS system with the production control at the shop floor and with the cost accounting. The APS architecture is open to include new modules and algorithms (Fleischmann and Meyr, 2003), which most likely will be used in the future to improve MPC- and supply chain planning. A few APS systems vendors have e.g. incorporated real simulation capabilities in their APS packages.

2.2.2 APS system definition

So is it possible to agree upon one definition of APS systems? It is difficult to define an APS system by comparing it with its procedures since this will most likely make the understanding of an APS system more muddled. Many ERP systems include APS functionalities and it will be an impossible task to differentiate between the different systems. Neither is it a good idea to define the APS system as a number of predefined software modules in accordance with the SCP matrix. Modules change names, alternative modules with new functionalities are increasingly launched, and the functionality in the modules might differ between vendors. Therefore, this thesis considers it appropriate to define an APS system by its unique characteristics.

First of all, an APS system is a computer program that supports planning tasks at different planning levels. One of the first applications for APS systems is *decision support* (Bermudez, 1996; de Kok and Graves, 2003; Entrup, 2005; David et al., 2006). An APS system extracts master- and transaction data from an ERP system (or legacy system), to support decision making, and sends the decision back to the ERP system for final execution. Master data is the basic characteristics of instances of business entities such as customers, products and suppliers, whereas transaction data describes relevant events in a company, e.g. orders, invoices, payments, deliveries etc. (Haug and Stentoft Arlbjorn, 2010). Decision making is closely related to the capability to quickly create new plans (Entrup, 2005). An APS system uses computer random access memory, i.e. data is processed in the computer's memory alone, which leads to the ability to reschedule very quickly (Kappich et al., 2011). *Simulation* within commercial off-the-shelf APS systems is usually what-if scenario analyses. What-if simulation is the functionality of easy generating and comparing different scenarios (van Eck, 2003).

According to Bermudez (1996) the implication of adding the word 'advanced' to scheduling and planning is its' *simultaneously consideration of constraints* to improve the schedule and production plan. The use of constraints to help model the company specific manufacturing environment is also many times identified as something unique of APS systems (e.g. APICS, 2010; van Eck, 2002; Entrup, 2005; David et al., 2006). Generally, constraints are a set of limitations, rules, and objectives that govern the physical and financial realm of possibilities for meeting the business plan (Bermudez, 1996). Limitations might include something as general as the availability of material or machine capacity, or as detailed as the need for a minimum labor skill at a machine for a specific part. Rules might be as general as specifying that customer orders are considered ahead of forecast demand or as specific as the need to clean a machine after certain number of production hours. Objectives are used to describe the company business plan and might include target safety stock levels, customer service levels, or sales revenue.

Optimization from the APS system vendors' point of view is the systematic approach to improving the plan or schedule based on the constraint of the business (Bermudez, 1996). *Optimization* is also a commonly mentioned characteristic of APS systems (e.g. Stadtler and Kilger, 2005; Fleishmann and Meyr, 2003). In general, APS system vendors agree on the concept of soft and hard constraints (Entrup, 2005). Soft constraints have no physical limitation and include business goals such as minimizing set up costs or maintaining a target safety stock level. Hard constraints are usually physical limitations such as limited machine capacity or material availability. While hard constraints have to be fulfilled, the violation of soft constraints only renders a penalty in the objective functions. Common techniques or *algorithms* used to achieve an optimized plan or schedule include: linear programming, genetic algorithms, theory of constraints, and heuristics (David et al., 2006).

Based on the above discussion the following characteristics should be included in a definition of APS system: 1) gives support to planning at short term, mid term and long term periods, 2) generation and evaluation of different scenarios,

3) simultaneously consideration of constraints, 4) use of mathematical algorithms to solve optimization problems. The definition provided by APICS identifies those characteristics and is therefore used as the APS system definition in this thesis. The last sentence in the APICS definition "the five main components of APS system are demand planning, production planning, production scheduling, distribution planning and transportation planning" has however been excluded. The reason is that the author believe it would be to narrow the definition too much to state that APS system should include some predetermine modules.

2.3 The use of APS systems in MPC processes

The following section describes the use of APS systems in the S&OP, MPS and PAC processes. It is described how an APS system can be used to support the APS system user in performing the different activities in the MPC processes.

2.3.1 The use of APS systems in S&OP processes

The S&OP process typically involves representatives from different functions, e.g. sales, purchasing, marketing, finance, distribution, production, logistics, that in different ways make use of the APS system and the APS system output.

To support activity 1 and 2 "creating a consensus forecast and a preliminary delivery plan", an APS system usually comprises 'sophisticated' methods as well as room for manual adjustments. Typically the APS system generates a statistical forecast by using various forecast methods, which the user thereafter can adjust manually. Most APS systems support the method of collaborative forecasting, where input can be collected from all involved departments, including customers, to make sure that as much as possible of the relevant information is used (Entrup, 2005). In some processes the statistical forecast is taken as it is whereas in other processes a number of people (e.g. sales managers and customers) make manual adjustments to the forecast. Typically a central planning organization or a central planner is responsible for the generation of the preliminary delivery plan in the APS system. In practice this means creating the aggregated forecast and making the final adjustments to it (based on the input from sales managers, customers and pre planning meetings) and pressing the button in which the preliminary delivery plan is automatically transferred to the planning engine. A common feature of an APS system is the possibility to easily aggregate and disaggregate forecasts based on different customer segments, product groups, time buckets or internal organizational functions (Kreipl and Dickersbach, 2008). This gives an overview of the forecast on whatever dimension and level desired, which might be used during pre meetings when the final delivery plan is agreed upon and when discussing the forecast accuracy, possible sales-increase, and specific customer order profitability. APS systems also support what-if simulations, where the user might investigate the impacts certain actions, like promotions and discounts, have on a products' customer demand, stock levels, production or transportation quantities. These methods are valuable when planning to actively influence and guide customer demand instead of simply estimating it (Fleishmann and Meyr, 2003).

To support activity 3 to 5 in the S&OP process, i.e. balancing demand with available capacities and assigning demand (production and distribution amounts) to production sites and distribution centers, APS systems support the development of production plans. APS systems have the ability of producing plans for the 'entire' supply chain in terms of including several production sites, sub-contractors and distributors in the planning model (Stadtler and Kilger, 2005), i.e. integral planning. Input to the planning engine is the preliminary delivery plan and master data collected from the ERP system. The data from the ERP system is usually automatically sent to the planning engine but sometimes data has to be typed in manually. In general the central planning organization or the central planner is responsible for the generation of the plans in the APS system. The plans can be generated by the APS system automatically (by pressing the button) or by some interaction by the user (Wiers, 2009; Rudberg and Thulin, 2009). Typically, the user has the possibility to steer/test/influence the plans after his/her own desire and requirements. The user might e.g. turn constraints on or off, change the sequence in which constraints are evaluated, and/or by consider it hard or soft (Bermudez, 1996). The user might be interested in the effects of changed capacity or changed demand and can test those effects by generating different plans. Most algorithms compare each new plan against an old one. In making this comparison, the algorithms must evaluate the various trade-off between inventory, machine utilization and delivery performance in conjunction with other constraints. In general, APS systems use scorecards that list constraint violations, which allow the user to visually assess the impact of changes to the plan (Hvolby and Steger-Jensen, 2010). The different scenarios can be used as input to planning meetings and discussions in which the production plan are finalized. The delivery and production plans generated by the APS system are typically sent to planners at the production sites and/or purchasing departments to support master production scheduling and purchasing planning.

2.3.2 The use of APS systems in MPS processes

Compared to the S&OP process, the MPS process typically does not involve the top management. The MPS process might still involve representatives from different functions but might as well be run as an automated calculation procedure involving one person. The MPS process has to be more dynamic than the S&OP process since cancellation or rescheduling of orders may occur. The options regarding modifications of the master production schedule are limited by available capacity, yet the limitations are greater for MPS than S&OP since the planning horizon is shorter. In principle the MPS process consists of the same acivities as the process of S&OP and the same relationship exists between delivery plan and master production schedule (Jonsson and Mattsson, 2009).

The use of APS systems in the MPS process is similar to the S&OP process and the APS system support in the development of delivery plans and master production schedules is the same as in the development of delivery plans and production plans. Still, instead of only considering customer forecasts, real customer orders are also included in the calculation of the master production schedule. Besides, an additional task of the MPS process is to give information to the sales function about what can be promised to customers and when deliveries can be made. APS systems support this task by calculating customer order promises based on an available/capable to promise calculation (ATP/CTP). In general the procedure looks as follows: an order is entered in the

ERP system, the requested delivery time and volume is checked in the APS system, if available products or production capacity is found in the inquired lead time a delivery promise is returned to the ERP system. In a proper sense, ATP considers available stock and released orders for production and/or purchasing, whereas CTP check for potential supply (e.g. raw material, work in process, finished goods and production and capacity capacities) (Fleishmann and Meyr, 2003; Pibernik, 2005). ATP is however often used as a general term (Fleishmann and Meyr, 2003). An important factor in the order promising process is the response time that is allowed after the arrival of the order. In many cases the answer is expected immediately. As a consequence the order promising process has to be performed separately for every single order arrival, without knowledge of future orders. Naive use of ATP would therefore lead to first-come-first-serve priority, which is usually undesirable (ibid). APS systems use business rules that decide how the APS system should look for available capacity and which customers that should be prioritized in getting the available capacity.

2.3.3 The use of APS systems in PAC processes

The PAC process typically consists of a site scheduler who is responsible for generating the schedule (dispatch list). In general it is the site scheduler that uses the APS system whereas the operators use the output from the APS system.

The use of an APS system in PAC starts when the released manufacturing orders generated at the order planning level are downloaded to the APS system. If the ERP system relies on MRP for material planning, consideration is only taken from the demand side as MRP assumes infinite capacity. A rough level of capacity considerations can be taken if a master production scheduling process has been carried out before running the MRP. However, to achieve perfect synchronization, consideration must also be given to capacity shortage and disruptions in the inbound material flow, which is the case if the APS system takes over material planning at the order planning level (Mattsson and Jonsson, 2009). Interesting to notice is that most APS systems are slaves under the MRP system as it is the MRP system that is generating the manufacturing orders, which the APS system thereafter tries to make the best out of.

The APS system supports the sequencing activity by producing a schedule of operations for each work centre in the sequence in which operations are expected to be carried out where available capacity is considered (van Eck, 2003). A schedule may be generated with the aid of simple priority rules or with the help of more sophisticated algorithms. Common scheduling heuristics are versions of genetic algorithms and constraint-based programming since optimization algorithms cannot calculate the actual optimum within an acceptable timeframe (Kreipl and Dickersbach, 2008). The APS system usually gives the user the possibility to generate different schedules, which effects can be visualised on a dashboard. Most APS systems also allow the site scheduler to make use of interactive manual planning with help of drag and drop functions in a Gantt chart (ibid). This is a chart with time on the horizontal axis and resources on the vertical axis. The bars in the chart display the operations that are scheduled on the resources. By dragging and dropping bars to various locations, the user can change the plan without having to type in order numbers, start times and end times etc. (Wiers, 2009). The impact of the planning steps is immediately visible in the Gantt chart. Often the APS system allows the site scheduler to define whether adjacent operations are also rescheduled automatically (Kreipl and Dickersbach, 2008). Operations for a manufacturing order cannot start unless the material and tools are available; this availability check can be supported by the APS system or is handled manually after the APS system has generated the schedule. When the final schedule has been decided upon it is sent back to the ERP system from where it is sent to the shop floor through printouts or terminals connected to the ERP system. Typically, operators report on the progress of orders on the shop floor to the ERP system.

2.4 Consequences of using APS system

This section reviews previous literature concerning the consequences of using APS systems. DeLone and McLean (1992) recognised that there is a serial nature of information flow and impact. In this sense information flows through a series of stages from its production through its use to its influence on individual performance, which eventually have some organizational impact. Consequently, information system success can be captured at different levels, e.g. technical level, semantic level and the influenced level (ibid). An information system might impact beyond the immediate user and researchers have suggested additional IS impact measures, e.g. work group impact, industry impact and societal impact (DeLone and McLean, 2003). According to DeLone and McLean (2003) the choice of where the impact should be measured will depend on the system being evaluated and their purposes. This thesis suggests that the use of APS systems results in consequences at four different levels as illustrated in Figure 5. The use of APS systems in the MPC process results in consequences on the realization of the MPC process, which in turn have some impact on the MPC process output, i.e. plans and schedules. The MPC process output are thereafter used in the business processes, which have some impact on the performance in the business processes, which in turn have some impact on the company values in form of competitiveness and profitability.

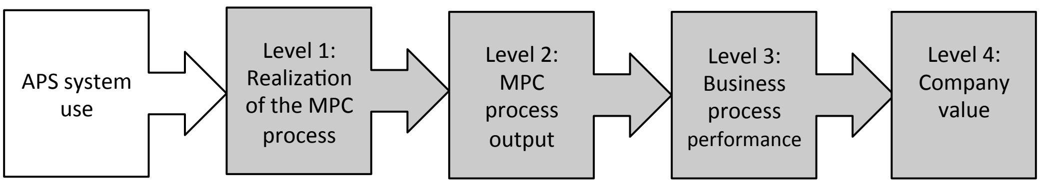

Figure 5: Consequences of APS system usage can be captured at different levels.

2.4.1 Positive consequences

Numerous trade journals and software vendor's sales brochures have described resulting benefits of APS systems such as improvements in lead-times, inventories, productivity, alignment of various plans existing within a corporation, increased availability of critical material and components, improved feasibility of plans, and more focused planning as planners can concentrate on exceptions and bottlenecks (Entrup, 2005). From a scientific perspective the realized benefits are assessed less enthusiastically (ibid). The following section presents studies of in-house developed decision support systems and commercial off-the-shelf software since the APS system refers to both (Rudberg and Thulin, 2009). Table 4 summarises the findings from the studies.

Brown et al. (2001) present a large-scale linear programming optimization model used at Kellogg's to support production and distribution decision-making at the operational and tactical levels. The usage of the model developed in-house at Kellogg's has resulted in better decision-making and overall cost savings. Gupta et al. (2002) describe a DSS that helps Pfizer plan its distribution network. The model is useful in strategic, tactical, and operational planning situations. The DSS has generated many benefits: improved transportation-scheduling support has led to savings in freight costs, elimination of customer deductions has amounted to several thousand dollars saved annually, and a strategic manufacturing plan has saved millions each year. However, the greatest benefits identified were the intangible ones: the DSS helped managers to understand the cost and service implications of proposed network alternatives. It also raised people's awareness of and ability to act on supply chain issues. It enhanced the firm's ability to remediate supply chain problems, resulted in proactive improvements, and increased people's confidence in the planning. Further, the DSS led to optimization modelling in other parts of the organization.

Wagner and Meyer (2005) identified a number of benefits in a case company implementing an APS system to support long-term production and distribution planning, master production scheduling, and short-term production scheduling. The most important improvements measured were: reduced planning time, reduced inventory levels, reduced overtime, and less emergency transport between distribution centres. Reuter (2005) found that the implementation of an APS system to support demand fulfilment, procurement planning, and short-term production planning resulted in a reduction of planning cycle times and communication efforts, increased forecast accuracy, and better control of decentralised sales regions.

Fleischmann et al. (2006) explain the modelling of the DSS used at BMW to support strategic planning. The model made the planning process more transparent, reduced the planning effort, and allowed planners to investigate various scenarios more frequently than they were doing in the past. All in all, it greatly improved the decision support for BMW's overall planning. Dehning et al. (2007) examine the financial benefits of IT-based supply chain management systems. They suggest that SCM systems add value to the inbound logistics through the availability of more current and accurate information regarding orders that are shared with suppliers. In addition, SCM systems support operation processes by coordinating marketing forecasts, production schedules and inbound logistics. They also increase a firm´s ability to adapt to unplanned events. As a consequence, inventory levels and costs can be reduced and higher capacity utilization achieved. Based on a literature review, 50 industrial success stories and four detailed interviews about APS system implementations Gruat La Forme et al. (2009) identify a number of quantifiable and qualitative benefits. Quantifiable benefits assessed with APS systems are reduction of inventory, increased customer service levels and reduction of total costs. Qualitative benefits are improved decision making and availability of critical components.

Rudberg and Thulin (2009) identified the following benefits of an APS supported master production scheduling process; higher throughput at a lower total cost, higher service level with reduced total capacity and lower inventory, increased supply chain visibility and coordination, more time-efficient planning and re-planning with fewer persons involved in the planning process, more proactive planning through the possibility to swiftly run a number of scenarios at very short computing times, better and more frequent communications between various functions within the company, and better integration between production and distribution planning leading to more efficient use of scarce resource. Cederborg (2010) conducted a multiple case study including four companies that had implemented an APS system supporting the tactical planning process. The most mentioned benefits were: reduced inventory levels, increased planning speed, more synchronized production and demand, and real time overview of the supply chain. The companies also reported on a more optimized production mix with regard to resources, improved forecast accuracy, increased customer service, reduced overtime in production, improved on-time deliveries, and reduced non value added activities in production.

Table 4: APS system benefits identified in previous literature

		Brown et al. (2001)	Gupta et al (2002)	Wagner and Meyer (2005)	Reuter (2005)	Fleischmann et al (2007)	Dehning et al (2007)	Gruat La Forme et al. (2009)	Rudberg and Thulin (2009)	Cederborg (2010)
Level 4	Reduced overall costs	X	X				X	X	X	
Level 3	Reduced inventory levels			X			X	X	X	X
	Increased customer service		X					X	X	X
	Improved on-time deliveries									X
	Higher capacity utilization						X		X	
	Less emergency transport			X						
	Reduced over time			X						X
	Reduced non value added activities									X
	Availability of critical components							X		
Level 2	Syncronized demand and supply plans									X
	Improved forecast accuracy				X					X
Level 1	More accurate information						X			
	Reduced planning time			X	X	X			X	X
	Improved decision making	X	X					X		
	Better understanding (cost and service)		X							
	Increased confidence in planning		X							
	Enhanced ability to act in supply chain issues		X							
	Proactive improvements		X				X		X	
	APS usage in other parts of the organization		X							
	Improved supply chain visibiliy					X			X	X
	Improved integration and coordination						X		X	

The most commonly mentioned benefits in previous literature are: reduced overall costs, reduced inventory levels, and reduced planning time followed by increased customer service. When reduced overtime in production is regarded as part of capacity utilization, it will join increased customer service as the second most mentioned benefit. Overall costs, inventory levels, customer service, and capacity utilization are relatively easy to measure, which might be why those benefits are commonly mentioned in the literature. Reduced planning time is very much what one would expect to gain from implementing an APS system. One of the main purposes of the APS system is to aid planners in their decision making by calculating and proposing plans and schedules (Stadtler and Kilger, 2005) and by doing so take over time consuming and complicated tasks from planners. Other commonly mentioned benefits are improved decision making, proactive improvements, and improved supply chain visibility.

IS literature has used a number of different ways to categorize benefits, e.g. intangible and tangible (Schroder et al., 1981; Al-Mashari et al., 2003), operational, managerial/organizational and personal (Money et al., 1988), and strategic, informational, personal (Mirani and Lederer, 1998). In the APS system literature a common way to categorize the benefits are in intangibles and tangibles (e.g. Schroder et al., 1981; Money et al., 1988; Gupta et al., 2002; Cederborg, 2010). Few of the identified studies of APS systems in Table 4 do make any difference between benefits based on the level they are captured. Some studies do, however, identify that there is a cause-and-effect relationship between benefits. Dehning et al. (2007) e.g. find that the SCM system supports operation processes by coordinating delivery and production plans and by increasing the firm's ability to adapt to unplanned events which in turn lead to reduction in costs, increased capacity utilization, and reduction of inventory levels. Gupta et al. (2002) found that the use of DSS raised people's awareness of and ability to act on supply chain issues, leading to enhancement of the firm's ability to remediate supply chain problems, resulting in proactive improvements. It is also identified that the achieved benefits are closely connected to the functionality supporting certain planning tasks. Gruat La Forme et al. (2009) e.g. found that the customer service levels are improved due to a reliable delivery model, which is achieved when using an APS system for available-to-promise or capable-to-promise calculations.

2.4.2 Negative consequences

The literature concerning the negative side of using APS systems is much poorer than the positive side of using APS systems. This being so, APS system literature is complemented with literature on ERP systems. David et al. (2006) investigate the limitations of APS systems and the possible effects on the performances. (1) An APS system can take process and resource constraints into account to determine batches or sequences of jobs. However, there is a risk that new customer requirements or unexpected events (e.g. breakdowns, supply problems) will cause changes to the batches or sequences of jobs. If e.g. a product is delayed owing to a missing part, the batch to which this product belongs would have to be rescheduled. As several unexpected events occur during day-to-day operations, the modification induced in the production plan can be numerous, so that the system becomes nervous. In order to avoid these problems, a possible solution is to keep the planning model simple. However, by doing so, the results of the APS system calculation may not be representative enough of the shop floor reality, which in turn might result in an infeasible plan. (2) In an APS system, the planning calculation aim at balancing production and demand. This means that if the expected quantity that is required is not matched, the system generates new production orders, in order to meet the quantity needed. However, if there exist tolerance, production orders can be generated even if not required, which results in a risk of producing unnecessary products and overestimating the capacity requirements. (3) The number of BOM levels that an APS system can handle is limited.

Marcus et al. (2000) presented the results from a study of the problems and outcomes in ERP projects. A number of problems derived in different phases in the ERP experiences cycle were identified, which if left unsolved could create problems in later phases and affect the outcomes. In the onward and upward phases, the following problems were identified: (1) Unknown business results. Many adopters who had been using ERP long enough to have business results did not know whether they had realized improvements. (2) Disappointing business results. Some adopters in the onward and upward phase reported that their business results had not been achieved. (3) Fragile human capital. Many adopters were not in a strong position to go forward with ERP because of the fragile state of their ERP human capital. Many organizations had lost and had difficulties replacing ERP knowledgeable IT specialists and end-users. This resulted in that organisations failed to realize the full business benefits from ERP, that they became dependent on outside help to make future technology upgrades and business improvements and that they were unable to recover gracefully from future problems. (4) Migration problems. Difficulties in upgrading ERP systems.

In a case study on ERP systems conducted by Häkkinen and Hilmola (2008) ERP system users gave comments describing the overall negative effects that ERP system implementations had brought either to their own work or to the organization as a whole. Negative effects were; (1) More complicated and fragmented data-processing activities. The process of acquiring and entering certain information was more complicated and time-consuming than in the prior system. (2) Reduced flexibility both in terms of modifying system use and outputs in response to changing needs and in terms of providing flexible service solutions to customers. (3) Negative impacts of increased integration. The data quality was more dependent on the fact that the system was being used correctly and in the agreed way in order not to cause data and report unreliability. (4) A more demanding and complicated process when implementing changes to the system.

The above studies identify a number of negative consequences, which can be captured at level 1-4 in Figure 5. The limitations of APS systems identified by David et al. (2006) result in unfeasible plans that can be connected to the MPC output (level 2) and the production of unnecessary products and overestimating capacity requirements which can be connected to the business process (level 3). No achievement of expected and/or potential benefits, unknown business results, non-utilization of full business benefits as identified by Marcus et al. (2000) can be seen as negative consequences on any level. A more complicated process and negative impact on increased integration as identified by Häkkinen and Hilmola (2008) can be connected to the realisation of the MPC process (level 1). Häkkinen and Hilmola (2008) also identified that ERP system implementation might result in reduced flexibility in terms of modifying system use and outputs in response to changing needs, something that probably might result in negative consequences for the MPC output (level 2). It also reduced flexibility in terms of providing flexible solutions to customers, which is more connected to the business processes (level 3).

2.5 Variables influencing the consequences of using APS systems

This section reviews previous literature concerning the variables influencing the consequences of using APS systems. Table 5 summarises the findings from the studies. The section ends by presenting the categorization of the variables that will be used in the analysis and in the discussion of this thesis.

2.5.1 Variables according to previous literature

The empirical work on the implementation and use of planning systems is not widespread but it does exist (Zoryk-Schalla et al., 2004). In 2002 Petroni conducted a survey on MRP systems with the intention of filling the gap relating the scarcity of empirical studies concerning MRP system implementation. The study investigated the importance of organizational, managerial, and technological variables to ensure successful MRP implementations. A successful implementation was regarded as enhanced performance compared to the situation before the MRP system was implemented. The measures of success were connected to levels 1, 2 and 3 (Figure 5) and were obtained from combined consideration of four studies in MRP success carried out during the 1980's. The major findings of the study were that top management support, level of integration, and data quality strongly affected benefits. Petroni (2002) also highlights that there are many problems of effectively running MRP systems. Possible reasons for this are the complexity of the MRP system and that the MRP system requires a considerable amount of training. Besides, organizations often underestimate the extent to which they have to modify. In fact, many re-implementations of MRP systems are the results of a failure to implement business changes along with the software. Another variable concerns the resistance from the personnel to the organizational change that is influenced by the adoption of new technologies.

Wiers (2002) addresses the question of system integration and concludes that it is important to determine what functions should be supported by the ERP system and which functions should be supported by APS systems prior to an APS system implementation in order to make the implementation of the APS system smooth. Zoryk-Schalla et al. (2004) examine the APS systems modelling process and highlight that modelling is a key success factor for implementation of APS systems. It is suggested that extensive support from highly trained modellers are needed as APS systems may not be capable of assisting the modeller in properly defining the planning process and planning model. Besides, as humans play an essential role in operating the APS system the actual knowledge about hierarchical planning structures and algorithms are insufficiently developed to allow for easy implementation of APS systems.

Lin et al. (2007) presented a reappraisal of APS systems in industrial settings and proposed an approach to APS systems implementation. The authors identified several pitfalls connected to an ITO framework consisting of individual (I), technological (T), and organizational (O) dimensions.[1] The framework was developed during the 1980s within the nuclear power industry (Berglund and Karltun, 2005). The system view of the ITO-concept was considered successful for improving safety and developing a more throughout safety culture and has thereafter been spread to other domains. It has for example been used by authors within the MPC subject in order of analyse and further develop the understanding of highly complex tasks (e.g. MacCarthy et al., 2001; Webster, 2001; Berglund and Karltun, 2005). In the study of Lin et al. (2007) it was found that the I-dimension was overlooked in the APS system implementation; implementers assumed the workforce had higher levels of I skills than they actually did, and relied too much on the automation capabilities of APS systems. Some pitfalls connected to the T-dimension were that the assumption of quality input data could not hold, that the system dynamics of APS systems were complex and, therefore, also difficult to understand and manage. Pitfalls connected to the O-dimension were that the difficulties of business process re-engineering and weaknesses in data management procedures to ensure data quality were neglected. It was suggested that business process reengineering should precede APS system implementation to rationalize ITO dimensions in business processes. Besides, the authors emphasised the importance of empowered humans taking control of system behaviour and planning results, and treating the APS system as a foundational platform to build other transparent decision supporting tools when implementing APS systems.

Rudberg and Thulin (2009) present findings from a case study at Lantmännen, which went through a major restructuring of its supply chain with the help of an APS system. The project management came to the conclusion that it most likely would have been possible to carry out the restructuring of the supply chain without implementing the APS system. However, all people involved in the project were convinced that the positive consequences (at levels 1 to 4) would not have been reached fully without the support from the APS system. A prerequisite for effectively using the APS system was that the organization employing the APS system was operated effectively, in this case through the restructuring of the supply chain and the centralization of the master planning function. Setia et al. (2008) developed a framework for organizational value creation from agile IT applications and used APS systems as an example. It suggested that the fit between an APS system, the supply chain objectives and organizational structure, the extent to which the APS system is used in the business process and the extent to which the system is deployed throughout the supply chain, were antecedents to value creation using the APS system. Setia et al. (2008) further suggested that the APS system was fit for organizations looking for new opportunities to dynamically evolve their structure and plans.

[1]The framework used by Lin et al. (2007) is called HTO where H stands for ”human”, T for ”technological” and O for ”organisational”. In paper III and IV “human” has been replaced by “individual” and the framework is consequently changed to ITO. The meaning is exactly the same and in order to keep away from misunderstanding the ITO framework will be used without exceptions in the thesis.

Those organizations typically have flexible and informal organizational structure and decentralized decision making. An APS system is also said to fit with “complex tasks environment with large number of product categories, frequent demand patterns, and uncertain supply conditions”. In fact “firms with less complex products or narrower product lines might find negative returns from these systems due to the additional effort required to manage them”. A number of propositions are developed and tested in two case companies. The propositions found strong support regarding the role of antecedents and moderators on creating agility through the implementation of APS systems.

Wiers (2009) identifies that an APS system implementation usually means that planning and scheduling decisions are transferred from the shop floor to the new APS system. This might mean disagreement between the scheduler and the shop floor about the decision freedom regarding production control permission to the shop floor, leading to a problematic use of the APS system. Wiers (2009) identifies four shop types based on uncertainty and human recovery in which it is applicable to implement APS systems. 1) The smooth shop, characterized by no uncertainty (e.g. machine breakdowns, rush orders, rework) and no human recovery, i.e. no decision freedom regarding production control decisions. 2) The social shop, characterized by no uncertainty and human recovery. 3) The stress shop, characterized by uncertainty and no human recovery. 4) The sociotechnical shop characterized by uncertainty and human recovery. According to Wiers (2009) the smooth shop offers the best promise for the implementation of an APS system; the shop is stable and optimization can be performed with precise operation timing and sequence. In the social shop the APS system might suggest detailed scheduling since the uncertainty is low, still those are unlikely to be followed since operators have decision freedom. In the stress shop, the schedules need to be revised frequently. The APS system can support the scheduler in making changes and receiving feedback on the shop floor. In the sociotechnical shop implementing and using APS systems is a big mistake. According to Wiers (2009), a classical error is to implement an APS system that creates detailed schedules, which are being ignored by the shop floor, however most likely with good reason.

Cederborg (2010) examined critical success factors (CSF) of ERP implementations to see if they were applicable even in APS system implementations, by conducting a multiple case study. He found that there was a connection between having several benefits (level 1 to 3) of the APS system implementation and having several CFSs. The four most important CSFs were: the system already present should fit the chosen APS system, fit between APS system and business processes, project champion, and top management support.

Table 5 summarises the identified variables based on the literature, which might influence the consequences of using APS system. The most commonly mentioned variables are: the fit between the APS system and the environment/organization/task, the APS system user, and system integration. The studies highlight the importance to select an APS system that suits the environment, the organisation and the planning task. Studies suggest that if the APS system is implemented in unsuitable environments the company might suffer by having to put too much effort into managing the system or by not achieving the expected benefits. In addition to the fit, it is important that the personnel using the APS system have a good knowledge in hierarchical planning structures and algorithms and can take control of system behaviour and planning results in order to receive benefits. In general, APS systems mean fewer but more empowered planning and scheduling personnel (Bermudez, 1996). The APS system also has to be integrated in the existing IT infrastructure. The main interactions exist between APS and online transaction processing systems, e.g. ERP system and legacy system (Stadtler and Kilger, 2005). Another important system is Data warehouse, which stores major historical data of a business (ibid). It is important to resolve which business functions that should be performed by the APS system and which should be performed by the ERP system (Wiers, 2009).

The second most mentioned variables identified in previous literature are top management support, data quality, and the APS system itself. The importance of having the support from the top management is crucial for increasing the level of employee motivation and acceptance of the potential improvement that the new technology could cause (Petroni, 2002). The APS system receives data from different systems in order to generate plans or schedules (David et al., 2006). It is therefore important that changes in each system are propagated to ensure that all systems have the correct data (Stadter and Kilger, 2005). The complexity of a planning system has also been identified as a variable influencing the consequences of using the system. Lack of transparency and traceability of a planning system is problematic as it might create mistrust of the planning results (Kreipl and Dickersbach, 2008). Project champion, planning organisation, business reengineering, and modelling are other variables mentioned that should have an influence on the consequences of using APS systems.

Table 5: The variables influencing the consequences of using APS system.

	Petroni (2002)	Wiers (2002)	Zoryk-Schalla et al. (2004)	Lin et al. (2007)	Rudberg and Thulin (2009)	Setia et al. (2008)	Wiers (2009)	Cederborg (2010)
Top managemet support	X							X
Project champion								X
Planning organisation					X			
Business reengineering	X							
System integration	X	X						X
Data quality	X			X				
Modeling			X					
APS system user	X		X	X				
APS system	X			X				
Fit APS system/task/process /environment						X	X	X

2.5.2 Categorization of variables

Over the years the IS literature has suggested a number of different ways of categorizing variables that influence benefits or hinder benefits from being achieved. Cox and Clark (1984) provide an extensive review of literature in MPC. They identified three groups of variables that had a negative influence on MRP implementations: (1) management problems consisting of poor pre planning, lack of cooperation and procrastination, (2) technical problems consisting of system design, data structure, file integrity, management of inventory levels, and rescheduling, (3) people problems including communication issues, system education, user participation, and system acceptance. Guimaraes et al. (1992) identified five groups of variables that influenced the user satisfaction and DSS benefits: (1) characteristics of the implementation process, including top management support, user training, user involvement, (2) characteristics of the decision makers, including organizational level and DSS experience, (3) characteristics of the DSS, including the supported phase level of managerial activity and source of information, and (4) characteristics of the business task, including task structure and certainty, task difficulty, task variability and task interdependence. Zhu and Kraemer (2005) proposed three aspects of a firm's context that influences the process by which technological innovations are adopted, implemented and used: (1) technological context referring to the existing technologies in use and new technologies relevant to the firm, (2) organizational context referring to descriptive measures about the organization such as scope, size and the amount of slack resources available internally, and (3) environmental context referring to the arena in which a firm conducts its business – its industry, competitors and dealings with government. Dezard and Sulaiman (2009) investigate the current literature of critical success factors of ERP implementations and categorized those into five main categories: (1) ERP software, consisting of system selection, software troubleshooting, and system quality, (2) external expertise, consisting of vendor support and use of consultants, (3) ERP user, consisting of user training and education, and user involvement, (4) ERP adopting organization, consisting of top management support, business plan and vision, organizational culture, enterprise-wide communication, and business and IT legacy system, and (5) ERP project, consisting of project management, business process reengineering, change management program, ERP team composition, and project champion.

Based on the identified variables in the APS system literature (Table 5) three main groups of variables that might influence the consequences of using APS systems are suggested: planning environment related variables, MPC process related variables, and implementation related variables. In the section below those groups will be motivated and described. The intention of categorizing variables of influence is to help survey the situation and organize our knowledge (Dezard and Sulaiman, 2009).

Planning environment related variables relate to variables within the planning environment. Setia et al. (2008), for example, suggests that the number of product categories, frequent demand patterns and uncertain supply conditions influences the consequences of using an APS system. Wiers (2009) identified that the uncertainties in the manufacturing process influence the use of APS systems. The importance of a good fit between the planning environment and the planning approach, planning methods and planning systems in order to receive benefits have been identified in previous studies as well (e.g. Fisher, 1997; Jonsson and Mattsson, 2003; Jonsson, 2008; Fleischmann and Meyer, 2003;

Kaipia and Holmström, 2007; Tenhiälä, 2011). APS systems are usually argued as suitable in planning environments which are too complex for more simple planning systems (e.g. de Kok and Graves, 2003; Günter, 2005; Gen et al., 2008). Based on the supply chain complexity of Bozarth et al. (2009), the complexity in the planning environment that in this thesis is suggested to influence the use of APS system is defined as: "the level of detail and dynamic complexity that affects the MPC process". Detail complexity refers to the distinct number of components and parts that make up a system whereas dynamic complexity refers to the unpredictability of the input to a system and to a system's response to this input.

MPC process related variables relate to variables within the MPC process. Rudberg and Thulin (2009) for example identify the planning organisation as an important variable influencing the use of APS system and its consequences. Lin et al. (2007) further identify the individual user. The importance of the business process as such in order to achieve benefits out of the IS has been emphasized in previous studies as well. Clause and Simchi-Levi (2005) stress that business processes and IS should work in tandem for achieving business performance as supporting business processes is a must in order to effectively use advanced planning software. Several studies have shown that the organizational infrastructure, usually characterized by educated, trained, motivated and empowered personnel (Boyer et al., 1997; Muscatello et al., 2003; Yu, 2005; Bozarth, 2006) but also by the functioning of the planning organization (Grimson and Pyke, 2007; Jonsson, 2008), is of high importance in order to make technology and software investments successful.

Implementation related variables relate to variables connected to the previous phases in the APS system lifecycle. The selection of the APS system and the implementation process is influencing the IS use and output (Schroeder et al, 1981; Marcus and Tanis, 2000; Yu, 2005; Finney and Corbett, 2007). Consequently variables connected to the implementation of the APS system is seen as an important group of variables that might influence the consequences of using APS systems.

2.6 The conceptual framework

Previous studies of APS systems identify a number of benefits that might be achieved when using APS systems. The benefits most frequently mentioned relate to levels 3 and 4, i.e. concern the benefits at the level of the business process and/or the company. Only a few negative consequences of using APS systems have been reported in previous studies. A number of variables of importance for successfully implementing APS systems have also been identified in previous studies. Some studies regard a successful APS system implementation in terms of a project that is completed within time and budget. Other studies regard a successful APS system implementation in terms of receiving expected benefits. No matter definition of implementation the majority of the identified variables are connected to activities within phases when the APS system is implemented. Few variables identified are connected to the phase in which the APS system is actually used. Besides, the variables identified influence everything from level 1 to level 4 consequences and it is not clear in the majority of the studies which variables that are important for achieving which consequences. This might be one reason why it is not clear whether and how an APS system adds value to a company.

The conceptual framework that will be used in the analysis and discussion of this thesis is presented in Figure 6. Three groups of variables influencing the consequences of using APS systems have been identified based on previous literature, planning environment related variables, MPC process related variables, and implementation related variables. Research question 1 deals with the lower box in Figure 6, i.e. negative and positive consequences of using APS systems in MPC processes. Research question 2 deals with the upper box in Figure 6, i.e. variables influencing the consequences of using APS systems in MPC processes (level 1 and 2).

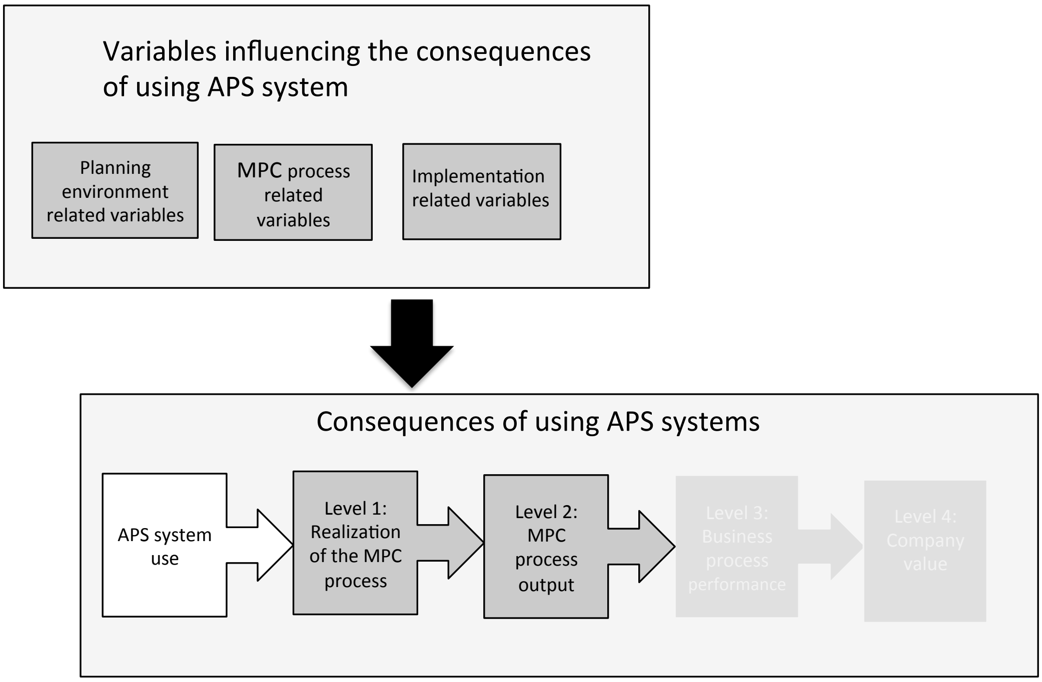

Figure 6: Conceptual framework

3 Methodology

This thesis consists of four case studies and one survey study. The chapter starts with a brief introduction of the research process, and then focuses on the research strategy, whereby the link between the research questions, the methods and the contributions of each study is described. The case companies are thereafter presented. In the last section, the quality issues of the research are discussed.

3.1 Research process

The research process started in February 2007 as a part of the project "Integrating the Supply Chain through APS systems (ISCAPS)". The ISCAPS project was a joint venture research project between Chalmers University of Technology and Linköping University funded by the Swedish government-owned authority Vinnova. The point of departure for the ISCAPS project was that the interest of APS systems was large but the knowledge regarding APS systems implementation and use was low, especially at the strategic and tactical levels. The overall purpose of the ISCAPS project was to investigate how the integration of the supply chain could be supported with APS systems.

When the author of this thesis started her PhD studies there were some understanding of what the thesis should deal with. It was therefore possible to formulate a "working purpose"; *"to increase the understanding of how APS systems are used in practice and to identify prerequisites for achieving a successful use"*. The author was aware that the purpose probably would change during the process and kept it more as a help to stay focused. The author started to scan previous literature in different areas; operations management, operations research, supply chain management, logistics management, information systems, and production planning and control. Literature such as scientific journals, conference proceedings, business-oriented publications, and theses provided important background information. The aim was to increase the author's personal knowledge about the subject area, to inform the author about the existing state of knowledge, as well as to increase the author's understanding of the methodological handicraft. The literature review has been conducted continuously throughout the research process (Figure 7). From the start, the literature review felt quite daunting. In particular the subject area did not seem to have any clearly defined boundaries and the author found it difficult to choose between the various literatures and know how to combine them. As the author became more aware of what she wanted to do the process of conducting literature review became more focused. The author got for example better in defining keywords and in matching her language to that of the source she was searching within. She also developed her skills in being able to read actively and critically. The five studies, which have been collected during the research process have to a large extent driven the way of how the literature review was conducted.

It was quickly discovered that a large source of confusion was the definition of APS systems. The term APS system was used to define different concepts, while several terms were used to define other similar concepts. It was not possible to define APS systems only with the help of existing literature; the author needed some practical understanding. Together with another PhD student involved in the ISCAPS project, interviews of APS systems consultants and system vendors stressing that they were using APS systems were conducted. The following questions were asked: what did APS systems mean for them and what functionalities were included in their systems. The interviews increased the knowledge about commercial off-the-shelf APS systems available on the market and what functionalities those APS systems include, as well as creating opportunities for skilled people within the industry to be involved during the research process.

Early into the research process, the author had the opportunity to join case study number 1, which was conducted by two senior researchers in the ISCAPS project. The purpose of the study was exploration, i.e. to gain preliminary insight into the topic and to provide the basis for more in-depth research. The findings of this case study were presented in Paper I (Figure 7). A number of research directions were derived and the author became particularly interested in how APS systems could be used in order to achieve positive consequences. Case study number 2 was designed to address this question. A paper presented at the Euroma conference 2008 was generated based on this case study. After having been on parental leave, it was discovered that the paper contained too much information. The research question was too wide and could be separated into two parts, one dealing with the benefits of using APS systems and the other dealing with variables affecting benefits. In order to fully answer those questions additional data was needed. The results became two separate papers. Paper II focused on the benefits received when using APS systems in the S&OP process whereas Paper III focused on the variables influencing the benefits achieved in the S&OP process (Figure 7).

Up to this point the focus had been on the strategic and tactical planning levels in accordance with the ISCAPS project. Still, most of the literature concerned the operational planning and it was also here that most of the applications were found. The author therefore wanted to increase the understanding of how APS systems were used in the detailed planning in order to find out if it was possible to make some general conclusions about the use of APS system in MPC processes. As a consequence, case study number 3 was designed. Paper IV was generated with a first version presented at the Euroma conference 2009.

Papers I, II, IV and an earlier version of Paper III were included in the licentiate thesis "Advanced planning and scheduling systems in manufacturing planning and control processes" which was presented in the end of 2009. The author found it necessary to investigate the negative side of APS systems. Case study number four was designed to collect and analyse these data and the results from Paper IV were presented at the Nofoma conference 2010. In order to develop explanations for some of the findings in the studies conducted on a more comprehensive basis a survey study was designed. The purpose was to explain what makes different planning methods successful. The output from the survey resulted in Paper VI, which was finished after the author came back from her second parental leave at the end of 2011 (Figure 7).

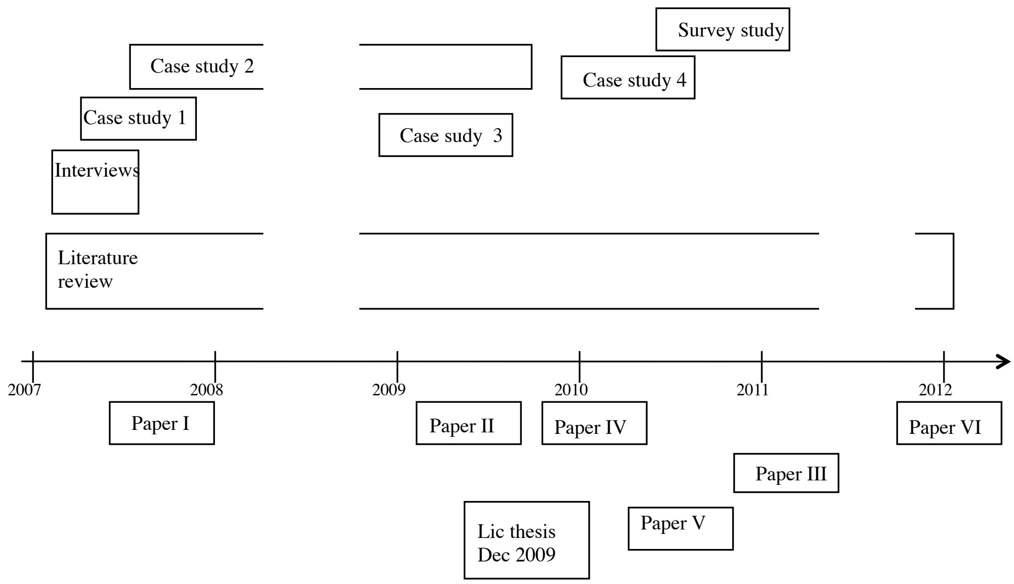

Figure 7: The research process

3.2 Research strategy

The strategy has been to start wide and open in order to search for interesting problems and issues within the phenomenon "APS system use in MPC processes"; thereafter to identify and describe key variables, and linkages between variables; and finally to test certain hypothesis and propositions. An important aim for the author has been to learn about different ways to conduct and analyse data. The strategy is reflected in the six papers that have been conducted. The research questions in Paper I make way for the following four papers (II-V), which focus on different issues. Finally, Paper VI captures some of the findings from the previous papers and explains certain relationships while making more general conclusions about the findings. Different methods have been used to answer the research questions, i.e. single case study research, multiple case study research, and survey research. It is important to choose the most appropriate method for the investigation of a research question (Yin, 2002). No method is better than the other; instead there should be a fit between the research question, the method and the intended contribution of the study (Karlsson, 2009). Or as Flyvberg (2006) express it, "good social science is problem driven and not methodology driven in the sense that it employs those methods that for a given problem, best help answer the research question at hand". To motivate the fit, the research question of the study, the method used and the contribution of each study will be described in the following sections. It is worth mentioning that the focus is on the research questions of the five studies and not the research questions posed in the cover essay.

3.2.1 Case study 1

The research questions were formulated as "how can APS systems be used for solving problems at tactical and strategic levels?" and "what are the perceived effects of using APS systems?" Those research questions cover several parts; they focus both on the tactical and strategic levels, the use of APS systems, and the perceived effects of using APS systems. It is explorative as it aims to find interesting issues and problems rather than describing and explaining issues and relationships. According to Hellvik (1984), an explorative study is useful for designing a more precise problem definition. The intended contribution was to get an idea of how APS systems were used to support planning on tactical and strategic levels in order to identify future research areas. The senior researcher involved in the study had a general understanding of planning systems and some experience with APS systems. Thus, it was possible to produce a conceptual framework before conducting empirical data. This facilitated the data collection and the analysis of the empirical data.

The research method used was case study. According to Voss et al. (2002) case study research is a method, which *"uses the data from case studies, either alone or triangulated with data from other sources as its bases"*. So why is the method of case study suitable for addressing the research questions? The case study method provides an excellent means for studying emergent practices (ibid). It is usually said to be appropriate in early, exploratory investigations where the variables are still unknown and the phenomenon not fully understood (Meredith, 1998; Gerring, 2007). In fact many doctoral theses begin with one or more case studies in order to generate a list of research questions that are worth pursuing further (Voss et al, 2002). The case study method is also suitable when the context and experiences are critical (Barratt, 2011), which was very much the situation in this case as the experience of APS systems users were important in order to understand how APS systems could be used to solve different planning problems and what this meant for the APS systems users. Stuart et al. (2002) stress that lack of a well-supported definition favours the use of case studies. Also this criteria corresponded well with the situation as APS systems lacked a well-supported definition. According to Yin (2002) case study research is appropriate when the research question focuses on "how", "why", and "what" questions; when focus is on contemporary events; and when the researcher does not have any control over behavioral events, which was the situation in this case. To address the research question, case companies A, B and, C were selected. The companies were previously known to the authors as companies that used APS systems in a qualified way to support planning at tactical and strategic levels. This was an important selection criteria as the implementation of an APS system does not guarantee that the APS system is used in a qualified manner. The strategy of choosing cases, which are the easiest to access, is usually referred to as *convenience* sampling (Flick, 2002). This sampling strategy will not allow definite findings to be generated because of the problem of generalization, but could provide a springboard for further research (Bryman and Bell, 2007).

3.2.2 Case study 2

The research questions in Papers II and III originate from the same study, case study 2. The initial research question was formulated as "how to successfully use APS systems in the S&OP process?" From the authors point of view a successful use was when the APS system could be used in such a way so that it supported the fulfilment of the S&OP aims. Thus, the intended contribution was to identify benefits and variables, and a linkage between the benefits and variables, hence build theory (Voss et al., 2002). One of the most important functions of case study research is the elucidation of causal mechanism (Gerring, 2007), which made case study research an appropriate method for addressing the research question. Besides, case study research is strong in theory building, particularly when there are uncertainties in the definition of constructs (Voss et al, 2002). Building theory from case studies involves using one or more cases to create theoretical constructs, propositions and/or midrange theory from case based empirical evidence (Eisenhardt, 1989). Although plenty has been written about typical benefits of using IS and how to achieve benefits there is very little written about APS systems in particular. APS systems differ from previous planning systems in terms of implementation, use and expected benefits (e.g. Wiers, 2002). Consequently, there was a need to understand how the use of APS systems can support the S&OP process and what variables influence a successful use. As it was important to dig deeply into the APS supported S&OP process a single case study was considered as an appropriate choice. Single case studies are many times said to be weak in generalizability of the conclusions, models or theory (Voss et al., 2002; Eisenhardt and Graebner, 2007). Still, sampling decisions always fluctuate between the aim of covering as wide a field as possible and of doing analysis, which are as deep as possible (Flick, 2002). It might for example be difficult to give deep descriptions and explanations if including many cases (Flinck, 2002). Single case studies are also sometimes said to suffer from observer bias, i.e. the risk of misjudging of a single event and of exaggerating easily available data (Voss et al., 2002). The risk of observer bias exists in all case research, but are somewhat mitigated when events and data are compared across cases (ibid). The author used multiple respondents and viewpoints to minimise for observer bias. Interviews were also complemented with other data collection methods. An underlying assumption was that an APS system is particularly needed in planning environments characterized by high planning environment complexity. Thus it was important to find a case company that used an APS system in a complex planning environment. It was also important that the case company was rather satisfied with its APS system in order to understand how to receive benefits. Case company D was selected for those reasons.

An important question when developing new theories from case studies is the role of existing theories in this theory-building process (Barratt et al., 2011). On the one hand, the grounded theory approach is based on pure inductive logic, where the new theory is derived strictly from data (ibid). On the other hand, a number of articles have suggested the use of a priori construct to help shape the initial design of theory building research. Voss et al. (2002), suggests doing this through a construction of a conceptual framework that explains the main issues that are being studied, key factors, constructs or variables, and presumed relationships among them. Eisenhardt (1989) emphasises that the use of a priori constructs is only to be considered as tentative and may not be part of the resultant theory. A conceptual model based on previous literature in IS and MPC and experiences from APS systems was applied early in the study. The model identified benefits of using APS systems, and variables influencing the APS system use and identified benefits.

The author really enjoyed collecting data but shortly became aware of the difficulties in finding analytical paths through the large and cumbersome data collected. It was also discovered that the initial research question included two parts, the identification of benefits and the variables influencing a successful use, which needed to be investigated somewhat differently. New research questions were formulated; "what potential benefits may be achieved when using APS systems in the sales and operations planning (S&OP) process?", "how does the context impact a successful APS system usage in S&OP process?", and "how do individual, technological, and organizational dimensions mediate this"? In case study research, it is not uncommon for the research question to evolve over time and for constructs to be modified, developed, or abandoned during the course of the research (Voss et al., 2002). In fact, this could be seen as an asset because it might allow for the development of more knowledge than if the research questions were fixed (ibid). Still, it is important to not use it as an excuse for inadequate specifications of research questions or constructs.

To answer the research question focusing on the benefits, it was found insufficient to only include the APS system adopters' objectives, expectations and perceptions as the standards for identifying benefits. Therefore, in parallel with additional data collection at company D, a Delphi "type" of study was conducted. The objective of a Delphi method is to obtain the most reliable consensus of a group of experts (Flynn et al., 1990). This method is a proven popular tool in IS research (Okoli and Pawlowski, 2004). In general, this method is primarily employed in cases where judgmental information is indispensable. Typically a series of questionnaires are used interspersed with controlled opinion feedback (ibid). The Delphi type of study was used to identify potential benefits of using APS systems in more general terms. The study employed had many similarities with a Delphi study, but there were also some differences. A Delphi study does not depend on a statistical sample; instead it requires qualified experts who have a deep understanding of the issue at hand (ibid). Fifteen representatives from the industry and academia, with experience from APS system implementation and use, were selected to participate in the study group. The representatives were selected with help of members within the ISCAPS project. Besides, the author got in contact with many APS system vendors and consultants during the annual Plan conference in Stockholm 2007. The selected group of fifteen experts corresponds well with the recommendations of 10-18 experts suggested by the literature (ibid). In a Delphi study, the respondents are anonymous; however, that was not the case in this study. The independent experts were invited to a workshop. Before the workshop they were asked to add benefits to a list that was produced with the help of literature and data collection from the first round at case company D. They were also asked to rank to what extent they perceived the listed benefits would occur. During the workshop, the list was discussed and adjusted and a new list was developed. The results from the second round were discussed with the expert group, who considered the results to represent relevant consensus ranking the potential benefits.

In order to answer the research question focusing on variables influencing the consequences, some additional data was needed at company D. The first round of data collection and analysis had identified a number of variables of importance for the successful use APS systems. Those variables called for a different categorization than the initial categorization proposed. Literature in combination with the data collection was added, analysed and the conceptual framework refined. The second round of interviews was needed in order to understand how the identified variables affected the perceived consequences of the use of APS systems.

3.2.3 Case study 3

The initial research question was formulated as "how are APS system used in PAC and which are the experiences of using APS systems". The contribution of the study was to produce a framework for how APS systems could support the different activities in PAC and to identify pros and cons of doing so. The author needed to understand how APS systems could support the PAC process in detail, therefore a single case study was the method used for research. Voss et al. (2002) suggest using the method of in-depth field studies or a few focused case studies when constructing a theory from case study research. Case company E was selected for the study since it had long and wide experience of using APS systems in PAC. Besides, the manufacturing process at company E was a typical job shop process where the use of sequencing and priority decisions are needed; hence the support of APS systems should be appropriate, according to previous literature (e.g. Jonsson and Mattsson, 2009).

During the data collection and analysis, a number of variables were identified, which influenced how APS systems were used in PAC activities. This sparked the interest for further investigation of those variables and the initial research question was changed to "how do the manufacturing process, the shop type, and the data quality, i.e. shop floor characteristics, influence the use of APS systems in PAC"? From the theory and the experience from the data collection at case company E, a conceptual framework was produced defining the shop floor characteristics and the different ways APS systems could be used in PAC activities. In order to understand how the shop floor characteristics influenced the use of APS systems in PAC activities, case companies F and G were added to the data collection and analysis and additional data were collected at case company E.

3.2.4 Case study 4

The research questions were formulated as "what problems exist in the onward and upward phase of the APS system implementation?" and "how do individual, technological, and organizational dimensions influence the problems in the onward and upward phase"? The intended contribution was to build theory in terms of identifying problems of using APS systems as well as variables influencing the problems and to identify linkages between problems and variables. The method used for data collection and analysis was case study research because it is seen as particularly suitable in investigation causality (Gerring, 2007). Three focused case studies at companies D, H and I, were selected based on the following criteria: 1) companies had entered the onward and upward phase. This as it is during this phase the majority of the outcomes are perceived (Marcus and Tanis, 2000), 2) the companies selected had experienced problems during the APS system implementation projects. This as one of the research questions was to identify problems of using APS systems.

Based on literature and prior experiences, a conceptual framework suggesting different phases that a company might experience during an APS system lifetime was suggested. The phases included typical activities undertaken. Variables of importance for using APS systems in a successful way, hence variables that might hinder the achievement of benefits were also identified. The data collection and analysis added to the understanding of which variables had influence on the perceived problems in the onward and upward phases. It was extremely difficult to disentangle variables influencing one problem from another and derive problems perceived in the onward and upward phase to previous phases in the implementation project analytically. According to Voss et al. (2002) one of the most difficult, but most important aspects we try to identify in research is the relationship between cause and effect. He also stresses that "the longer the period over which phenomena are studied, the greater the opportunity to observe the sequential relationships of events". It would have been impossible to pinpoint problems of using APS systems to an early phase in the APS system life cycle as it usually takes a while until outcomes appears (Marcus et al, 2000). Nonetheless, there are problems with historical data because participants may not recall important events and if they do, their recollection may be subject to bias (Voss et al., 2002). To cope with this kind of problem multiple sources were used and cross-checks were carefully carried out before attributing cause and effects.

3.2.5 Survey

The research question was formulated as "how do the complexity in the planning environment, process maturity, and data quality affect the capability of the planning methods to provide high MPS performance"? The contribution was to test some of the propositions developed in the previous studies. A survey is a suitable method when knowledge of a phenomenon is not underdeveloped, when generalization is an important intended contribution, and when the empirical evidence sought concerns "how variables are related", "what the relations hold", and "to what extent a given relation is present" (Forza, 2002; Merriam, 1998). In fact, a survey is one of the preferred methods when theory-testing research is to be carried out (Barratt, 2011), which was also the reason for why a survey was used as the method to address the research question. The survey approach was explanatory with the aim of explaining the contribution of different planning methods on MPS performance. Theory-testing survey research puts great importance on a pre-existing theoretical model (Forza, 2002). Prior to the survey design, a theoretical model defining the different constructs, motivating the hypothesis, and the conditions under which these relationships were expected to hold were developed. The constructs and measures were partially developed in papers III and V. Data was collected by a questionnaire sent to Swedish manufacturing companies with more than 100 employees. 326 filled questionnaires were received corresponding to a response rate of about 30%. Bi-variate correlation analysis, t-test and step-wise regression analyses were conducted to analyse the data.

3.3 Case companies

Four out of five studies in this thesis are case studies. All together they refer to nine case companies. The case companies differ in terms of size, industry, detail and dynamic complexity. All case companies do however use APS systems in accordance with the APICS definition of APS systems to support MPC processes. In the below section the companies are briefly presented, and Table 6 shows which case companies are included in which studies.

Case company A: one of Scandinavia's leading producers of vegetable oils and fats. In 2005, this company merged with a Danish company. The company uses an APS system for a supply chain design evaluation of how to utilize two identical production sites in the most optimal way. Case company A was included in Study 1.

Case company B: is one of the leading groups within the drover and agriculture industry in Sweden. It is a producer cooperative that works with marketing, distribution, sales, processing, and supply. The company uses an APS system to support the master production scheduling process and was included in Study 1.

Case company C: is the biggest Nordic manufacturer of heavy steel plates. The company uses an APS system as a support to the master production scheduling process. Case company C was included in Study 1.

Case company D: is a company in the chemical industry that manufactures, markets, sells and distributes chemicals used at the surface of other chemicals. The company is divided into three regional organizations: America, Asia, and Europe, the latter of which is studied in this thesis. Case company D uses an APS system to support the sales and operations planning process and was included in Study 2 and Study 4.

Case company E: is a division of the business area construction and mining technique at a Swedish manufacturing company. It develops and produces drilling machines. The company uses an APS system to support PAC and was included in Study 3.

Case company F: manufactures garage doors. The company consists of three production sites whereof the Swedish site is studied in this thesis. Case company F uses an APS system to support PAC and was included in Study 3.

Case company G: develops, manufactures, and globally markets metal cutting solutions. The company consists of several production sites and the focus in this thesis is on the production site in Sweden. Case company G uses an APS system to support PAC and was included in Study 3.

Case company H: manufactures and sells soft cheese, dairy products, and salad dressings. It employs 600 people and consists of five different production sites whereas the site in Sweden is studied in this thesis. Case company uses an APS system to support master production scheduling process and was included in Study 4.

Case company I: is a brewery company that produces and sells beer and soft drinks. The company employs 1100 people. There are four breweries geographically dispersed, each supplying its own market. The brewery located in Sweden is studied in this thesis. Case company I uses an APS system to support the master production scheduling process.

Table 6: The relations between the conducted case studies and the included companies

	Case study 1	Case study 2	Case study 3	Case study 4
Company A	X			
Company B	X			
Company C	X			
Company D		X		X
Company E			X	
Company F			X	
Company G			X	
Company H				X
Company I				X

3.4 Research quality

The most prominent criteria for evaluating research are validity and reliability. Validity is concerned with the integrity of the conclusions that are generated from a piece of research whereas reliability is concerned with the question of whether the results of the study are repeatable (Bryman and Bell, 2007). What is good research is partly approach dependent (Karlsson, 2009). Consequently, the research quality of the two approaches used in this thesis, case study and survey will be examined below.

3.4.1 Case study

In order to establish the quality of case study research, four tests are commonly used as a basis for validity and reliability; (1) construct validity, which occurs in the data collection and composition, (2) internal validity, which occurs in the data analysis, (3) external validity, which occurs in the research design, and (4) reliability, which occurs in the data collection (Yin, 2002).

Construct validity means that the operational measures used to measure the constructs actually measures the concepts they are intended to measure (Karlsson, 2009). According to Yin (2002), this first test is especially problematic when conducting a case study. Critics of case studies point to the fact that a case study investigator fails to develop a sufficient operational set of measures and that "subjective" judgments are used to collect data. It has been problematic to establish the correct operational measures for the concepts studied in this thesis. The concepts of APS system, benefits, successful use, and problems have not been well defined in previous literature. Different concepts have been used to describe similar or the same terms and a number of different measures have been used in different studies when measuring the concepts. Considerable effort has been given to defining these concepts. A vast amount of literature has been read and a number of experts on APS systems and IS systems have been consulted to validate the author's interpretation and categorization of the operational measures.

The tactics for ensuring construct validity occur in the data collection and composition. According to Voss et al (2002), one way to increase the construct validity is by using multiple sources of evidence, i.e. evidence from two or more sources, but converging on the same set of facts or findings. In all case studies presented in the thesis, a number of data collection methods have been used. The main source of data collection has been interviews. The study has been reinforced with site visits, participation in meetings, educational lessons, power point presentations including information about the planning processes and the APS system project, internal data such as description of priority rules, rules for master data etc., observation and questionnaires. Multiple respondents were used when it was impossible to identify one single person with the required knowledge, or when the events being studied could be interpreted differently. In case studies 2 and 4, several perspectives were needed to answer the research questions. In case study 2, the APS system user perspective was complimented by experts' perspective. In case study 4 the experiences gained from company participants involved in the APS system implementation were complimented with the experiences from the consultants involved in the APS system project. Another form of triangulation is the use of multiple investigators (Barratt et al., 2011). This was used in case study 1 and to some extent in case studies 2 and 4.

Semi-structured interviews have been used in all case studies carried out in this thesis. Kylén (1994) stresses that semi-structured interviews usually are flexible and that they minimize misunderstanding. Semi-structured interviews were appropriate as the author had a fairly clear focus of the investigations, which made it possible to address specific issues (Bryman and Bell, 2007). Case studies 3 and 4 involve several of case companies, which made it important to have some structure of the interviews in order to ensure cross-case comparability. In general, the interview took place at the interviewees office or in a conference room. The author initiated the interview by telling the interviewee what the research was about, its purpose, and that his or her answers were treated confidentially. Reflecting on the interview technique, the author has improved a lot from the beginning of her process. In particular she has been better in handling silence and give the interviewee time to think. She has been better to listen to what is said and how it is said and is more prepared to challenge what is said, for example, dealing with inconsistencies in interviewees replies. After the completion of the interviews, they were typed up and sent to the interviewees for validation. Each interviewee's response was triangulated with answers from other participants and thereafter used as follow-up interviews to clarify differences. Key informants were also asked to review the draft of the case report. According to Yin (2002), this is a relevant tactic for composition.

A second tactic in the data collection used in the case studies is to establish a chain of evidence (Yin, 2002), i.e. explain how someone else could, beginning with the same raw material, derive the same summary values for the various constructs in the study (Stuart et al., 2002). All interviews, observations, and documentation have been collected and the time and place has been clearly stated in the documents. The questions asked in the interviews have been noted at the bottom of the documents of the interview and the questions of concerning the observations and documentations have been written at the bottom of the document.

Internal validity is the extent to which we can establish a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships (Stuart et al., 2002). Gerring (2007) relates case study research to survey research and stresses that although case studies in general are weaker with respect to external validity, *"the corresponding virtue is its internal validity"*. Voss et al. (2002) maintain that one of the main advantages of case study research is that it increases the chance of being able to determine the link between cause and effects. In case studies 2, 3 and 4 causal relationships were investigated.

In order to enhance internal validity it is important to produce high quality analyses (Yin, 2003). Still, analysis of case studies is one of the least developed and most difficult aspects of doing case studies (ibid). Unlike statistical analysis, there are few fixed formulas or cookbook recipes to guide the novice. One important step in the search for causality has been to get to know the data collected. Detailed case stories have been developed and data has been structured according to the conceptual framework and/or other categorisations identified during the data collection and writing ups of the material. In case study 2, the author for example illustrated the activities within the S&OP process by charts and linked the use of APS system functionalities to each activity as given by the different actors involved in the S&OP process. Similar illustration was made in case study 3. In case study 4 the different activities as identified by the interviewees were derived to the phases of an APS system lifecycle. The experiences and perceptions of APS system implementations were written down, linked to the different phases. The search for causality did result in an additional number of interviews, introduction of new literature and new categorization. In case study 2, two installations of APS system were compared and in case study 3 and 4 several case companies were included. Consequently, patterns were compared and contrasted in a cross-case analysis were differences and similarities were noted. According to Voss et al. (2002), a cross-case analysis increases the internal validity of the findings.

External validity refers to the domain to which a study's findings or presumed causal relationships may be generalized (Stuart et al., 2002). According to Yin (2002) the external validity problem has been a major barrier of doing case studies and a frequently posed question is *"how can you make generalizations if the cases aren't representative (*Eisenhardt and Graebner, 2007*)"*. Case study research includes, by definition, only a small number of cases, which makes the issue of representativeness rather problematic (Gerring, 2007). Still, generalize findings from a sample to the population from which it was selected is just one form of generalization (Bryman and Bell, 2007). This so called statistical generalisation is not necessary the right one, as many case studies aim at developing new insights and theories (Flick, 2002; Eisenhardt and Graebner, 2007). According to Flyvberg (2006) statistic generalization is considerably overrated as the main source of scientific progress. The term science literally means "to gain knowledge" and generalisation is only one of many ways by which people gain and accumulate knowledge. Thus, a purely descriptive case study without any attempt to generalize can certainly be of value in this process (ibid). The aim of case study 1 was, for example, to generate interesting research areas, whereas case studies 2, 3 and 4 aim for theory building. In case study research, analytical generalisation is seen as the appropriate way of making generalisation (Yin, 2002; Voss et al., 2002; Eisenhardt and Graebner, 2007). In an analytical generalization, the investigator is striving to generalize a particular set of results to some broader theory (Stuart et al., 2002). Theoretical frameworks and literature reviews have been the main vehicle for (analytical) generalizing of the findings in the case studies.

Generalizability is closely connected to the sampling procedure (Flyvberg, 2006). In broad terms sampling could be divided into random and non-random sampling (Bryman and Bell, 2007). In case study research non-random sampling is usually used, by which the cases are selected according to different criteria (Voss et al., 2002). Literature has suggested a number of non-random sampling strategies (e.g. Flick, 2002; Gerring, 2007; Yin, 2002). No strategy is right *per se*; instead the appropriateness of the strategy chosen should be assessed with respect to the research question and degree of generalizability, which is striven for in the study (Flick, 2002). The case studies in this thesis were selected based on their expected level of relevance to the research topic, where the study object (i.e. MPC process in focus and role of APS system in the MPC process) and research question constituted the selection criteria. For all cases, the companies selected should use an APS system in accordance with the APCIS definition. Researchers, consultants, system vendors, and the authors' participation in different seminaries and conferences helped in identifying relevant cases. The selection procedure may have resulted in that some cases were selected in favour of other cases and there is no guarantee that the cases are representative. The findings of the case studies may only be valid for the unique context of the case companies included. Still, the case companies represent a "wide" context as they represent different sizes, industries, and planning environment complexity. There should therefore be similarities between the studied situations and those of several other companies.

Sampling does not only concern the selection of cases but also the selection of people to be interviewed. Flick (2002) suggests a number of general criteria for the selection of interviewees. First, the interviewee should have the necessary knowledge and experience for answering the questions. The main user/s of the APS system were usually identified as the key respondents, who had knowledge in answering many of the questions. The key respondents helped in identifying other relevant interviewees. Second, the interviewee should have the capability to reflect and articulate, have the time to be asked, and should be ready to participate in the study. The majority of respondents have taken their time to prepare for the interview, enthusiastic answering the questions, read and comment on the summarised interview, and answered following up questions if necessary.

Reliability is the extent to which a study's operation can be repeated with the same results (Voss et al, 2002). The goal of reliability is to minimize errors and bias in a study. Case studies are many times seen as allowing for more room of the researcher's subjective and arbitrary judgment than other methods (Flyvberg, 2006). According to Flyvberg (2006) this is however not true, in fact experiences indicate that the case study contains a greater bias towards falsification of preconceived notions than towards verification. Indeed, the authors background in terms of education, experiences, research context etc. matters and it would be wrong to state that the author entered the research project completely unbiassed. The author was for example rather sceptical to APS systems as a support to MPC processes from the start. Personal biases can shape what you see, hear and record and it is therefore important to try to counter for this, although researchers should not overreact (Voss et al., 2002). As far as possible the author has done what she can (based on the knowledge she had at the time) to remove bias during the research process. Multiple interviewers has for example been used in some of the interviews and the interviewers discussed their interpretations and read each other notes afterwards. The authors' interpretations and findings have also been discussed with other researcher and experts in order to minimize bias. In accordance with Yin (2002) the author has documenting as many steps as possible and tried to conduct the research as *"if someone were looking over your shoulder"*. In all studies conducted in this thesis, a case study protocol has been used to deal with the documentation problem in detail. A protocol is more than a questionnaire and contains not only the questions to be asked but also the procedures and the general rules to be followed (Yin, 2002). The research protocol used in this thesis outlined the subjects covered during the interview, stated the questions asked, and indicated the specific data required. The protocol has served both as a prompt for the interview and as a checklist to make sure that all topics were covered. The protocol was sent to the interviewees in advance to the interview, so that the interviewee(s) could prepare properly. When possible, the protocol was tested in initial interviews with key respondents at the organisation.

To improve reliability, notes have also been taken during all interviews, site-visits, meetings, and workshops (Voss et al, 2002). The notes have not only included formal collection of data but also recorded ideas, impressions etc. as soon as they occurred. This has been very helpful, not least in the data analysis, as those have pushed the authors' thinking. Some interviews have been recorded. There are divided views on whether tape-recorders should be used in interviews (Bryman and Bell, 2007). When exactness of what people have said is important, then taping will be a benefit. If interviews are more focused on objective data, as in the cases in this thesis, then the benefits of taping are reduced (ibid). On the negative side, transcribing tapes is very time consuming, it often takes place some time after the interview, can be seen as a substitute for listening, and may inhibit interviewees (ibid). In those cases when the interview was recorded the author felt more relaxed during the interview and could focus completely in asking questions and listening to the respondent. Still, some interviewee seemed uncomfortable of being recorded and the author experienced that she gained more informal information when the interviews were not recorded. No matter if the interview was recorded or not, the author had made a role to herself to always summarised the interview right after it took place to maximise recall. The summarised interviews were sent to the interviewee in an email where the author thanked for the interview and if needed asked some follow up question for clarification. After each interview, site-visit, workshop or meeting, the author expanded the typed notes. For example, the author has commented on problems and ideas that arose during the interaction with the case companies. Pretesting of questionnaires was done in case study 2 in order to enhance reliability (Okoli and Pawlowski, 2004). In order to insure the respondents' understanding of the concepts, the author spoke to the key informant at the case company and adjusted parts of the vocabulary to better fit the case company's terminology.

3.4.2 Survey

The following section describes how the quality of the survey has been established.

Validity indicates if the scale measures what it is supposed to measure (Forza, 2002). *Content validity (face validity)* is a judgement of the extent to which a summated scale truly measures the concept that it is intended to measure, based in the content of the items (Flynn et al., 1990). In order to ensure content validity extended and published scales have been used as much as possible. It was, however, necessary to develop several new measures. These were based on existing literature and own case study experience. APICS terminology and definitions (Blackstone, 2010) were used, because this was considered the most established – both in practice and academia. Bryman and Bell (2007) stress that content validity might be established by asking other people whether or not the measure seems to be getting at the concept that is the focus of attention. Preliminary drafts of the questionnaire were also discussed with academic researchers and the questionnaire was pre-tested by conducting five pilot studies at different manufacturing organisations. This resulted in some minor modification. Content validity is subjective in nature and can always be debated. *Construct validity* on the other hand can be tested in factor analysis, which was also done in the survey. It measures whether a scale is an appropriate operational definition of a construct (Flynn et al., 1990).

The population of the study was Swedish manufacturing companies with more than 100 employees. Addresses were drawn from the Swedish postal service's database (PAR), resulting in 1103 addresses to unique companies. 1103 questionnaires were sent out and 326 filled in questionnaires were received. Although it is generally assumed that a representative sample is the outcome of this selection strategy there are sources of bias (Bryman and Bell, 2007). Bryman and Bell (2007) stress that, as far as possible, bias should be removed from the selection. Still, it is incredibly difficult to remove bias all together and to derive a truly representative sample. One source to bias is if the sample frame is inadequate. In this study, some of the addresses drawn from PAR were not valid any longer. This problem could, however, be identified by the administrator of the survey as she received an email if the address was invalid. The companies with the invalid addresses were phoned and the new addresses to the product manager, production planning manager or supply chain/logistics manager were identified. Another source of bias is if there is non response. The problem with non response is that those who respond to the questionnaire may vary in various ways from those that do not responded to the questionnaire. Non-response bias tests were conducted by comparing firm size and industry belongings between early and late responses and between all respondents and the entire selection. It was found that the sample was bias towards larger firms. The reason is probably that focus was given to large firms when reminding firms by phone as it was expected that large firms are more advanced users, and it was important to end up with enough responses from advanced users. The small bias towards larger firms was not considered as a large problem here as the aim was not to describe in general how Swedish manufacturing companies conduct their MPS process, but to compare different planning methods.

Reliability measures the extent to which a questionnaire, summated scale or item which is repeatedly administered to the same people will yield the same result (Flynn et al., 1990). Reliability is a prerequisite to establishing validity, but not sufficient (Bryman and Bell, 2007). To test for whether or not the item that make up the scale were consistent, so called *internal reliability* (inter-item reliability) Cronbach' coefficient alpha was used. Cronbach's coefficient alpha is the most widely used measure for testing internal reliability (Sakakibara et al., 1993; Bryman and Bell, 2007). Its use has grown as a result of its incorporation into computer software for quantitative data analysis. It measures the internal consistency within a particular scale, by calculation an average of the correlation coefficient of each item within a scale with every other item, as weighted by the number of items within a scale. A computed alpha coefficient will vary between 1 (denoting perfect internal reliability) and 0 (denoting no internal reliability) The figure 0.80 is typically used as a thumb to denote an acceptance level of internal reliability, although many writers accept a slightly lower figure (Bryman and Bell, 2007). Cronbach's alpha test was used for summated scales. Table 7 gives an overview of the five studied conducted in the thesis.

Table 7: An overview of the studies

	Case study1	**Case study2**	**Case study3**	**Case study4**	**Survey**
Papers	I	II and III	IV	V	VI
Research question/s	How can APS systems be used for solving planning problems at tactical and strategic levels? What are the perceived effects of using APS systems?	What potential benefits may be achieved when using APS systems in the S&OP process? How do the context impact a successful APS system usage? How do the ITO dimensions mediate a successful APS system usage?	How do the shop floor characteristics influence the use of APS systems in PAC?	What problems exist in the onward and upward phase of the APS system implementation? How do ITO dimensions in the implementation phases influence the problems in the onward and upward phase?	How do the complexity in the planning environment, the MPS process maturity and data quality affect the capability of planning methods to provide high MPS performance?
Data collection methods	Interviews Document-tation	Interviews Document-tation Observation Questionnaire	Interviews Document-tation	Interviews Document-ation	Question-naire
Contribution	Generate research areas	Theory building	Theory building	Theory building	Theory testing

4 Summary of appended papers

This chapter contains a brief summary of the papers included in this thesis with the focus on the results and the contributions. Note that the full papers are appended to the thesis. In the appended papers some papers have purposes whereas other have research question/s. In order to follow the same structure research questions are used here. This means that some purposes have been rewritten as research question/s in this chapter.

4.1 Paper I- Applying advanced planning systems [2] for supply chain planning: three case studies

Paper I introduces the use of APS systems at mid-and long term planning levels and connects it theoretically and empirically to four areas; planning complexity, planning model and design, planning data and planning organisation.

4.1.1 Research questions

The research questions were formulated as; 1) how can APS systems be used for solving planning problems at tactical and strategic levels? 2) What are the perceived effects of using APS systems? The study was based on a literature review and empirical data from three manufacturing companies using APS systems for solving planning problems at the tactical and strategic level.

4.1.2 Results and contribution

The paper showed that even though all case companies used APS systems for solving planning problems on strategic and tactical levels, it was used a bit differently among the different companies. One case company used an APS system to generate decision support for cost efficient supply chain design, whereas the other two companies used APS systems for continuous master production scheduling in situations with finite capacity constraints. Still, in all cases the overall aim was to create holistic perspectives of complex planning problems, eliminate sub-optimization, and achieve commitment to an "optimum" plan.

It was found that APS systems were used to deal with high planning problem complexity. Nevertheless, the type of complexity differed between the case companies. All case companies dealt with complexity in terms of a large number of variables. Some also dealt with multiple business constraints and decision rules. It was found that the use of finite capacity planning put a higher requirement on up-dated work centre data. Although many assumptions and simplifications of the problems were made in all case companies, the perception was that the output was good enough. The gathering and registering of basic data was not considered to be problematic in any of the case companies. For all case companies, several organizational units were involved and affected by the planning process. For two of the three case companies it was more important to generate commitment to one single plan than finding the optimal plan.

[2] In Paper I advanced planning systems (APS) was used instead of advanced planning and scheduling (APS) systems.

The planning effects identified were for example; slightly higher transportation costs due to lower fill-rates, decreased production costs and less capital tied up in inventories because of better throughput, reduction of the total planning time, increased control of the material flows and cost structure, decreased process and demand uncertainties, and increased communication between logistics, manufacturing, marketing, and sales functions. It was found that the planning organisation had an important role in the perceived effects.

The paper contributed with increased knowledge on how APS systems can be used for solving planning problems at tactical and strategic planning levels and identified some perceived effects of doing so. This should be interesting both to practitioners and researchers as there are few documented cases on how an APS system is used to support planning problems on tactical and strategic levels. The paper also generated some research issues; 1) the feasibility of an APS system in situations with various planning environment complexities, 2) how design of the planning model creates complexity and affects the planning process, 3) data gathering requirements when using APS systems, 4) the role and design of the planning organisation and 5) how to achieve positive planning effects such as finding global optimum of plans, global commitment to the same plan and developing supply chain process integration.

4.2 Paper II-The potential benefits of advanced planning and scheduling systems in the sales and operations process

Paper II focuses on the positive consequences of using APS systems in the S&OP process and is influenced by the following research area, “how to achieve positive planning effects”, identified in Paper I.

4.2.1 Research question

The research question was formulated as: what potential benefits may be achieved when using an APS system in the S&OP process? In particular, the paper tries to structure different types of benefits, and find out if the benefits perceived are different in the S&OP activities. Focus is also on how the use of APS system influences the perceived benefits. The research methods used were a case study and a Delphi study. The case company was a company in the chemical industry with long and wide experiences of using APS systems in the S&OP process. The group of experts in the Delphi study consisted of fifteen industry and academic representatives with experiences from APS system implementations.

4.2.2 Results and contributions

A list of eighteen potential benefits was identified with the help of the interviews at the case company and the Delphi study with APS experts (see Table 8). It was found that the APS system users in the case company perceived many benefits connected to decision support, planning efficiency, and learning effects. Decision support benefits were according to APS experts and APS users the type of benefits most likely to be achieved.

Table 8: The potential benefits when APS system is used in the S&OP process

Decision support benefits	Allows visualization of information
	Makes information easy to access
	Makes it possible to identify unexpected future events
	Makes it possible to analyze unexpected future events
	Make it possible to analyze the problem picture and solve the problem as a whole
	Allows quantifiable what-if scenario analysis
	Results in reliable delivery plan (low forecast error)
	Gives optimal/feasible plans
	Gives integrated plans
Planning efficiency	Results in high data quality
	Gives focus on data quality
	Simplifies planning activities
	Lead to less time spend on planning activities
Learning effects	Results in good knowledge about the planning processes
	Results in good knowledge about the supply chain
	Makes the planning activities important
	Makes the planning activities enjoyable

The case study analysis showed that the benefits perceived in the S&OP activities were a bit different and that it depended on the aim of the activity, which functionality that was exploited and on user characteristics. How the system was used was influenced by the planning model and by access to planning data.

The paper contributed with knowledge of which benefits that can be expected when using APS systems in S&OP processes. They can assist companies in understanding the benefits to be expected from using APS system in the S&OP process. The case study analysis gives further insight into how APS systems may be employed and what benefits different APS systems user-categories may expect when it is used in an appropriate way.

4.3 Paper III-When to use APS systems in sales and operations planning

Paper III focuses on the impact of the planning environment complexity and the S&OP aims on the capability of the APS system to support the S&OP process in fulfilling its aim. It also focuses on different variables connected to individual, technological and organizational (ITO) dimensions to mediate such use of APS systems. This paper was inspired by two of the research issues generated in Paper I; the feasibility of an APS system in situations with various planning complexity and how to achieve positive planning effects.

4.3.1 Research questions

The research questions were formulated as; 1) how do the complexity in the planning environment and S&OP aims impact a successful APS system usage? 2) how do the individual, technological and organizational (ITO) dimensions mediate a successful APS system usage? A successful usage was seen as when the APS system was supporting the S&OP process in fulfilling its aim/s. The study was carried out at the same company as described in Paper II. Still, whereas focus in Paper II was on the recent APS system installation (2007) at the company, focus in Paper III was on the recent and the old APS system installation (2001 and 2007).

4.3.2 Results and contribution

Four propositions were derived concerning the relationship between the complexity in the planning environment, the S&OP aim, ITO dimensions and a successful use of APS system. Those were:

1) **APS systems are an appropriate support to the S&OP process in fulfilling its aims. This is especially true for ambitious aims and complex planning environments.** The case analysis found that the detail and dynamic complexity in the planning environment and high ambitious S&OP aims placed a need for APS functionalities. In the case company it would have been difficult to generate feasible and balanced plans and fulfil ambitious S&OP aims without the use of APS functionalities. The need of an APS system seemed less important for less ambitious aims.

2) **Knowledge and understanding of APS systems, APS functionalities and the S&OP process are mediating a successful use of APS systems. This is especially important in complex environments**. The case analysis found that the I-dimension was particularly critical in order to successfully use APS systems. It was found that lack of understanding of APS functionalities resulted in an over-confidence in the APS system. This in turn resulted in that it was difficult to get commitment to the APS generated plans and that it was difficult to understand why the plans looked as they did.

3) **Correct model design, integration between ERP and APS systems, and high data quality are mediating a successful use of APS system. This is particularly important for generating high quality plans, and especially when the aim is to generate optimal plans.** The model design, integration and data quality were of high importance for the quality of the plans. There seemed however to be a limit for how much complexity that could be modeled as a complex planning model results in long computational time.

4) **An S&OP process with planning meetings and a formal S&OP team with executive and cross-functional involvement are mediating a successful use of APS systems.** The case analysis found that in order to fulfil ambitious S&OP aim it was important to have a formal S&OP team, planning meetings and executive and cross-functional involvement as well as support of an APS system. Still, no matter of the level of S&OP aim ambitious, variables within the O-dimensions were of high importance for successfully using APS systems.

The paper contributes with understanding of how the context and ITO dimensions influence the use of APS functionalities. As for managerial implications, suggestions are given for when it is appropriate to use APS systems in different aim and complexity contexts and different levels of ITO-dimension maturities.

4.4 Paper IV-Shop floor characteristics influencing the use of Advanced Planning and Scheduling (APS) systems

Paper IV focuses on the use of APS systems in PAC. Accordingly, Paper IV is the only one of the six papers dealing with the use of APS systems at the short term planning and execution level.

4.4.1 Research question

The research question was formulated as: how do the manufacturing process, the shop type and the data quality i.e. shop floor characteristics influence the use of APS systems in production activity control (PAC)? The methodology used was multiple case studies at three case companies with different shop floor characteristics, who all used a similar APS system for supporting production scheduling.

4.4.2 Results and contribution

APS systems were used to support PAC activities in the three case companies. In particular, APS systems supported the activities sequencing and dispatching. The case analysis showed that the shop floor characteristics influenced the way the APS system was used in PAC activities; the shop type and data quality influenced the decision of how often to make the APS run and which freedom to give to the shop floor. The manufacturing process influenced how the dispatch list was created. The data quality was in turn influenced by the reporting from the shop floor and the feedback given to the shop floor.

It was found that the manufacturing process was not a crucial factor for deciding if or if not an APS system ought to be implemented. Instead, it is important to identify the scheduling problem and investigate if the problem is suitable to handle with an APS system. In the literature in MPC it is many times argued that advanced scheduling algorithms, such as those employed in APS systems, are most suitable in job shop processes. This study showed that APS systems were also successfully used in line-processes characterized by sequence dependent setup times. This study found that the level of data quality needed depended on how the APS system was used; if the APS system was used as a guide, the need for high data quality was not as great. If, however, it was used to give detailed schedules with precise operation timing and sequences, high data quality was a must. The case analysis showed that the shop type had a large influence on how often to make the APS system run and the use of the dispatch list on the shop floor.

The paper contributes with knowledge on how different shop floor characteristics influence the use of APS systems in PAC activities. The study covers previous literature by analysing how APS systems influence PAC as a whole. The study has managerial implications since the main aspects identified in the study may be useful when implementing APS systems in PAC.

4.5 Paper V-Problems in the onward and upward phase of APS system implementation: why do they occur?

Paper V focuses on the problems of using APS systems in S&OP and MPS processes. This being so, Paper V is the only one of the six papers explicitly dealing with problems of using APS systems.

4.5.1 Research questions

The research questions were formulated as: 1) what problems exist in the onward and upward phase of the APS system implementation? 2) how do the individual, technological and organizational (ITO) dimensions in the implementation phases influence the problems in the onward and upward phase? The methodology used was multiple case studies at three case companies using APS systems for tactical planning.

4.5.2 Results and contribution

Six major problems were identified in the case companies. They were categorized in to three separate groups: *Process related problems* concern difficulties to move forward, dependency on the consultancy firm, and too much time spent in the system. *System related problems* concern using other planning systems in parallel with the APS system (e.g. Excel for reports) and not using the appropriate potential of the APS system. *Plan related problems* occur when the plan generated from the APS system contains errors or is not considered feasible.

The ITO-dimensions in the different phases influenced the problems that arose in the case companies. The I-dimension was especially prominent and influenced all problems. In the project phase the following I-dimensions were identified; lack of understanding of which data and parameters that were of importance, lack of understanding for how to design the planning model, and lack of knowledge of the planning process. During the shakedown phase, users found it difficult to understand how to interpret the output. In the onward and upward phase*,* users lacked knowledge and understanding of what the APS system could or could not do. The T-dimension was most evident in the project phase in form of difficulties to receive data, difficulties to integrate the APS system with the ERP system, and shortage in the planning functionality. The T-dimension caused problems in the form of too much time spent in the system, use of parallel systems, and incorrect plans. T-dimensions were also identified in the shakedown and onward/upward phase as lack of functionality. The system was not considered user-friendly and did not generate reports, which lead to the use of parallel systems or/and non-use of APS system. The O-dimension was apparent in the chartering phase and the project phase, were it was found as responsibility and prioritization issues. This in turn had some influence on problems in the onward and upward phase in form of dependencies on consultants, use of parallel system, un-used potential and incorrect plans.

Six propositions were generated:

1) **Understanding of optimization reduces the problems in the onward and upward phase of an APS system implementation.** An APS system is sometimes compared with a car engine where the user does not need to understand the details behind the engine to be able to drive the car. Still the APS system is not only driven in form of generating a plan, the plan should also be used in the organization and to do so it is important to be able to interpret and understand the result. Lack of such understanding might lead to all identified problem types.

2) **Small and focused project teams reduce the negative influence of the I-dimension on the problems in the onward and upward phase of an APS system implementation**. The influence of the I-dimension of the problem types decreased with the number of people involved in the implementation project. This might seem obvious, as it is often easier to stay focused and transfer understanding, knowledge and motivation with fewer people in the project. An APS system is a "low-user system" and from this perspective not many people need to know how to actually use the system.

3) **Top management priority to the APS project reduces the problems in the onward and upward phase of an APS system implementation.** An APS system implementation will affect many people at different divisions since it usually changes the way the planning process is being run. The study shows that there is a risk that the project is not given enough priority by the top management. It is important that the project leader is given mandate from the top management and that effort is made to gain acceptance of the APS system supported planning processes in the organization.

4) **The I-, and O-dimensions are more important than the T-dimension in order to reduce the problems in the onward and upward phase of an APS system implementation.** An APS system is an advanced technical system requiring a small project team, therefore it is possible to expect the I- and O-dimensions to be less important than the T-dimension. However, the case study analysis and previous literature suggest the opposite as I- and O- dimensions result in negative influence on the T-dimension.

5) **Understanding of how data is structured in the ERP system reduces the incorrectness of APS system generated plans.** Low data quality did not seem as important as one would expect, what creates problems in the onward and upward phase is incorrect assumptions of how the ERP system works, because an APS system requires that the basic data is registered correctly in the ERP system. In fact, an APS system implementation many times works as a catalyst for increased data focus.

6) **Focus on the ITO dimensions in the chartering phase reduces the problems in the onward and upward phase of an APS system implementation.** In the case companies there were not much emphases on the activities in the chartering phase. Still many of those activities will have large influence later on. It is for example during this phase that the decision is taken if an APS system is the solution to the problem, the particular APS system is selected and key performance indicators are defined.

The paper contributes with understanding about the problems of using APS systems and how variables derived in different phases might influence those problems. A number of managerial implications in form of six propositions about APS system implementations are given.

4.6 Paper VI-Linking planning methods for capacity balancing to master production scheduling performance

Paper VI tests some of the propositions generated from previous papers, with focus on the MPS process.

4.6.1 Research question

The research question was formulated as: how do the complexity in the planning environment, the MPS process maturity, and data quality affect the capability of planning methods for capacity balancing to provide high MPS performance (planning performance and plan feasibility). A survey of planning methods for balancing available and required capacity in the development of the master production schedule in Swedish manufacturing companies was conducted. Six types of planning methods, ranging from no capacity consideration to advanced constrained-based optimization, for balancing capacity are defined and tested.

4.6.2 Results and contribution

Seven hypotheses were generated and tested statistically.

1) **The more advanced the planning methods, the higher the MPS performance.** The results indicated that the MPS performance improves when moving from very simple, or no actual method for capacity balancing, to a little more advanced methods, but not when moving to the very advanced methods including mathematical algorithms.

2) **Simple planning methods contribute to less MPS performance, the higher the complexity in the planning environment is.** The results indicated that the complexity in the planning environment did not influence the MPS performance to any large extent.

3) **Advanced planning methods contribute to less MPS performance, the higher the complexity in the planning environment is.** The results indicated that the complexity in the planning environment did not influence the MPS performance to any large extent.

4) **Simple planning methods contribute more to MPS performance, the higher the MPS process maturity is.** The results found that the MPS process maturity were of high importance for successfully using simple planning methods and for receiving high MPS performance.

5) **Advanced planning methods contribute more to MPS performance, the higher the MPS process maturity is.** The results found that the MPS process maturity were of high importance for successfully using advanced planning methods and for receiving high MPS performance.

6) **Simple planning methods contribute more to MPS performance, the higher the data quality is.** The results found that data quality was of high importance for using simple planning methods and receiving high MPS performance.

7) **Advanced planning methods contribute more to MPS performance, the higher the data quality is.** The results found that data quality was of high importance for using advanced planning methods and receiving planning performance, but not for receiving plan feasibility.

The results of this study give tentative support for that advanced planning methods alone is not enough for achieving high MPS performance. Other factors such as MPS process maturity and data quality were found much more important in explaining MPS performance, than the use of planning methods. Neither did the complexity in the planning environment seem to influence the successful use of planning methods to any large extent. In accordance with the findings from this study, we support the guidelines to companies to invest in the process before investing in a more advanced planning method. The paper contributes with understanding of the importance of the planning environment complexity, the MPS process maturity and data quality in order successfully using planning methods. The findings of the study should have direct managerial implications as they show the perceived MPS performance of conducting different MPS methods with various planning environment complexity, MPS process maturity and data quality. They could thus be used as guidelines for successfully using planning methods and receiving high MPS performance.

5 Results

The following chapter presents the results of the thesis where they are linked to the two research questions formulated in the introduction. The results are also presented in the appended papers contributing to the research questions in different ways, which is illustrated in Figure 8. Papers III and IV cover all aspects in both research questions whereas Paper II focuses on the benefits of using APS systems. Papers I, V and VI focus on the variables influencing the consequences of using APS systems. Three out of six papers deal with the S&OP process, three out of six deal with the MPS process and one deals with the PAC process.

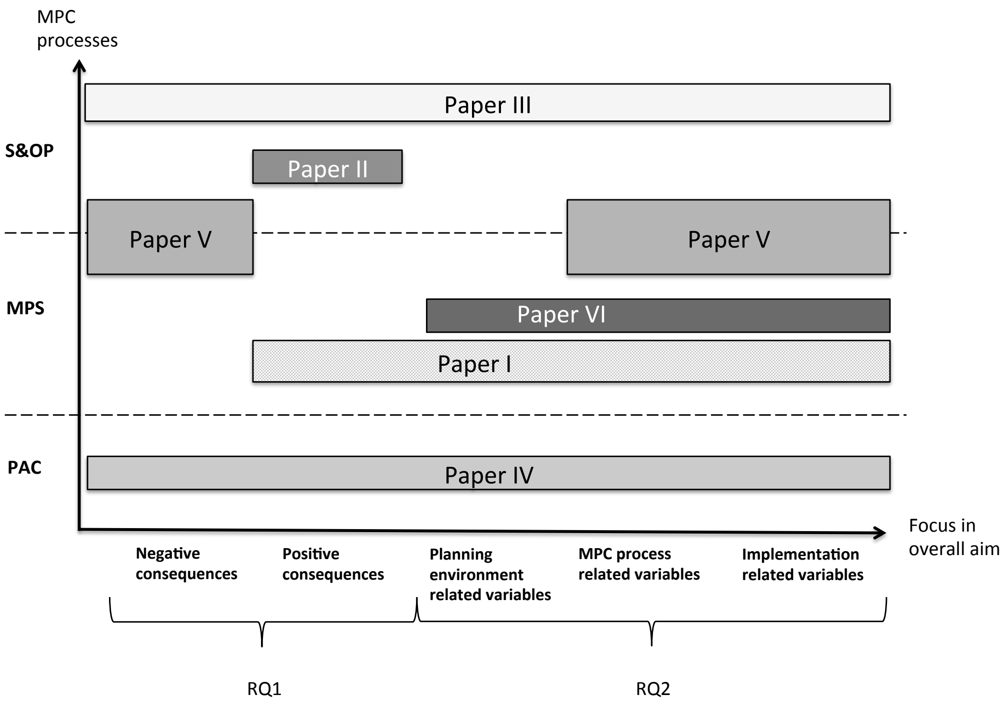

Figure 8: Links between the research questions and appended papers.

5.1 Consequences of using APS systems in MPC processes

The first research question was formulated as: *what are the consequences of using APS systems in MPC processes?* Papers I-V contributed to answering this question. APS system use and consequences are related in the following way: the use of an APS system results in consequences for the MPC process, which can be captured at different levels. Focus is on the realization of the MPC process (level 1) and the MPC process output (level 2). This section is divided into the S&OP, the MPS, and the PAC processes. Within each sub section, level 1 and level 2 consequences and the influence of APS system use on consequences as identified in the papers is described. In the last section, a summary of the separate sections is given.

5.1.1 Consequences of using APS systems in S&OP processes

Papers II and III studied the use of APS systems in S&OP processes. The S&OP process was studied at one company, company D, which implemented two different APS systems (2001 and 2007) under different circumstances. Papers II and III identified a number of consequences that could be derived to levels 1 and 2.

The following positive consequences concern level 1. The organisation has obtained a comprehensive view that was not there before the APS system was implemented. The production sites have started to communicate with each other and the majority of the employees have understood that they belong to the same company and that it is important to cooperate to reach common goals. The use of APS systems has provided the users with better information when decisions need to be made which has made it easier to plan in advance. The quality during the meetings has also increased and the general impression is that beliefs have been replaced by facts. The APS system has been seen as a support for the S&OP process to take place as it has enhanced the coordination and integration among the internal supply chain. The second APS system installation (2007) has also meant that users have saved time in planning. E.g. production managers do not have to chase demand figures and can put more time into problem solving. A number of positive consequences identified in Papers II and III can be derived at level 2. It was e.g. found that the use of APS system functionalities resulted in feasible (accurate and constrained) production and delivery plans that were used in the detailed planning at the sites, by the contract manufacturers, and by raw material suppliers. The use of an APS system has also increased the forecast accuracy, which has lead to a more accurate delivery plan. The possibility to integrate the production plans in the same planning model and to use optimization has created a common and optimized production plan.

Papers II and III identified some negative aspects of using APS systems. APS system users of the two APS system installations stressed that there is more potential to be derived from the APS system than is being used. An example is that it would have been valuable to include contract manufactures in the model and support decision from were capacity should be bought. The result of that APS system was not used to its full potential is that the APS system does not support certain planning tasks and that some expected benefits are never realised. APS system users in the first installation (2001) also stressed that they had to put excessive time into the system compared to what they received from it. Thus, they did not see the APS system as an added value to their work, instead they stressed that it was difficult and time consuming to learn yet ‘Another Planning System’. The additional work, non support of planning tasks and not fulfilment of expected benefits could be connected to the realization of the S&OP process, i.e. level 1. It was further identified that the system sometimes gave odd figures that were difficult to retrace, which caused users to lose confidence in the system. Incorrect plans and difficulties in interpreting the output have to do with the MPC output and are therefore seen as level 2 consequences.

Paper II focused on positive consequences of using APS systems in the S&OP process and identified a list of 18 benefits. Those benefits were grouped into decision support, planning efficiency, and learning effects. Decision support benefits were closely connected to the use of APS system functionalities and levels 1 and 2 benefits. Planning efficiency referred to how the use of APS systems may result in reduced overall planning time, which concerns level 1 consequences. Learning effects referred to how the use of APS systems increased the understanding and confidence in planning, which concerns level 1 consequences. It was found that the use of APS system functionalities and the extent to which functionality was used influenced levels 1 and 2 consequences. The use of integral planning, for example made it for example possible to integrate the production sites in the same process and conduct common production plans, which supported a comprehensive view and encouraged the production sites to start communicating with each other. It was found that some functionalities could have been used to a larger extent. APS system users would have liked to use what-if simulation during meetings. This was not done, and the intention of supporting decision making by using scenario based analysis during the S&OP meeting could not be realized.

Paper III focused on the successful use of APS systems in S&OP processes. A successful use was defined as when the APS system was used to support the S&OP process in fulfilling its aim. The two APS system installations were studied in case company D. It was found that the major reason for the different results of the two installations was the way the APS system was used to support the S&OP process. In 2001 the APS system was used with none or little human interaction and overtook many of the activities in the S&OP process. The APS system generated forecast was taken more or less as it was to create a delivery plan, which was automatically converted into a production plan. This resulted in an automatic planning process, which became a show only for a few people. The APS system output lacked traceability and frequently gave incorrect suggestions. The aim of creating consensus among one set of plans and generate feasible plans could not be achieved. In 2007, the APS system was used in combination with the operative users and was seen more as a supportive tool aiding the users in their tasks. Personnel contributed with their knowledge in the development of the plans and became involved in the process. This lead to higher confidence in the plans, more correct plans, and that the plans were used to a larger extent in the organisation. Paper III showed that the way an APS system was used in 2007 was much more successful in the particular company studied since it meant that the S&OP aims could be fulfilled.

5.1.2 Consequences of using APS systems in MPS processes

Papers I and V studied the use of APS systems in the MPS process. Companies B and D were included in Paper I and companies H and I were included in Paper V.

Paper I identified a number of positive consequences of using APS systems in MPS. At level 1, APS system users reported on improved decision support, increased control of material flows in the chain and the cost structure, higher understanding of the supply chain trade off, better capacity management, increased visibility of demand and delivery performance, better management of uncertainties in the supply chain, reduced total planning time, and increased communication and confidence between logistics, manufacturing, marketing and sales functions. APS system users also stressed that the use of the APS system has resulted in feasible MPS as consideration was taken to constraints (level 2).

Paper V focused on problems in the onward and upward phase of an APS system experience cycle and identified process related, system related, and plan related problems. Process related problems concerned difficulties to move forward with the APS system, dependency on a consultancy firm, and too much time spent in the system. System related problems concerned the use of a parallel system, and not using the appropriate potential of the APS system. Plan related problems regard an incorrect production plan. The majority of those problems concern the use of the APS system. Spending too much time to make the system work, compared to what is gained from using the system and incorrect plans could, however, be seen as consequences of the APS system use at level 1 and 2, respectively.

5.1.3 Consequences of using APS systems in PAC processes

Paper IV studied the use of APS systems in PAC. Companies E, F and G were included in Paper IV.

The following positive consequences were identified; improved decision support, simplified way of working, and decreased administrative lead times (level 1). APS system users also reported on a synchronised material and production plan, a feasible schedule, and the possibility to adjust the schedule after demand variations (level 2).

A number of negative aspects were identified in Paper IV. Users reported on a planning model that did not correspond with reality, that the system did not take consideration to reduced capacity due to maintenance, limited analytical capabilities of the APS system, and difficulties extracting information from the APS system. The APS system users thought that it should be possible to use APS systems to a higher extent, e.g. hand over material and tool checks to the APS system. Many of those aspects could be an effect of limited capabilities of the APS system itself, but could also be an effect of an inappropriate use of the APS system. No consideration of maintenance capacity, as reported by one company, is for example not a limitation of the APS system but has more to do with how the APS system is used as it is possible to consider maintenance capacity in the APS system. It is also possible to hand over material and tool checks to the APS system, hence the problem of not doing so has to do with the APS system use and not the capabilities of the APS system. Limited analytical capabilities and difficulties of extracting information was, however, identified by many APS system users and all of the studied case companies used other programs for reporting, which indicated that those problems actually concern the capabilities of the APS system. The problem of a planning model that does not correspond with reality is connected to the modelling of the APS system. It certainly influences the consequences of using APS systems, but is connected to the implementation and not to the APS system use, or levels 1 and 2 consequences. Operators using the output also reported on a schedule of low quality, which is considered as a level 2 consequence. The operators in one company, pointed out that the schedule suggested a strange priority, that operation times in the schedule did not correspond to real operation times, and that the schedule could look completely different from day to day. Consequently, some operators in this company used their own priority rules instead of the APS system generated schedule.

It was found that the APS systems were used differently in terms of which functionality one used to solve the scheduling problems, how frequently the APS system was run, and how much decision freedom the APS system/shop floor had. The schedule was generated with the help of simple priority rules or more sophisticated algorithms. Consideration was taken to capacity, or infinite capacity was used. The APS system was run each time a disturbance at the shop floor arose, or it was run on a regular basis. The APS system decided the priority of operations or some decision was given to the operators to circumvent the list. The identified ways of using APS systems influenced consequences in the PAC process. In situations when the APS system was run very often, it resulted in a schedule that looked different from day to day, which was difficult to follow. In situations when the APS system was not run in order to handle disturbances, the schedule corresponded poorly with reality.

5.1.4 Summary consequences of using APS systems in MPC processes

The results from the above sections are summarised in Table 9 where the positive and negative consequences in the MPC processes are presented. Some consequences are similar for all processes. It is, for example, found that the use of APS systems can support the realisation of MPC processes by improving the decision support, simplifying planning activities and reducing planning time. Also the use of APS systems can support the MPC output by generating feasible plans and schedules. For all MPC processes, the use of APS systems might obstruct the realisation of the MPC processes if planning activities are perceived as more difficult to conduct with APS systems than without APS systems, or if expected benefits are not achieved. The use of APS systems might also obstruct the MPC output by generating plans and schedules, which are difficult to retrace and/or are incorrect.

Table 9: Summary consequences of using APS systems at levels 1 and 2

	S&OP	**MPS**	**PAC**
Positive Consequences Level 1	Papers II and III: better information when decisions are to be made, less time spent on planning activities, simplifies planning activities, results in a comprehensive view, increases communication and integration, increases knowledge in planning, increased data quality, proactive planning.	Paper I: improves decision support, reduces total planning time, increases visibility, increases control of material flows and cost structure, better capacity management, better management of uncertainties, increases communication and confidence in planning, increased data quality.	Paper IV: improves decision support, decreases administrative lead times, simplifies way of working, decreases administrative lead times.
Positive Consequences Level 2	Papers II and III: feasible production and delivery plans, increases forecast accuracy, integrates and optimizes production plans.	Paper 1: feasible and optimal MPS where consideration is taken to constraints.	Paper IV: synchronized material and production plan, feasible schedule possibility to convert the schedule after demand variations
Negative Consequences Level 1	Papers II and III: expected benefits never realized, put more time into the system than is received from it.	Paper V: expected benefits never realized, too much time spent in the system compare to what is gained.	
Negative Consequences Level 2	Paper II and III: odd figures, difficult to retrace figures, incorrect plans, lost trust to the plans.	Paper V: incorrect plans.	Paper IV: production schedule suggested a strange priority, the schedule looks completely different from day to day, lost trust to the schedule.

5.2 Variables influencing the consequences of using APS system

The second research question was formulated as: *which are the variables that influence the consequences of using APS systems in MPC processes?* Papers I, III, IV, V and VI contributed with findings to this question. This section will be divided into the following sub sections: planning environment related variables, MPC process related variables, and implementation related variables. Within each sub section the variables identified within each group and their influence on APS system use and consequences is described. In the last section, a summary of the separate sections will be given.

5.2.1 Planning environment related variables

In Papers I, III, IV and V it was found that APS systems were highly required when dealing with complex planning problems. Those planning problems were to a large extent influenced by the detail and dynamic complexity in the planning environment, and by the aim of the MPC process. Paper III identified that the many entities in the S&OP process in the form of multiple production sites and sales departments with dependencies, placed a need for the functionality integral planning. The high demand uncertainty placed a need of forecast and demand tools, and what-if simulation. The capacity restrictions placed a need of constraint based planning. The aim of geographical optimization, i.e. the decision from which production sites it was most cost-efficient to produce which products and which market to serve, placed a need for functionality optimization. Paper I identified that the large numbers of entities in the MPS process in the form of multiple production sites, manufacturing processes, products, markets, supply uncertainties, demand uncertainties, capacity limitations, multiple business constraints, and decision rules placed a need for APS system functionalities such as optimization, and constraint based planning. Paper IV identified that the number of production sites, work centres, products, sequence dependence set up times, and bottlenecks placed a need of finite capacity and tools for priority decisions in PAC activities.

Paper III investigated in what situations it is appropriate to use APS systems. It was found that APS systems are appropriate in planning environments characterized by high detail and dynamic complexity and with high ambitious S&OP process aims. This does not mean that APS systems would not generate benefits in situations where there are low detail and/or dynamic complexity and/or low ambitious aims, only that one probably could achieve the same benefits with a less advanced planning system, which is easier to implement, understand and use. In a situation characterized by low detail and dynamic complexity, statistical forecast and constraint based planning are probably enough to generate feasible delivery and production plan. When complexity is increased in terms of multiple production sites with dependencies, demand uncertainties, and aim of geographical optimization as in company D, constraint based planning and statistical forecast needed to be complemented with integral planning, what-if simulation, and optimization in order to generate feasible plans. There seemed, however, to be a level in which the situation became too complex to handle by the APS system. In case company D, the planning model resulted in extensive computer time, which made it impossible to make use of what-if scenario analysis during the S&OP meetings.

In Paper VI it was tested if the use of advanced planning methods for capacity balancing in MPS better handled the complexity in the planning environment than simple planning methods. This hypothesis was not supported. The statistic analysis showed that higher complexity in the planning environment was correlated with lower plan feasibility and planning performance. The complexity in the planning environment did, however, not have any large influence on the capability of planning methods in providing MPS performance.

Paper IV found that the disturbances in the manufacturing process (such as machine breakdowns, illness of operators, unavailability of tools, rush orders, scraps, and rework) influenced how often it was appropriate to make a new APS system run, which in turn influenced the feasibility of the schedule. In a situation characterized by high uncertainty, a new APS system run was needed frequently in order to obtain correspondence between the schedule and reality. In a situation characterized by low uncertainty there was, however, no reason to make the APS system run more often than to guarantee that released orders were performed within the given customer lead time. It was found that there was a limit for how often it was possible to make a new APS system run. If the schedule changed too frequently it became difficult to follow the list as it caused major changes in the schedule i.e. final state problems. It was also identified that the flexibility to cope with uncertainties on the shop floor influenced the execution of the schedule. If there was high flexibility to cope with uncertainties, operators felt tempted to use their own priority rules.

5.2.2 MPC process related variables

Papers I, III, IV and VI identified a number of variables within the MPC process that influence the use of APS systems and its capabilities of providing benefits. Paper III found that the existence of a formal S&OP team, planning meetings, cross-functional and executive involvement, and knowledge and understanding of S&OP and APS systems have a positive influence of the APS system use and the capability of fulfilling S&OP aims. It was identified that many levels 1 and 2 benefits were derived from the S&OP process alone, without the use of APS system. Still in S&OP processes with ambitious S&OP aims, APS system were required in order to fulfil aims and derived certain benefits.

Paper VI identified that it was important for the MPS process to be carried out in consecutive and repetitive steps, that people from different units participate in the MPS process, and that the actors involved in MPS had good knowledge in planning, methods, and IT in order to use planning methods in such a way that benefits could be derived. The importance of involving people from different functions was found more important to successfully use advanced planning methods than simpler planning methods. In addition it was found that the MPS related variables were more important than the use of advanced planning methods in order to obtain feasible plans and planning performance. Paper I emphasised the importance of a central function actively working with the involved part, planning meetings and education, and training of APS systems in order receive benefits when using APS systems.

5.2.3 Implementation related variables

Papers III, IV, V, and VI found that variables related to the implementation of the APS system had a large impact on the use of an APS system and its consequences.

Paper V investigated how individual, organisational and technological variables in the implementation process are related to the problems arising when the APS system is used. Individual variables captured the human activities in the organisation. It was found that lack of understanding of the planning situation, difficulties in conveying the message of what the company wanted to accomplish with the APS system, and low knowledge of how data was structured in the ERP system obstructed model design, validation of the model, and data collection during the project phase. Other papers also emphasises the influence on model design and data quality on APS system use and consequences. Paper IV, for example found that the way the model was designed influenced the schedule. The deficient correspondence between the planning model and reality resulted in a schedule of low quality. Paper II identified that lack of planning data resulted in that the decision of from where to buy capacity could not be supported. Paper VI identified that the data quality directly influenced the plan feasibility and had more influence than the use of advanced planning methods in order to achieve MPS performance.

Paper V further identified that the I variables lack of understanding of what the APS system could or could not do, resistance against the system, lack of motivation, difficulties in interpreting the APS system output and understanding the value of updating data and parameters in the ERP system made it difficult to conduct the activities during the shakedown phase and onward and upward phase.

Technological variables represented the variables closely connected to the APS system. It was found that the APS system lacked functionality, the system was not considered user friendly, it was difficult to integrate the APS system with an ERP system, and it was difficult to collect data. Those difficulties mainly arose during the project phase, but also during the shakedown and onward upward phase, and had an influence on the problems during which the APS system was used. Organisational variables comprised how activities were organized and structured. During the chartering phase, people in the implementation process had different expectations on the APS system and company personnel were involved late in the project. Also, during the project phase and the shakedown phase, companies had difficulties with prioritizing the project and suffered from unclear roles. Those difficulties, if not solved, had a negative influence on the way the APS system was used in later on.

5.2.4 Summary of variables influencing consequences

The results from the above sections are summarised in Table 10, were the identified variables and their influence on APS system use and consequences is presented. It was found that the detail and dynamic complexity in the planning environment places a need of APS systems. It was, however, identified that APS systems cannot handle too much complexity. The complexity in the planning environment was also found to influence the plans and schedules negatively, no matter of planning method used.

The variables within the MPC process that were found to influence the use of APS systems and levels 1 and 2 consequences were: the way the process was carried out, the organisation structure, and knowledge. It was found important that the MPC process was carried out in structured steps, which are clearly defined, managed, measured and controlled in order to use the APS system in such a way so that benefits could be derived and MPC process aims be fulfilled. Furthermore, it was found important to have a formal unit taking responsibility of the APS system supported planning process. The person/s using the APS system need to have good knowledge in IT, APS functionalities, and planning.

The variables identified within the implementation were: model design, system integration, data quality and APS system capabilities. The way the model was configured and its correspondence with reality influenced the feasibility of the plan (level 2). System integration was influencing level 1 and level 2 consequences. It was identified that the lacking integration between the ERP system and the APS system resulted in excessive manual labour, which lead to that a lot of time was spent on non value adding activities (level 1). It was also found that the lack of integration resulted in infeasible plans and schedules (level 2). Data quality was found to influence the feasibility of plans and schedules (level 2), independently if APS system was used or not.

Table 10: Summary of identified variables and their influences

Group of variables and papers	Variables identified	Influence by the variables
Planning environment (Papers I, III, IV and V)	• Detail complexity: number of entities and dependencies among entities. • Dynamic complexity: the uncertainties and restrictions in the production system, supply and demand.	Influence the way APS systems 'should' be used, which in turn influence level 1 and level 2 consequences. Influence the model design and the plan feasibility (level 2).
MPC process (Papers I, III, IV, VI)	• Activities carried out in consecutive and repetitive steps • Knowledge in planning, planning methods, IT, APS system functionalities • Cross-functional and executive involvement • Formal planning organisation • Existence of planning meetings	Influence the use of APS systems, which in turn influence level 1 and level 2 consequences. Influence level 1 and level 2 consequences directly without use of APS system.
Implementation (Papers II, IV and V)	• Model design. • System implementation. • Data quality. • APS system capabilities.	Influence the use of APS systems, which in turn influence level 1 and level 2 consequences. In particular level 2 consequences. Data quality influences level 2 consequences directly without use of APS system

6 Discussion

The discussion focuses on the relationships between variables, APS system use, and levels 1 and 2 consequences and originates from chapter 5. Section 6.1 focuses on the consequences of using APS system and relates the results in chapter 5 to the literature. Section 6.2 focuses on the variables influencing the consequences of using APS system and relates the results in chapter 5 to the literature. In section 6.3, the identified relationships between variables, APS system use and consequences are illustrated in a framework.

6.1 The consequences of using APS systems

The thesis found that APS systems can support the realisation of the MPC process (level 1) by improving the decision support, simplifying planning activities and reducing planning time. Improved decision support has been recognised as a benefit of APS systems in supporting processes at different levels in previous literature as well (Brown et al., 2001; Gupta et al., 2002; Gruat La Forme et al., 2009). Reduced planning time and simplified planning activities are some of the most mentioned benefits of APS system in previous literature (e.g. Wagner and Meyer, 2005: Reuter, 2005; Fleischmann et al., 2006; Rudberg and Thulin, 2009; Cederborg, 2010) independently of the planning process studied.

The majority of previous studies do not make any difference between different planning levels (e.g. Gupta et al., 2002; Wagner and Meyer, 2003), which makes it difficult to understand which benefits can be derived in which process. In the thesis a number of benefits for the S&OP and MPS process were identified that were not identified in the PAC process. The use of APS systems in S&OP and MPS processes supported integration, coordination and communication among different units, increased the visibility of the planning process, gave focus to data quality, and increase the understanding of planning. Many of those benefits have to do with the integration between different functions in the processes. As the PAC process normally only involves one or a couple of persons, this might be why those benefits were not identified here. The benefits of improved supply chain visibility, improved integration, and coordination between functions are however identified in studies focusing on strategic and tactical planning (Fleischmann et al., 2007; Dehning et al., 2007; Rudberg and Thulin, 2009; Cederborg, 2010). This gives some support for the idea that benefits connected to the integration between different functions are to be found mainly in S&OP and MPS processes. Although it was found that the use of APS systems might bring on high data quality it is more an indirect consequence of system use. Thus, focus on and high level of data quality is not seen as positive consequences of using APS systems at level 1, but as a variable influencing the consequence of system use. Proactive planning was identified as a consequence of using APS systems in the thesis, something that has been recognised in a number of previous studies (Gupta et al., 2002; Dehning et al., 2007; Rudberg and Thulin, 2009). Proactive planning was identified in the S&OP process but not in the MPS and PAC processes. What-if simulation analysis was, however, only used in the S&OP process, which might explain why proactive planning was only identified here. The close connection between the functionality used and the benefits achieved is noted by Gruat La Forme et al. (2009) as well.

The thesis identified that the use of APS systems could support the MPC process output (level 2) by generating reliable delivery plans, common and optimal production plans, feasible MPS and schedules, and synchronised material and production plans. Previous studies have recognised that the use of APS systems result in improved forecast accuracy (Reuter, 2005) and synchronised production and demand (Reuter, 2005; Cederborg, 2010). Literature also suggests that the use of advanced planning and scheduling algorithms are of importance in order to generate feasible plans and schedules (e.g. Fleischmann and Meyr, 2003; Stadler and Kilger, 2005; Vieria and Pavetto, 2006).

There has not been much written about the negative aspects of APS systems, in particularly not on the negative side of using the systems. Some studies focus on negative aspects related to the implementation process (e.g. Lin et al., 2007). David et al. (2006) is the only found study, which implicitly focuses on negative consequences of APS systems. David et al. (2006) link the limitation of the APS system to negative consequences. This thesis focuses on the use as related to negative consequences of APS systems. A number of problems of using APS systems in S&OP and MPS processes are identified, for example, difficulties to move forward with the system, consultancy dependency, use of parallel systems, and not using the appropriate potential. It was found that those problems in turn might result in negative consequences, for example that planning tasks become more difficult to conduct with APS systems than without APS systems and incorrect and plans and schedules. It is interesting to notice that many APS system users think that expected benefits has not been realised at the same time as they stress that it should be possible to use APS systems to a larger extent. This indicates that it is difficult to make good use of APS systems. Still, the expectations of APS systems seem rather high from the start, which could be another reason for why expected benefits are not always achieved. Günter (2005) found that there is a discrepancy between the expectations of the companies and the capabilities of the APS systems, resulting in that plans many times are not considered as feasible. The thesis identified that APS systems generated plans and schedules many time are difficult to interpret and understand and that APS systems might generate incorrect plans and schedules. This in turn resulted in distrust to the plans, leading to that plans were not followed. In some cases distrust to the plans resulted to distrust in the APS systems and in worst cases distrust to the planning organisation responsible for the APS system supported MPC process. The importance of understanding how the resulting plan/schedule is calculated in order to make use of plans/schedules has been emphasised in previous studies on planning and APS systems (Stoop and Wiers, 1996; Taal and Worhmann, 1997; Kreipl and Dickerbach, 2008). Marcus and Tanis (2000) also identified that ERP system users are unwilling to use systems if they do not trust the data and reports, something that might lead to re-installation of the system.

It was found that the extent to which the APS system was used and the way the APS system was used influenced the consequences to be achieved in the MPC process. Previous studies have concentrated on the implementation aspects of

APS systems in order to understand how benefits are or are not achieved, which has resulted in that the actual use has more or less been forgotten. Nevertheless, ‘use’ has perceived a lot of attention in previous IS literature. Some researchers stress that use is part of the independent variables in the same way as the consequences of use (e.g. DeLone and McLean, 2003). This view has, however, been criticized by others (e.g. Seddon, 1997) considering that IS use is to be seen as a dependent variable. Some of the papers in this thesis have studied a ‘successful’ use, which has been defined as when it is used in such a way so that the aim of the MPC process is fulfilled and/or benefits is achieved. Therefore, use has been closely integrated with consequences and has been viewed differently than the variables within the planning environment, MPC process, and implementation. During the writing of the thesis it has been difficult to separate aspects connected to the use from consequences of use, indicating that use and consequences are close interconnected. This does support the view that use is to be treated somewhat different than planning environment related variables, MPC process related variables and implementation related variables.

6.2 The variables influencing the consequences of using APS system

The thesis identified a number of variables that are influencing consequences of using APS systems in MPC processes. It was found that the complexity in the planning environment influenced the need for APS systems. Previous studies have not explicitly dealt with the question of when it is appropriate to implement and/or use APS systems. Still an underlying assumption is that APS systems are suitable in complex environments where simple planning methods cannot adequately address complex trade-offs between competing priorities (de Kok and Graves, 2003; Rudberg and Thulin, 2009). Previous studies do, however, not explain what a complex environment is. This thesis has been able to identify the variables, which places a need of APS systems. Not only is the need of APS systems driven by the many times conflicting business objectives (which is the reality of almost any MPC process), and the aim of the MPC process, but also is it driven by the detail and dynamic complexity as defined by Bozarth et al., (2008). This thesis links detail and dynamic complexity to APS system functionalities and finds that detail complexity to some extent can be handled by the functionalities optimization and integral planning whereas dynamic complexity to some extent can be handled by constraint based planning, what-if simulation and fast rescheduling capabilities. Apart from influencing the need of APS functionalities, it was found that the detail and dynamic complexity influences the way the APS functionalities ‘should’ be used. The disturbances in the manufacturing process (dynamic complexity) were, for example, found to influence how often it is appropriate to run the APS system in order to achieve a feasible schedule. There is, however, a limit for how much complexity APS systems today can handle. It was identified that APS systems suffer from the final state problem, which has been recognised in previous studies on APS systems (Kreipl and Dickerbach, 2008). Besides, when detail and dynamic complexity are increased, the complexity in the planning model might also increase. It is not possible to model too much complexity in APS systems as it results in too long computer time, a problem identified by Stadtler and Kilger

(2005) and Günter (2005). Nonetheless, a simple model might result in a low correspondence with reality (David et al., 2007).

Whereas the complexity in the planning environment to a large extent influenced the appropriate use of APS system, i.e. how the APS system should be used, the MPC process related variables and implementation related variables seemed to influence how the APS system was actually used. A number of variables connected to the MPC process, which influenced the way the APS system was used were identified. It was found that the 'maturity' of the MPC process in terms of activities being carried out in consecutive and repetitive steps, the structure of the organisation and the knowledge among the personnel influenced the way APS systems were used and its capabilities of providing benefits. Previous studies have identified the need of having both a mature business process and advanced software in place in order to obtain high planning performance (Clause and Simchi-Levi, 2005). Still, very few studies have focused on the role of the business process in order to make good use of an information system. Consequently, many of the identified variables connected to the MPC process have not been emphasised in previous studies. The importance of good knowledge among the users in order to successfully use planning systems has, however, been recognised in many studies on planning systems in general (Guimaraes et al., 1992; Marcus et al., 2000) and APS systems in particular (Zoryk-Schalla et al., 2004, Lin et al., 2007; Hvolby and Steger-Jensen, 2010). Education is a cornerstone in most IS implementations, but it is often centred on computed/system operations, rather than on understanding the manufacturing planning and control concepts that the software system is supposed to support (Jonsson, 2008). This thesis found that it is important to have an understanding of what optimisation is all about and have a good understanding in planning and the MPC process, which the APS system is supporting. In the S&OP and MPS processes, additional MPC process variables were identified as important for using the APS system: cross functional and executive involvement, a formal planning organisation, and planning meetings. One reason for why those variables were not observed in PAC is that PAC does not involve several of people at different functions. As such the organizational focus is rather on local efficiency, developing an organization where the planner has the knowledge, authority, and enough time to make use of APS functionality in appropriate ways.

The implementation related variables identified as having a large influence on the APS system use and levels 1 and 2 consequences were: model design, system integration, data quality, and the capability of the APS system. Zoryk-Schalla et al. (2004) highlight the need of extensive support from highly trained modellers since APS systems may not be capable of assisting the modeller in properly defining the planning process and planning model. The results from the papers in the thesis confirm this and also identify the need to convey the message of what the company wants to accomplish with the APS system to consultants in the modelling process; something that requires a good knowledge of the planning situation and APS system capabilities among the company implementing the APS system. Previous studies have emphasised the importance of integrating APS systems in the existing IT structure in order to successfully use APS systems (e.g. Günter, 2005; Viswanathan, 2010). In this thesis it was found that system integration influence the feasibility of the plan and the way APS systems could be used to support planning activities. The importance of data quality has been recognised in many studies on planning systems (Schroeder et al., 1981; Little et al., 1995; Jerke et al., 2002) and on planning activities in general (APICS, 2010). It was identified in this thesis that the accuracy, i.e. conformity of the stored and actual value and the access to data, influenced the design of the model and the feasibility of plans and schedules. One conclusion derived is that it is important to have a good understanding of how data is structured in the ERP system in order to gather data correctly. Besides, it is of high importance that parameters and data figures in the ERP system and APS system are updated frequently. This requires a high discipline of the APS system and ERP system users. Previous studies of planning and scheduling systems support this conclusion. Little et al. (1995) stress that the use of advanced scheduling tools is likely to produce benefits only if operated in a structured and disciplined manner since these systems rely on a significant volume of detailed and accurate data. The system itself also influenced the way it could be used. A number of problems when using APS systems were connected to the APS system capabilities. It was, for example, identified that it is difficult to extract information from APS systems, and that the analytical capabilities are limited.

6.3 Relationships between variables and consequences

Figure 9 illustrates the relationships that has been derived in this thesis between planning environment related variables, MPC process related variables and implementation related variables, APS system use and levels 1 and 2 consequences. The relationships are explained and motivated in the following section.

Relationship 1, the influence of the APS system use on the realization of the MPC process: A number of positive consequences and some negative consequences that the use of APS systems may results in for the MPC process realisation have been identified. It is found that not only the use or non use of APS functionalities, but also the extent by which the APS system is used and the way the APS system is used influences the realisation of the MPC process.

Relationship 2, the influence of APS system use on the MPC output: Some positive and negative consequences resulting from the use of APS systems and impacting MPC output have been identified. It is found that not only the use or non use of APS functionalities, but also the extent by which the APS system is used and the way the APS system is used influences the MPC output.

Relationship 3, the influence of realization of the MPC process on the MPC output: Although a few level 2 consequences seemed to originate from level 1 consequences, most of the identified level 2 consequences originated directly from APS system use. The reason for this might be that many planning activities are directly linked to the MPC output, for example the support of APS systems to generate a production plan and schedule.

Relationship 4, the influence of the planning environment related variables on the APS system use: The detail and dynamic complexity in the planning environment influenced the 'appropriate use' of APS functionalities. High detail complexity placed a need of integral planning and dynamic complexity placed a need of frequent rescheduling and what-if simulations. It was found that the dynamic complexity influenced how often the APS system should be run, indicating that the planning environment related variables not only influence which functionalities should be used, but also how the APS system should be used.

Relationship 5, the influence of the planning environment related variables on the implementation related variables: It was indicated that the dynamic and detail complexity in the planning environment influenced the configuration of the model. It was more difficult to configure a model that corresponds with reality in a planning environment characterized by high complexity.

Relationship 6, the influence of the planning environment related variables on the MPC output: It was found that the detail and dynamic complexity had a direct influence on the plan feasibility; the higher complexity the lower plan feasibility.

Relationship 7, the influence of the MPC process related variables on the APS system use: It was found that the variables within the MPC process influenced how an APS system was used. A number of variables were identified which have not been mentioned directly in previous studies.

Relationship 8, the influence of the MPC process related variables on the realisation of the MPC process: It was found that the variables within the MPC process directly influenced level 1 consequences, at least in the MPS and S&OP processes.

Relationship 9, the influence of the MPC process related variables on the MPC output: It was found that the variables within the MPC process directly influenced level 1 consequences, at least for the MPS and S&OP processes.

Relationship 10, the influence of the implementation related variables on the APS system use: It was found that the implementation related variables influenced how an APS system was used and its consequences.

Relationship 11, the influence of the implementation related variables on the MPC output: The papers indicated that the data quality influenced the feasibility of the plans, whether the APS system was used or not.

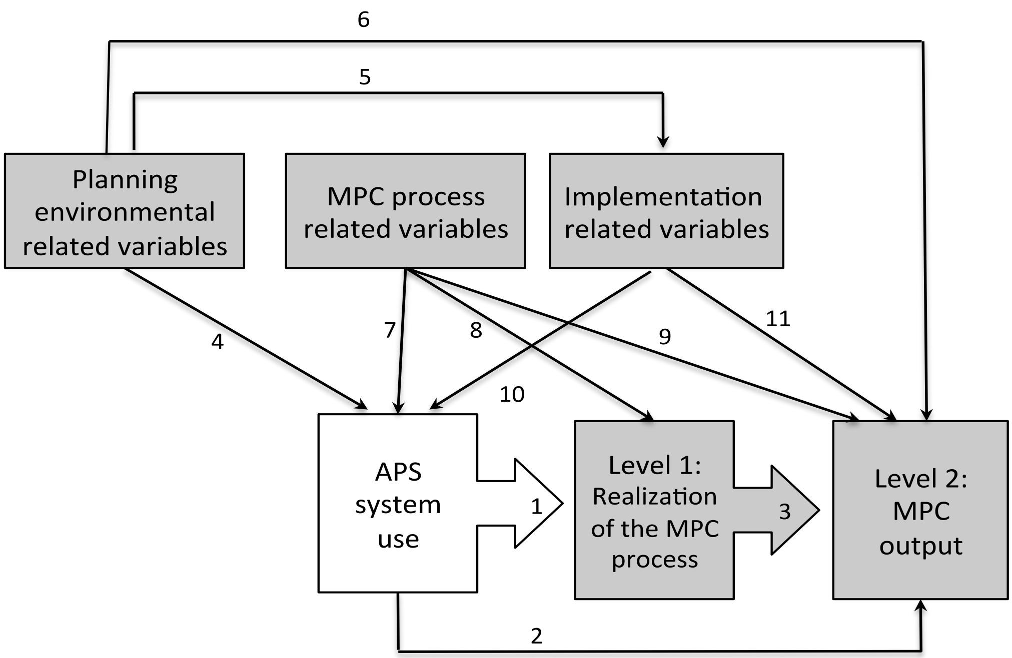

Figure 9: Found relationships in the papers between APS system use, level 1 and 2 consequences, and variables in the planning environment, MPC process and implementation.

Figure 9 illustrates a number of relationships between APS system use, levels 1 and 2 consequences and variables in the planning environment, MPC process and implementation. It is, however, important to emphasise that there are an additional number of relationships that has not been studied. There are also a number of variables within each box that has not been studied. Besides, the variables could be categorised in many different ways. The figure does not try to depict how everything is coherent but only focuses on relationships, which has been identified in the papers. Some relationships have been found in several studies and even been tested whereas others have just been indicated in one case study.

Based on the identified relationships in this thesis it is possible to derive a number of findings at a more comprehensive level. First, an APS system has the capability to provide a number of benefits to the MPC process, but it requires a lot from the personnel implementing it and using it. This is something that has been identified also when installing MRP systems and ERP systems (Petroni, 2002). There are, however, some indications for that APS systems are more difficult to use as they rely on mathematical models, which are difficult to design (Zoryk-Schalla et al., 2004), understand (Lin et al., 2007) and use. In one of the paper it was for example found that advanced planning methods are more dependent on a mature MPC process than simpler planning methods to work effectively. Second, although the APS system has the ability to provide benefits to the MPC process, the way the process is conducted, the knowledge among the personnel, and the data quality are found as more important than the APS system. Previous literature has come to similar conclusions (Boyer et al., 1997; Grimson and Pyke, 2007; Jonsson, 2008) indicating that companies have most to gain by investing in the process prior to investing in APS systems.

Third, it was found that the dynamic and detail complexity place a need of APS systems and influence how APS system ‘should’ be used. Still, in one paper it was found that those variables did not have any large influence on advanced planning methods’ capability of providing benefits. This indicated that the fit between the environment and the system might not the most important variables when choosing to implement an APS system. Fourth, although the MPC and implementation related variables are of importance for the achievement of levels 1 and 2 benefits, it is the actual use that directly influences benefits. Previous literature has identified that relatively little focus has been given to the use of IS and how this influences benefits (Zhu and Kraemer, 2005; Yu, 2005). DeLone and McLean (2003) stress that “system usage is a key variable in understanding success but too frequently simple usage variables are used to measure this complex construct. More research is needed to refine the multidimensionality of system usage”. This thesis has identified that there are a number of variables concerned with APS system use that influences levels 1 and 2 benefits. Fifth, the detail and dynamic complexity in the planning environment makes any MPC process difficult to conduct, which is something that the use of APS system cannot change. This indicates the importance of having realistic expectations on APS systems and not to fall in the trap of believing that APS systems can solve any planning problems.

7 Conclusion and further research

This section concludes the thesis, summarises the contribution of the thesis and gives suggestions for further research.

7.1 Conclusion

This thesis focuses on how APS systems can support MPC processes in adding value to the company by focusing on the consequences of using APS system in the MPC processes and the variables influencing the consequences of using APS systems.

Previous studies have not explicitly studied which consequences the use of APS systems might result in. There has not been any clear separation between different planning processes or the level on which the consequences are captured. This has probably contributed to the rather unclear understanding of what to expect from APS systems. This thesis has identified that the use of APS systems can result in consequences on four different levels; the MPC process realisation (level 1), the MPC output (level 2), the business process (level 3), and the manufacturing company (level 4). A number of consequences when using APS system in the S&OP, MPS and PAC processes at level 1 and 2 were identified.

The thesis is different from previous studies conducted on APS systems, because special focus is given to the APS system use instead of the APS system implementation when trying to understand how benefits are achieved. When researching on planning systems it is often assumed that a successful implementation directly results in achievement of certain benefits. A successful implementation does, however, not necessarily mean an efficient use of the system. Rather, the actual use is of high importance for how benefits are generated and more research is demanded in order to understand the role of the system use and to refine the multidimensionality of system use. This thesis found that not only was the use or non use of high importance for the achievement of benefits in the MPC process, but also to which extent the APS system was used and the way the APS system was used to support planning activities. A number of variables within the MPC process that usually are not emphasised as important for achieving benefits with APS systems were identified.

An underlying assumption in APS system literature is that APS systems are suitable in planning environments, which are too complex for more simple planning systems. Yet, previous studies have not looked into what type of complexity makes APS system support appropriate. This thesis defines planning environment complexity and explores and explains how different variables within the planning environment influence the use of an APS system and its capability to provide benefits. It was found that the detail complexity, i.e. the number of entities and dependencies among entities and the dynamic complexity, i.e. uncertainties and restrictions in the production system, supply and demand influence the 'appropriate' use of APS systems.

Previous studies have identified a number of variables of importance in order to achieve benefits, but have not specified which variables are of importance for which benefits. Many studies have identified variables, which influence levels 1 to 4 benefits simultaneously. This thesis has identified eleven relationships between consequences at levels 1 and 2, APS system use, and variables within the planning environment, the MPC process, and APS systems implementation.

7.2 Managerial implications

Within each paper a number of managerial implications have been outlined. Those implications relate the use of APS systems in S&OP, MPS and PAC processes respectively. In this section managerial implications are derived at a more general level in terms of APS systems in MPC processes.

As early as in 1970s, advanced planning and scheduling models were developed to solve particular planning problems at specific companies. Still, most companies do not have the possibility to set off the required resources to develop tailor made planning systems, which might be one of the reasons for why commercial off the shelf APS systems have received a lot of attention from industry.

This thesis gives some support for the fuss about APS systems. If used effectively it simplifies planning activities, reduces planning times, provides decision support and generates feasible plans. Still, it is important to understand that no planning system, no matter of how advanced it is can create an effective MPC process by itself. The sometime considered 'easy way' of letting the installation of an IS drive the way for the establishment of the MPC process is in most cases unsuccessful. This thesis has found that the organisational structure, the way the process is carried out, the knowledge among the personnel involved in the MPC process, and the data quality is of high importance for effectively using APS systems. In fact, those variables are more important than the use of APS systems in order to perceive feasible plans and high planning performance. Thus, the answer to get an effective MPC process is often not an APS system.

So when is an APS system the suitable solution? This thesis has found that an APS system is good in handling a certain amount of complexity in the planning environment and ambitious MPC aims. In general terms, APS systems are appropriate to use when the MPC process is characterized by many conflicting objectives, capacity and material limitations, and when the aim is to become proactive and/or find optimal plans/schedules. For the higher planning levels the complexity of several entities with dependencies and/or the aim of integrating outside the focal firms boundaries makes the use of APS systems appropriate. This as APS systems can generate an integrated plan which makes it possible for companies to consider allocation of products/volume, transport restrictions and trade offs between inventory costs and transportation costs in a central process. In reality it is usually not possible to fully integrate customers and suppliers in the planning process, as it is difficult to receive accurate planning data from customers and suppliers. APS systems easily generate and evaluate scenarios, which makes it suitable in environments characterized by demand, production system, and supply uncertainties and/or in MPC processes with a proactive aim.

Still, it is not possible to include a very high level of complexity in the planning model as it results in long computer times. This being so there is a trade off between high correspondence with reality and the planning model and fast generation of new plans. APS systems suffer from the final state problem, making the use of APS systems inappropriate in situations where new plans have to be generated very frequently, which in particular is the case at lower planning levels characterized by much uncertainties.

The conclusion that APS systems suits relatively complex planning environments and high ambitious MPC aims does not mean that APS systems would not provide benefits in environments characterized by very low complexity and/or less ambitious MPC aims. This thesis has, however, found that it is very difficult to effectively use APS systems, making the implementation unnecessary if one could receive the same benefits without using APS systems or by using less advanced (and complex) planning systems.

So how to effectively use APS systems? First of all it is important to understand that what is an effective use varies a lot between the different MPC processes and between different contexts. In some situations the APS system could be run rather automatic whereas in other it should be complemented with human experiences. In some situations rescheduling is made very frequently whereas in other new schedules are only needed within the time it takes to manufacture products within the promised customer lead times. Derived from the findings of the papers in this thesis it is still possible to give some suggestions for how to create prerequisites for an effectively use.

When considering an APS system implementation it is important to start with the MPC process; where are we now, what are we aiming at and how do we get there. If the answer to the question of "how to get there" is the use of an APS system it is important to make sure that one has the prerequisites not only to undertake the implementation but also to run the system when it is handed over to the operational personnel. The use of APS systems require a rather mature MPC process in terms of organisational structure and knowledge among the personnel involved in the MPC process. Besides, APS systems rely on master data collected from ERP systems (and/or legacy system), making the use of APS systems very difficult if ERP system is not in place (with accurate data).

In the search for the right APS system one also chooses a long-term partner. The APS vendors do not only vary in APS system functionality, integration techniques, and user friendliness but also in experiences and industry focus. The system vendor and consultants play a major role in the implementation process where experiences from similar industries are highly valuable. This thesis found that many problems identified in the APS system usage have to do with the APS system capabilities and implementation process. It is therefore important to conduct a systematic selection approach, but also to have realistic expectations of what the APS system can accomplish. It was found in this thesis that few companies defined key performance indicators, which made it impossible to evaluate whether the APS system lived up to its expectations. It is important that everyone knows why the APS system is installed in order to realise certain benefits.

One of the advantages of implementing a commercial off the shelf system compared to a tailor made system is that one does not have to put the time and resources into developing the mathematical model. This however means that the system vendor and/or consultants are the ones that are responsible for the modelling process in most cases. It is of high importance of being involved in the design and validation of the model, both in order to get an understanding of the APS system but also as the company is the one that best knows about the company specific circumstances, which the model should reflect. In the thesis, it was found problematic to collect data and validate the model. One reason for this was a rather low understanding of how data is structured in the ERP system and mathematical programming. As the quality of data and a correct model are prerequisites for effectively using APS systems, the project tasks associated with data and validation should not be underestimated.

In general there are relatively few people that are involved in the generation of the plans in the APS system. Still there are a number of people that influence the input to the APS system and who are using its output. The feasibility of the plans is directly related to its input and to the extent to which it will be used. For people to update data figures and use the APS generated output it is, therefore, important that the system is accepted by its personal. The process of gaining acceptance should start when the decision to install the system is taken until the system is replaced. This process is facilitated by top management support, a project leader that is given mandate from the top management and by a planning organisation with executive level participation. To conclude, never forget that an APS system is a decision support system, supporting existing processes and people. Or as T.E. Chorman at Procter & Gamble Company expresses it (Camm, m.fl., 1997):

"Models do not make difficult decisions, managers do. But in the face of time constraints and an overwhelming number of alternatives, advanced planning models can be of great help"

7.3 Contribution

This thesis has resulted in a number of theoretical and practical contributions, which can be summarised into eight major points:

- *Definition and conceptualisation of a number of constructs.* For example the complexity in the planning environment, levels of APS system consequences, S&OP and MPS maturity, and planning methods for capacity balancing.
- *Description of how APS systems can be used to support MPC activities.* The case descriptions within this thesis give some understanding for how APS functionalities are used in different MPC processes and the affect of an APS system on MPC processes.
- *Identification of positive and negative consequences that the use of APS systems in MPC processes might result in.* A number of consequences at the level of the MPC process realisation and MPC output were identified. 18 benefits categorised into decision support, planning efficiency, and learning effects were identified in the S&OP process.

- *Identification of some problems that might occur when using APS systems in MPC processes.* Six major problems were identified when using APS systems in S&OP and MPS processes, which in turn were categorized as process, system and plan related problems.
- *Identification of the variables that influence APS system use and consequences.* A number of variables of importance in order to use APS systems in such a way so that benefits could be achieved were identified. Propositions regarding the influence of different variables were generated whereas some were tested. A number of different categorizations for analysing the influences of variables were also derived. For example, the individual, organisational, and technological framework, APS system experiences cycle, and planning environment related, MPC related, and APS implementation related variables.
- *Development of a conceptual model including identified relationships.* A number of relationships between the APS system use, levels 1 and 2 consequences, planning environment related variables, MPC process related variables, and implementation related variables were developed.
- *Development of a framework for when it is appropriate to use APS systems to support S&OP processes*. By characterizing different combinations of S&OP aim ambitiousness, planning environment complexity, individual, organisational and technological dimensions.
- *Generation of a number of suggestions for what to think about when implementing and using APS systems.* Those suggestions were derived in the individual papers as well as on a more comprehensive level in the covering essay.

7.4 Further research

This thesis has focused on the onward and upward phase in the APS experience cycle. In further research it would be interesting to use process research and explain how the APS system implementation unfolds over time and is guided and affected by changes on related variables. With such an approach, focus could be given both to the use and previous stages in the implementation. Although focus has been put on the onward and upward phase, several areas have been identified in earlier phases, something which could be investigated further as well. It would, be interesting to conduct deeper studies of implementation project management. Such studies could focus on the dependency issues between the consultant and the APS system buyer, or on the cultural issues of APS systems. The chartering phase was regarded as a critical phase because it was during this phase the company decide if APS systems should be implemented, and the system was selected. The companies studied in this thesis did not put much emphasis on this phase. It would therefore be interesting to study cases where a lot of focus is given to the activities in the chartering phase and explore the effects achieved.

Another focus in this thesis has been on the functionality in commercial off-the-shelf systems. An interesting finding was that there seems to be a limit for how much complexity APS systems can handle. Still the functionality in and the flexibility of commercial standard systems are limited and it would be interesting to study tailor-made APS systems in order to investigate if those systems better cope with complexity than commercial off the shelf systems. The thesis indicated that the functionalities integral planning and optimization are suitable for coping with detail complexity, whereas rescheduling, and what-if simulation are suitable for coping with dynamic complexity. The thesis also found that the complexity in the planning environment made the performance of any planning method worse and that advanced planning methods in fact did not handle complexity much better than simpler planning methods did. Thus, it would be interesting to study the fit between different functionalities and detail and dynamic complexity and its influences on levels 1-4 benefits in more detail. How important is the fit between functionality and the complexity in the planning environment in order to achieve benefits? Are some functionalities better at coping with detail and dynamic complexity than others? Where is the limit for how much complexity different functionalities can handle?

Focus in this thesis was given to the S&OP process, the MPS process and the PAC process. Still, APS systems are many times argued to support strategic decisions and planning processes involving the entire supply chain. It would be interesting to broaden the study object from MPC processes to supply chain planning processes. The thesis did not consider the order planning level. It would, therefore, be interesting to investigate the pros and cons making constraint based MRP calculation with APS system and the pros and cons of integrating finite production planning and scheduling in APS systems.

This thesis has identified a number of variables of APS system use that are of importance for the consequences of using APS system. Still, the relationships between APS system use and level 1 and level 2 consequences were not studied in detail and more research could be conducted in order to better understand those relationships and identify more APS system usage variables. It would also be interesting to focus on the identified variables within the planning environment, MPC process and implementation, and its influence on APS system use in more detail. How do for example variables within the MPC process influence the way the APS system is used? In further research, the suggested relationships and generated propositions could be empirically tested. It would be interesting to put more focus on each group of variables identified in the thesis (planning environment, MPC process, and implementation), for example identify variables within the MPC process and relate those impacts to levels 1 and 2 consequences.

8 References

Advanced planning and scheduling software, Bitpipe, Inc. http://www.bitpipe.com/tlist/Advanced-Planning-and-Scheduling-Software.html (2012-04-12)

Al-Mashari, M., Al-Mudimigh, A, and Zairi, M. (2003). "Enterprise resource planning: A taxonomy of critical factors", *European Journal of Operational Research*, Vol. 146, No. 2, pp. 352-364.

APICS (2000). *Basic of Supply chain management*, APICS Certified Supply Chain Professional Learning System, APICS, Alexandria, VA.

APICS (2010). *Using Information Technology to Enable Supply Chain Management*, APICS Certified Supply Chain Professional Learning System, APICS, Alexandria, VA.

APICS (2011). *APICS Dictionary.* In: JR, J.H.B. (ed.) APICS Dictionary. 13th ed. Chicago. APCIS The Association of Operations Management.

Arbnor, I. and Bjerke, B. (1997). *Methodology for creating business knowledge*, Sage, Thousand Oaks, CA.

Arnold, J.R. (1998). *Introduction to materials management*, Prentice-Hall Inc., United States of America.

Bakhrankova, B. (2010). "Decision support system for continuous production", *Industrial Management & Data Systems,* Vol. 110, No. 4, pp. 591-610.

Barratt, M., Choi, Y., and Li., M. (2011). "Qualitative case studies in operations management: Trends, research outcomes and future research implications", *Journal of Operations Management*, Vol. 29, No. 4, pp. 329-342.

Bermudez, J. (1996). "Advanced Planning and Scheduling Systems: Just a fad or a breakthrough in manufacturing and supply chain management", The report on manufacturing, Advanced Manufacturing Research, Inc. http://e-opt.informs.org/resources/uploads/APS%20Intro%201996.pdf (2012-08-04)

Bower, P. (2006). "How the S&OP process creates value in the supply chain", *The Journal of Business Forecasting*, Vol. 25. No. 2, pp. 20.

Boyer, K.K., Leong, K.G., Ward, P.T., Krajewski, L.J. (1997). "Unlocking the potential of advanced manufacturing technologies", *Journal of Operations Management*, Vol. 15, No., 4., pp. 331-347.

Bozarth, C. (2006). "ERP implementation efforts at three firms: Integrating lessons from the SISP and IT-enabled change literature", *International Journal od Operations and Production Management.* Vol. 26, No. 11, pp. 1223-1239.

Bozarth, C., Warsing D., Flynn B. and Flynn, J. (2009). “The impact of supply chain complexity on manufacturing plant performance”, *Journal of Operations Management*, Vol. 27 No. 1, pp. 78-93.

Brown, G., Keegan, J., Vigus, B. and Wood, K. (2001). “The Kellogg company optimizes production, inventory and distribution”, *Interfaces*, Vol. 31, No 6, pp. 1-15.

Bryman, A. and Bell, E. (2007). *Business research methods*, Oxford University Press Inc., New York.

Camm, J.D., Chroman, T.E., Dill, F.A., Evans, J.R., Sweeney, D.J., Wegryn, G.W. (1997). “Blendning OR/MS, Judgement, and GIS: Restructuring P&G’s Supply Chain”, *Interfaces*, Vol. 27, No. 1, pp. 128-142.

Cederborg, O. (2010). ”Assessing factors affecting results of APS implementations”, In Proceedings of the 17th International Annual EurOMA Conference 6-9 June, Porto, Portugal.

Cederborg, O. and Kjellsdotter, L. (2007). ”Characteristics of Advanced Planning Systems, In proceedings of PLANs Forsknings- och tillämpningskonferens. Jönköping.

Chau P., Kuan K. and Liang T.P. (2007). “Research on IT value: what we have done in Asia and Europe”, *European Journal of Information System*, Vol. 16, No. 3, pp. 196-201.

Chen, I.J. (2001). “Planning for ERP systems: analysis and future trend”, *Business process Management Journal,* Vol. 7, No. 5, pp. 374-386.

Chen, K. and Ji. P. (2007). “A mixed integer programming model for advanced planning and scheduling (APS)”, *European Journal of Operation Research*, Vol. 181, No. 1, pp. 515-522.

Chopra, S. And Meindl, P. (2004). *Supply Chain Management – Strategy, Planning and Operation*, 2nd ed., Prentice-Hall, Engelwood Cliffs, NJ.

Clause, E.H, and Simchi-Levi, D. (2005). “Do IT investments really pay off?”, *Supply Chain Management Review*, Vol. 9, No. 9, pp. 22-29.

Cox, J.F and Clark, S.J. (1984). “Problems in implementing and operating manufacturing resource planning information system”, *Journal of Management Information System*, Vol. 1, No, 1, pp. 81-101.

Davenport, T.H. (1988). ”Putting the enterprise into the enterprise systems”, *Harward Business Review*, July-August, pp. 1-11.

David, F., Pierreval, H., and Caux, C. (2006). “Advanced planning and scheduling systems in the aluminium conversion industry”, *International Journal of Computer Integrated Manufacturing*, Vol. 19, No. 7, pp. 705-715.

de Kok, A.G and Graves, S.C. (2003). *Handbook in Operations Research and Management Science Vol. 11- Supply Chain Management: Design, Coordination and Operation*, Elsevier, Amsterdam.

Dehning, B., Richardson J. V. and Zmud R.W. (2007). “The financial performance effect of IT-based supply chain management systems in manufacturing firms”, *Journal of Operations Management*, Vol. 25, No. 4, pp. 806-824.

DeLone, W.H. and McLean E. R. (1992). “Information System Success: The Quest for the Dependent Variable”, *Information Systems Research*, Vol. 3, No. 1, pp. 60-95.

DeLone, W.H. and McLean E. R. (2003). “ The DeLone and McLean Model of Information System Success: A Ten-Year Update, *Journal of Management Information Systems*, Vol. 19, No. 4, pp. 9-30.

Dezdar, S. and Sulaiman, A. (2009). “Successful enterprise resource planning implementation: taxonomy of critical factors”, *Industrial Management & Data Systems*, Vol. 109. No. 8, pp. 1037-1052.

Entrup, L. M. (2005). *Advanced Planning in Fresh Food Industries-Ingerating Shelf Life into Production Planning*, Heidelberg, Physica-Verlag.

Eisenhardt, K.M. (1989). “Building Theories from Case Study Research”, *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Feng, Y., D’Amours, S and Beauregard, R. (2008). “The value of sales and operations planning in oriented stand board industry with make to order manufacturing system: Cross functional integration under deterministic demand and spot market resource*”, International Journal of Production Economics*, Vol. 115, No. 1, pp. 189-209.

Finney, S., and Corbett, M. (2007). “ERP implementation: a compilation and analysis of critical success factors”, *Business Process Management Journal,* Vol. 13, No. 3, pp. 329-347.

Fisher, M.L. (1997). “What is the right supply chain for you product”. *Harvard Business Review,* Vol. 75, No. 2, pp. 105-116.

Fleischmann, B., Ferber. S., and Henrich P. (2006). “Strategic Planning of BMW’s Global Production Network”, *Interfaces*, Vol. 26, No. 3, pp. 194-211.

Fleischmann, B. and Meyr, H. (2003). Planning Hierarchy, Modeling and Advanced Planning Systems. In: de Kok, A.G. and Graves, S.C (eds). *Handbooks in OR and MS*, Elsevier.

Flick, U. (2002). *An introduction to qualitative research*, SAGE Publication Ltd, London.

Flynn, B.B, Sakakibara, S., Schroeder, R.G., Bates, K.A. and Flynn, E.J. (1990). ”Empirical research methods in operations management”, *Journal of Operations Management*, Vol. 9, No. 2, pp. 250-284.

Fontanella, J. (2001). “The Overselling of Supply Chain Planning Suites – 60 Manufacturers Speak Up, *AMR Research Report*.

Forslund, H. and Jonsson, J. (2010). “Selection, implementation and use of ERP systems for supply chain performance management”, *Industrial Management & Data*, Vol. 110, No. 8, pp. 1159-1157.

Forza, C. (2002). “Survey research in operations management: a process-based perspective”, *International Journal of Operations and Production Management*. Vol. 22, No. 2, pp. 152-194.

Flyvbjerg, B. (2006). “Five Misunderstanings About Case-Study Research”, *Qualitative Inquiry*, Vol. 12, No. 2, pp. 219-245.

Gayialis, S.P. and Tatsiopoulos I.P. (2004). “Design of an IT-driven decision support system for vehicle routing and scheduling, *European Journal of Operational Research*, Vol. 152, No. 2, pp. 382-398.

Gallucci, J. (2008). “How to mitigate risk and drive alignment with S&OP,” *Journal of Business Forecasting*, Vol. 24, No. 1, pp. 4-9.

Genin, P., Thomas, A., and Lamouri, L. (2007). “How to manage robust tactical planning with APS (Advanced Planning Systems), *Journal of Intelligent Manufacturing*, Vol. 18, No. 2, pp. 209-221.

Gerring, J. (2007). *Case study research – principles and practise*, Cambridge University Press, US.

Grimson, J.A. and Pyke, D.F. (2007). “Sales and Operations Planning: an exploratory study and framework”, *International Journal of Logistics Management*, Vol. 18, No. 3, pp. 322-346.

Grover, V., Jeong R.S. and Segars H.A. (1996). “Information systems effectiveness: The construct space and patterns of application”, *Information & Management*, Vol. 31, No. 4, pp. 177-191.

Gruat La Forme, F.A., Botta-Genoulaz, V., Champagne, J.P, and Millet, P.A. (2005). ”Advanced Planning and Scheduling system: An overview of gaps and potential sample solutions”, In Proceedings of the International Conference on Industrial Engineering and System Management IESM, May 16-19. Marrakech (Morocco).

Gruat La Forme., Botta-Genoulaz, V., and Champagne, J.P. (2009). ”The role of APS systems in supply chain management: A theoretical and industrial analysis", *International Journal of Logistics Systems and Management,* Vol. 5. No, 3-4, pp. 356-374.

Guimaraes. T., Igbaria, M., and Lu, M. (1992). "The determinants of DSS Success: An integrated model", *Decision Science,* Vol. 23, No. 2, pp. 409-431.

Gupta, V., Peter, E., Miller, T. and Blyden, K. (2002). "Implementing a distribution-network decision-support system at Pfizer/Warner-Lambert", *Interfaces*, Vol. 32, No. 4, pp. 28-45.

Günter, H.P. (2005), *Supply Chain Management and Advanced Planning Systems: A Tutorial*, Physica-Verlag HD.

Hahn, C., Duplaga, E. and Hartley, J. (2000). "Supply-chain synchronization: lessons from Hyundai Motor Company," *Interfaces*, Vol. 30, No. 4, pp. 32-45.

Hamilton, S. (2003). *Maximizing your ERP system a practical guide for managers*, The McGraw Hill Companies, Inc, New York.

Hammer, M. and Champy, J. (2003). *Reengineering the corporation: A Manifesto for Business Revolution,* Harper Business Essentials, United States of America.

Hellvik, O. (1984), *Forskningsmetoder i sociologi och stadsvetenskap*. Natur och kultur, Stockholm.

Helo, P. and Szekely, B. (2005). "Logistics Information systems: An analysis of Software Solutions for Supply chain co-ordination, *Industrial Management & Data Systems*, Vol. 105, No. 1, pp. 5-18.

Henning, G. (2009). "Production Scheduling in Process Industries: Current Trends, Emerging Challenges and Opportunities", In Brito Alves R. M, Oller Nascimento, C.A and Biscaia Jr, E. C . (ed.), *10th International Symposium on Process Engineering*, Elsevier, Amsterdam.

Hvolby, H.A, and Steger-Jensen, S.J. (2010). "Technical and industrial issues of Advanced Planning and Scheduling (APS) systems". *Computers in Industry*, Vol. 61, No. 9, pp. 845-851.

Häkkinen, L. and Hilmola, O.P. (2008). "Life after ERP implementation, long term development of user perceptions of system success in an after-sales environment", *Journal of Enterprise Information Management*, Vol. 21, No. 2, pp. 285-309.

Jacobs, R. F. and Weston, T. F.C. (2007). "Enterprise resource planning (ERP)-A brief history", *Journal of Operations Management*, Vol. 25, No. 2, pp. 357-663.

Jacobs, R., Whybark, C., Berry, W. and Vollmann, T. (2011). *Manufacturing planning and Control for Supply chain management*, McGraw-Hill.

Jonsson, P. (2000). "An empirical taxonomy of advanced manufacturing technology", *International Journal of Operations & Production Management*, Vol. 20, No. 19, pp. 1446-1474.

Jonsson, P. and Mattsson, S-A. (2003). "The implication of fit between planning environment and manufacturing planning and control methods", *International Journal of Operations and Production Management,* Vol. 23. No. 8, pp. 872-900.

Jonsson, P. and Mattsson, S-A. (2006). "A longitudinal study of material planning applications in manufacturing companies", *International Journal of Operations and Production Management*, Vol. 26, No. 9, pp. 971-995.

Jonsson, P, Kjellsdotter, L, and Rudberg, M. (2007). "Applying advanced planning systems for supply chain planning: Three case studies", *International Journal of Physical Distribution and Logistics Management,* Vol. 37, No. 10, pp. 816-834.

Jonsson, P. (2008). "Exploring problems related to the material planning user environment", International Journal of Production Economics, Vol. 113, No. 1, pp. 383-400.

Jonsson, P. and Mattsson, S-A. (2009). *Manufacturing Planning and Control*, McGraw-Hill Education, Berkshire.

Kaipia, R. and Holmström, J. (2007). "Selecting the right planning approach for a product", *Supply Chain Management: An International Journal,* Vol. 12, No. 1, pp. 2-13.

Karlsson, C. (2009). *Researching operations management*, Taylor & Francis, Inc., New York.

Kilger, C. (2008). Computer Assembly, In Stadtler, H and Kilger, C (ed.) *Supply Chain Management and Advanced Planning- Concepts, Models, Software and Case studies.* 4th ed. Springer, Berlin.

Klappich, D.C, Eschinger, C., Payne, T., Zimmerman, T. and McNeill, W. (2011). "Supply chain management market and vendor guide, 2011". Gartner, Inc.

Kostas, S., Metaziotis, J.E., Psarras and Kostas, A. (2003)."Production scheduling in ERP systems an AI-based approach to face the gap", *Business Process Management,* Vol. 9, No. 2, pp. 221-247.

Kreipl, S. and Dickersbach, J.D. (2008). “Scheduling coordination problems in supply chain planning”, *Annals of Operations Research*, Vol. 161, No. 1, pp. 103-123.

Kristianto, Y., Ajmal. M.M., and Helo, P. (2011). ”Advanced planning and scheduling with collaboration processes in agile supply and demand networks”, *Business process Management Journal*, Vol. 17. No. 1, pp. 107-126.

Kylén, J-A (1994). *Fråga rätt: vid enkäter, intervjuer, observationer och läsning*, Kylén Förlag AB, Stockholm.

Lapide, L. (2004). “Sales and operations planning Part 1: the process”, *The Journal of Business Forecasting*, Vol. 22 No. 4, pp. 21-28.

Lapide, L. (2005). “Sales and operations planning Part II: enabling technology”, *The Journal of Business Forecasting*, Vol. 24 No. 1, pp. 13-16.

Lin, C., and Pervan, G. (2003). “The practice of IS/IT benefits management in large Australian organizations”, *Information & Management*, Vol. 41, No. 1, pp. 13-24.

Lin, C.H., Hwang, S-L. and Wang, M-Y. (2007). “A reappraisal on advanced planning and scheduling systems”, *Industrial Management & Data Systems,* Vol. 107, No. 8, pp. 1212-1226.

Ling, R.C, and Goddard, W.E. (1988). *Orchestrating success – improve control of the business with Sale and Operation Planning*, John Wiley and Sons, US.

Little, D., Kenworthy, K., Jarvis, P. and Porter, K. (1995). “Scheduling across the supply chain”, *Logistics Information Management,* Vol. 8, No. 1, pp. 42-48.

Mabert, V.A. (2006). ”The early road to material requirement planning”. *Journal of Operations Management.* Vol. 25, No, 2, pp. 356-356.

Marcus, M.L., Axline, S, Petrie, D., and Tanis, C. (2000). ”Learning from adopters’ experiences with ERP: problems encountered and success achieved”, *Journal of Information Technology*, Vol. 15, No. 4, pp. 245-265.

Marcus, M.L and Tanis, C. (2000). The enterprise systems experiences – from adoption to success. In Zmusd, R.W (ed), *Framing the Domains of IT research: Glisping the Future Through the Past,* Pinnaflex Educational Resources, Cincinnti. OH.

McKay, K.N. and Wiers, V.C.S. (2003). “Integrated decision support for planning, scheduling, and dispatching tasks in a focus factory”, *Computers in Industry*, Vol 50, No. 1, pp. 5-14.

Merriam, S.B. (1998). *Case study research in education: a quantitative approach*. Jossey-Bass, San Francisco, CA.

Meredith, J.R. (1998). ”Building operations management theory through case and filed research”, *Journal of Operations Management*, Vol. 16, No. 4, pp. 439-452.

Michel, R. (2007). “Demand planning and collaboration solutions support S&OP”, *Manufacturing Business Technology,* Vol. 25, No, 3, pp. 18.

Miriani, R. and Lederer A.L. (1988). “An Instrument for Assessing Organizational Benefits of IS Projects”, *Decision Sciences*, Vol. 29, No. 5, pp. 803-838.

Money, A., Tromp, D., and Wegner, T. (1988). “The qualification of decision support benefits within the context of value analysis”, *MIS Quarterly*, Vol. 12, No. 2, pp. 223-236.

Moon, C., Kim, J.S, and Gen, M. (2004). “Advanced planning and scheduling based on precedence and resource constraints for e-plant chains”, *International Journal of Production Research*, Vol. 42, No. 15, pp. 2941-2955.

Muscatello, J., Small, M., Chen, I. (2003). “Implementing enterprise resource planning (ERP) systems in small and midsize manufacturing firms”, *International Journal of Operations and Production Management*. Vol. 23, No. 8, pp. 850-871.

Naden, J. (2000). “Have a successful APS implementation”, *IIE Solutions*, Vol. 32, No. 10, pp. 10.

Nuemann, K., Schwidth, C., and Trautmann, N. (2002). ”Advanced production scheduling for batch plants in process industries”. *OR Spectrum,* Vol. 24, No. 3, pp. 251-279.

Okoli, C, and Pawlowski, S.D. (2004). “The Delphi method as a research tool: an example, design considerations and applications”, *Information & Management*, Vol. 42, No. 6, pp. 15-29.

Olhager, J., Rudberg, M. and Wikner, J. (2001). “Long-term capacity management: Linking the perspective from manufacturing strategy and sales and operations planning”, *International Journal of Production Economics*, Vol. 69, No. 2, pp. 215-225.

Olhager, J. and Selldin, E. (2003). ”Enterprise resource planning survey of Swedish manufacturing firms”. *European Journal of Operational Research*, Vol. 146, No. 2., pp. 365-373.

Ohlager, J. and Selldin, E. (2007). “Manufacturing planning and control approaches: market alignment and performance”, *International Journal of Production Research*, Vol. 45, No. 6, pp. 1469-1484.

Olhager, J., Rudberg, M. and Wikner, J. (2001). “Long-term capacity management: Linking the perspective from manufacturing strategy and sales and operations planning”, *International Journal of Production Economics*, Vol. 69, No. 2, pp. 215-225.

Petroni, A. (2002). "Critical factors of MRP implementation in small and medium-sized firms", *International Journal of Operations & Production Management*, Vol. 22, No. 3, pp. 329-348.

Pibernik, R. (2005). “Advanced available-to-promise: Classification, selected methods and requirement for operations and inventory management”, *International Journal of Production Economics*, Vol. 93-94, pp. 239-252.

Pibernik, R. and Sucky, E. (2007). ”An approach in inter-domain master planning in supply chains”, *International Journal of Production Economics*, Vol. 108, No. 1-2, pp. 200-212.

Prescott, M.B and Conger, S.A. (1995). “Information technology innovations: a classification by IT locus of impact and research approach”, *ACM SIGMIS Database*, Vol. 26, No. 2, pp. 20-41

Proud, J.F. (1994). *Master Scheduling*, John Wiley and Sons, US.

Rajagopal, P. (2002). ”An innovation-diffusion view of implementation of enterprise resource planning (ERP) systems and development of a research model”. *Information & Management*, Vol. 40, No. 2, pp. 87-114.

Renkema, T., J.W. and Berghout, E.W. (1997). “Methodologies for information system investment evaluation at the proposal stage: a comparative review”, *Information & Software Technologies* , Vol. 39, No. 1. pp.1-13.

Reuter, B. (2005). Demand Planning of Styrene Plastic. In: Stadtler. H. and Kilger, C. (ed). S*upply chain Management and Advanced Planning- Concpets, Models, Software and Case Studies*. 4th ed. Berlin: Springer.

Rondeau, P.J, and Litterdal, L.A. (2001). ”Evolution of Manufacturing planning and control systems. From reorder point to enterprise resource planning”. *Production & Inventory Management Journal*, 2001-03-22. http://digitalcommons.butler.edu/cgi/viewcontent.cgi?article=1041&context=cob_papers (2011-06-01).

Rouse, M. (2009). Advanced planning and scheduling (APS), SearchManufacuringERP, http://searchmanufacturingerp.techtarget.com/definition/advanced-planning-and-scheduling-APS, (2012-04-12).

Rudberg. M., and Thulin, J. (2009). “Centralised supply chain master planning employing advanced planning systems”, *Production Planning and Contro*l, Vol. 20, No. 2, pp. 158-167.

Sakakibara, S., Flynn, B.B and Schroder, R.G. (1993). ”A framework and measurement instrument for just in time manufacturing”. *Production and Operations Management*. Vol. 2, No. 3, pp. 177-194.

Seddon, P.B. (1997). “A respecification and extension of the DeLone and McLean model of IS success”, *Information Systems Research*, Vol. 8, No. 3, 240-253.

Setia, P., Sambamurthy, V. and Closs, D. J. (2008). “Realizing business value of agile IT applications: antecedents in the supply chain networks”, *Information Technology and Management,* Vol. 9, No. 1, pp. 5-19.

Schroeder, R.G., Anderson, J.C., Tupy, S. E., and White E.W. (1981). “A study of MRP Benefits and Costs”, *Journal of Operations Management*, Vol. 2, No. 1, pp. 1-9.

Stadtler, H. and Kilger, C. (2005). *Supply Chain Management and Advanced Planning-Concepts, Models, Software and Case Studies*, 3rd ed., Springer, Berlin.

Stadtler, H. (2005). “Supply chain management and advanced planning- basic, overview and challenges”, *European Journal of Operational Research*, Vol. 163, No. 3, pp. 575-588.

Stoop, P.M. and Wiers C.S. (1996). “The complexity of scheduling in practice”, *International Journal of Operations and Production Management*, Vol. 16. No. 10, pp. 37-53.

Straube. F. (2006). *Trends and strategies in logistics – agenda for logistics management in 2010*, German Logistics Association, Bremen.

Tenhiälä, A. (2011). “Contingency theory of capacity planning: The link between process types and planning methods”, *Journal of Operations Management,* Vol. 20, No. 1-2, pp. 65-77.

Tavares Thomé, A.M, Scavarda, L.F, Fernandez, N.S., and Scavarda, A.J. (2012). “Sales and operations planning: A research synthesis”, *International Journal of Production Economics*, Vol. 138, No. 1, pp. 1-13.

van Eck, M. (2003). “Is logistics everything, a research on the use(fullness) of advanced planning and scheduling systems”, BMI paper, University of Amsterdam, Amsterdam.

Vieria, G.E., and Favaretto F. (2006). “A new & practical heuristic for Master production scheduling”, *International Journal of Production Research*, Vol. 44, No. 18/19, pp. 3607-3625.

Voss , C., Tsikriktsis, N., and Frohlich, M. (2002). “Case research in operation management”, *International Journal of Operations and Production Management*, Vol. 22, No. 2, pp. 195-219.

Wagner. M. and Meyer, H. (2005). Food and Beverages. In: Stadtler. H. amd Kilger, C. (ed). S*upply chain Management and Advanced Planning- Concpets, Models, Software and Case Studies*. 4th ed. Berlin: Springer.

Wallace, T.F. (2004). *Sales and operations planning, the how to handbook*, 2nd ed., T.F. Wallace & Company, Cincinnati, Ohio.

Wallace, T.F. (2006). "Forecasting and Sales & Operations Planning: Synergy in Action", *The Journal of Business Forecasting*, Vol. 25 No.1, pp. 6-36.

Weske, M. (2007). *Business Process Management: Concepts, Languages, Architectures*, Springer-Verlag Berlin Heidelberg.

Wiers V.C.S. (2002). "A case study on the integration of APS and ERP in a steel processing plant", *Production Planning & Control*, Vol. 13, No. 6, pp. 552-560.

Wiers, V.C.S. (2009). "The relationship between shop floor autonomy and APS implementation success: evidence from two cases", *Production Planning and Control*, Vol. 20, No. 7, pp. 576-585.

Yin, R.K. (2002). *Case Study Research design and methods*, Sage Publications, Inc., Thousand Oaks, CA.

Yu, C-S., (2005). "Causes influencing the effectiveness of the post-implementation ERP system", *Industrial Management and Data Systems,* Vol. 105, No. 1., pp. 115-132.

Zhu, K. and Kraemer, K.L. (2005). "Post-adoption variations in usage and value of e-business by organizations: cross-country evidence from retail industry", *Information Systems Research*, Vol. 16, No. 1, pp. 61-84.

Zoryk-Schalla A., Fransoo J. and de Kok T.G (2004). "Modelling the planning process in advanced planning systems", *Information and Management*, Vol. 42, No. 1, pp. 75-87.

Zmud, R.W and Randolph, C.B. (1990). "Information technology implementation research: a technological diffusion approach", *Management Science*, Vol. 36, No, 2, pp. 123-137.