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When should advanced planning and scheduling systems be used in sales and operations planning?

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Abstract

Purpose. We sought to explore how the context affects successful use of APS systems in S&OP processes, and how individual, technological, and organizational (ITO) dimensions affect this procedure.
Design/methodology/approach. This is a qualitative case study of two APS system-supported S&OP processes. The work aims to generate propositions concerning the relationships among the use of APS system, the context, ITO dimensions, and fulfillment of S&OP aims.
Findings. Use of APS systems was especially appropriate in support of S&OP processes in complex planning environments and when S&OP aims were ambitious. ITO dimensions were important influences on successful APS system use in most contexts. APS systems were not considered appropriate when having S&OP processes with ambitious aims and low individual and organisational maturities. Use of APS systems was also inappropriate when the extent of technological maturity was minimal. S&OP processes with ambitious aims, operating within a complex planning environment, are difficult if not impossible to implement without the support of APS systems.
Practical implications. Our suggestions on when APS systems should be used in different S&OP environments will be useful to companies implementing or about to implement APS systems.
Originality/value. APS systems offer great potential if they are effectively used to support S&OP. The understanding of when to use APS systems to support S&OP is however unexplored.
Keywords. Advanced planning and scheduling (APS) system, sales and operations planning (S&OP), S&OP aims, supply chain, complexity, case, design science.
Paper type. Research paper.

1 Introduction

Sales and operations planning (S&OP) is a tactical planning process performed to balance demand and supply and to ensure that the plans and performance of all business functions are aligned to support the strategic business plan (Ling and Goddard, 1988; Wallace, 2006). Traditionally, the S&OP process has sought to integrate organizational functions and to create consensus focused on one set of goals and plans (Feng et al., 2008). However, today, many organizational functions are located in different countries and companies are involved in activities through upstream and downstream linkages, which impose new co-ordination challenges on the S&OP process (Stadtler and Kilger, 2005; Affonso et al., 2008). In addition the S&OP process of tomorrow will most likely feature not only co-ordination of plans, but also revision of those plans to optimize profit (Grimson and Pyke, 2007, Viswanathan, 2010).

How should managers act to implement tomorrow's S&OP processes? Previous S&OP studies have emphasized the importance of individual and organizational factors (e.g., formal S&OP team and planning meetings) if S&OP is to be successful (Lapide, 2005; Grimson and Pyke, 2007). Although such issues are important, we argue that another critical factor is the use of advanced planning and scheduling (APS) systems. An APS system is an information system (IS) that uses advanced mathematical algorithms or logic to support planning tasks (APICS, 2010). APS systems embrace functionalities including integral planning, constraint-based planning, optimization, and what-if simulation (Van Eck, 2003; Stadtler and Kilger, 2005). These functionalities can serve as important supports of S&OP processes (e.g., Bower, 2006; Wallace, 2006; Michael, 2007, Viswanathan, 2010).

Few APS systems have been implemented in S&OP processes and few, either in practice or academia, understand when to use APS systems to support such processes (e.g., Jonsson et al., 2007; Rudberg and Thulin, 2008; Viswanathan, 2010). It has been argued that APS systems are 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, Rudberg and Thulin, 2008). However, no previous study has explored the type of complexity requiring APS system support. We do not know how the context of different S&OP aims and complexities within planning environment affects the ability of an APS system to support an S&OP process.

Effective use of an APS system places demands on those who implement and use that system (Zoryk-Schalla et al., 2004). In addition, the organization must be committed to the approach and the technological infrastructure must be of high quality. Ivert and Jonsson (2011) identified the importance of knowledge and understanding. Rudberg and Thulin (2008) emphasized the role played by a central planning function whereas Wiers (2002) stressed that APS systems must be integrated into existing IT infrastructure if they are to function properly. No study has yet analyzed how these various factors affect the utility of APS systems in S&OP processes. One manner in which to group factors important in successful implementation and use of IS is to define individual, technological, and organizational (ITO) dimensions (Zmud and Randolph, 1990). Similar ideas have been used in analysis of complex planning and scheduling situations (Berglund and Karltun, 2007; Lin et al., 2007; Ivert and Jonsson, 2011). ITO should thus be relevant when factors influencing APS system usage are considered, and affect the ability of such a system to support effective S&OP functioning.

The aim of this paper is to explore how to successfully use APS systems in the S&OP process. We define a successful use of an APS system to be a situation in which an APS system supports an S&OP process in fulfillment of the S&OP aim. Two research questions are posed: How does context impact successful use of APS system in the S&OP process? How do the ITO dimensions affect successful APS system use in this context?

Our research fills some knowledge gaps on how APS systems support S&OP aims, and constitute a deep case study on APS system usage. Most research on APS systems has focused on design of the mathematical model (e.g., Wiers, 2002; Lin et al., 2007); few studies have described how APS systems are used in practice (Wiers, 2009). Consequently, more case studies of APS system usage are required to develop an understanding of APS potential and prerequisites (Graut La Forme et al., 2005; Setia et al., 2008). Our analysis is a qualitative case study of two APS system-supported S&OP processes. First, we review the literature and identify key concepts. We next explain our case study methodology and the structure of our analysis. We then describe the cases, conduct within- and cross-case analysis, and move to a discussion and conclusions.

2 Theory

Herein, we describe the S&OP process, the aim and complexity thereof, define an APS system, and describe how APS functionalities can support S&OP activities. ITO variables that affect successful use of APS systems are also identified.

2.1 The S&OP process; the aim and the complexity

The S&OP process typically features five principal activities (e.g., Ling and Goddard, 1988; Lapide, 2004; Wallace, 2006; Grimson and Pyke, 2007; Jonsson and Mattsson, 2009):

- Activity 1: A sales/marketing department forecasts demand over an upcoming planning period.
- Activity 2: The sales/marketing department prepares a preliminary plan of future sales and delivery volumes. Inventory size and the extent of order backlog are considered.
- Activity 3: The production department and those responsible for procurement of start-up materials for manufacturing prepare a preliminary production plan.
- Activity 4: Managers of the company's business functions perform a reconciliation meeting. The aim is to make any adjustments to the plans so that a balance is achieved while meeting financial requirements.
- Activity 5: Any unsolved issues are communicated to top management. When agreement is obtained, a management group meeting authorizes the final plans.

The overall aim of such activities (the S&OP aim) has traditionally been to create a platform balancing demand and supply, creating consensus, and generating accurate delivery and production plans (Goddard and Ling, 1988; Proud, 1994; Feng et al., 2008). Recently, the S&OP process has become more ambitious. S&OP is to generate plans that optimize profit (Grimson and Pyke, 2007); to identify and analyze future possible scenarios with the aim of exploring and supporting mid- and long-term decisions (Gallucci, 2008); and to break outside of intra-organizational boundaries by integrating the activities of external customers and suppliers (Hahn et al., 2000).

Such aims reflect the more complex planning environments in which S&OP processes are supposed to operate.

The notion of complexity has been broadly discussed; no clear definition has emerged (Bozarth et al., 2009). The complexity of any S&OP process may be *supply chain complexity* as defined by Bozarth et al. (2009, p. 79*): "the level of detail complexity and dynamic complexity exhibited by products, processes and relationships that make up a supply chain."* According to Bozarth et al. (2009), detail complexity refers to the number of components or parts that make up a system, whereas dynamic complexity is defined as the unpredictability of the systemic response to a given set of inputs, driven in part by the interconnectedness of the many parts that make up the system. In the S&OP context, detail complexity is associated with the number of entities affecting the S&OP process whereas dynamic complexity deals with restrictions and uncertainties in materials supply, demand, and the production system.

2.2 APS systems supporting the S&OP process

The Association for Operations Management (APICS) (2010) defines APS systems as:

"[. . .] 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 systems are either add-ons or integral components of enterprise resource planning (ERP) systems, which in turn create a support mechanism for planning and decision-making at the strategic, tactical, and operational levels (Lin et al., 2007). One way to classify APS systems is to categorize modules in terms of the length of the planning horizon on the one hand, and the supply chain process on the other (Stadtler and Kilger, 2005). The focus here is on the functionalities within the modules supporting the S&OP process (Table 1).

To support activities 1 and 2 of the S&OP process, an APS system usually features "sophisticated" methods but also allows manual adjustments to be made to create a collaborative process. A common feature of an APS system is that it is possible to integrate input from various departments/companies into the forecasting process, and to aggregate/disaggregate forecasts using a pyramid forecasting approach (Kreipl and Dickersbach, 2008). To enable users to plan promotions, to modify the shape of the life-cycle curve, and deciding on the point in time at which new products will be launched, some APS systems enable the user to view the consequences of different scenarios (Stadtler and Kilger, 2005).

To support activities 3 to 5 of the S&OP process, APS systems feature integral planning, constraint-based planning, optimization, and what-if simulation. Integral planning allows the entire chain to be considered simultaneously. Several production sites, sub-contractors, and distributors may be included in modeling and a multi-site

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production plan may be generated (Stadtler and Kilger, 2005). Constraint-based planning means that constraints, for example materials availability, capacity, cost, and distribution requirements, are included in the APS model. Most APS systems take a two-or-three pass approach toward evaluation of constraints (van Eck, 2003). The first pass typically identifies a feasible plan, thus a plan that tries to meet all customer due date requests without violating any hard constraint. In the second pass, all constraints are incorporated in an attempt to improve the plan; this is termed optimization. A graphical interface enables the planner to compare various alternatives and choose the most acceptable solution. The ability to easily generate and compare different plans is termed what-if simulation (ibid).

APS systems are usually considered to be especially well-suited to environments wherein simpler planning methods cannot adequately address complex trade-offs between competing priorities (de Kok and Graves, 2003; Gen et al., 2008, Rudberg and Thulin, 2008). Setia et al (2008, p. 11) further argue that "*APS systems in a changing business environment is most appropriate for complex tasks with large number of products categories, frequent changing 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 these tools"*.

Table 1: Summary of APS functionalities supporting the various activities of the S&OP process (based on Ivert and Jonsson, 2010).

S&OP activity	**Aim of the activity**	**APS functionalities**
1: The sales/marketing department produces a forecast of expected demand in a coming planning period.	Creation of a consensus forecast.	• Statistical forecasting methods. • Integral planning (integration of data from different sales companies/sales managers and aggregate/disaggregate forecasts) • What-if simulation.
2: The sales/marketing department prepares a preliminary plan detailing the volume that the company wishes to sell and deliver.	Creation of a preliminary delivery plan.	
3: The production department and those responsible for procurement of manufacturing materials prepare preliminary production plans.	Creation of a preliminary production plan.	• Integral planning (integration of production sites, distribution sites, etc. into the model and use of a graphical interface to visualize the supply chain). • Constraint-based planning. • Optimization. • What-if simulation.
4: Representatives from various business units meet to adjust the plans to achieve a balance meeting financial requirements.	Adjustment of delivery and production plans.	
5: Top management meets to discuss the plans and necessary decisions are made. Plans are settled.	Settling of delivery and production plans.	

2.3 The individual, technological, and organizational (ITO) dimensions

This section defines the individual, technological, and organizational (ITO) dimensions, which is used to group factors important if use of an APS system is to be successful.

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The individual dimension (I) is defined as *"the importance of aspects that are strictly individual and at the same time considered important to perform a task or a change"* (Berglund and Karltun, 2007, p. 162). IS research has emphasized a number of factors that are important if IS is to succeed; these include system education, experience, and knowledge (e.g., Cox and Clark, 1984; Guimaraes et al., 1992; Petroni, 2002). Lin et al. (2007) found that the principal reason why plans are sometimes little trusted is that the individual dimension is neglected in APS system implementation. According to this study, the implementation team assumed that the IT skill level of the workforce was higher than was in fact the case and the complex and uncertain environment surrounding the planning process made it necessary to incorporate human knowledge of context-sensitive information. Ivert and Jonsson (2011) held that it was critical that those involved in the APS system implementation had a knowledge and understanding of model design, could identify the most important data and parameters, and knew how to interpret outputs.

The technological dimension (T) represents the technological prerequisites needed to make the APS system function efficiently. System integration, the quality of basic data, and model design are all of importance in this context (Stadtler and Kilger, 2005). In most instances, the ERP system will function as a type of "leading system" from which an APS system extract data. An APS system will then make calculations and feed the results back to the ERP system (Stadtler and Kilger, 2005). To successfully use an APS system, it is important that such a system is well-integrated with existing IT infrastructure (Wiers, 2002; Günter, 2005; Viswanathan, 2010). Any change to either system must be incorporated into the other system to avoid inconsistencies, and data must be meticulously maintained and updated (Jonsson et al., 2007; Lin et al., 2007). Zoryk-Schalla et al. (2004) examined the modelling process of APS systems and remarked that modelling is a key factor in successful use of such systems. It is sometimes forgotten that the APS model can become quite large, and computational time may be long (Günter, 2005). Correct modeling is, in reality, difficult. Lin et al. (2007) found that no sure method was available whereby APS system modeling could be verified. These authors found that even IT specialists did not fully grasp APS system dynamics. Indeed, the lack of transparency and traceability of a planning system is problematic as this creates distrust of the results (Wiers and Van Der Schaaf, 1997; Kreipl and Dickersbach, 2008).

The organizational dimension (O) represents the individual in an aggregated sense and comprises how activities are organized and structured (Berglund and Karltun, 2007). Business processes and IS need to work together to enhance business performance (Clause and Simchi-Levi; 2005). In this context, the maturity of the S&OP process is an important organizational factor. Based on the S&OP integration framework put forward by Grimson and Pyke (2007), we divide S&OP maturity into S&OP structure, the holding of planning meetings, and collaboration. The S&OP structure covers the existence of and executive-level participation in a formal S&OP team. Jonsson et al. (2007) found an obvious link between planning organization, the APS system, and planning effects. Rudberg and Thulin (2008) further conclude that a prerequisite for successful operation of an APS system is that the organization in question is efficient – in their case through restructuring the supply chain and the centralization of the planning function. Meetings and collaboration refer to holding of planning meetings dealing with activities 1 to 4 of the S&OP process; the final executive S&OP meeting dealing with activity 5; and collaboration between sales, operations, and other departments. Lin et al. (2007) identify several potential O-dimensional pitfalls in APS system implementation. Different organizations had different needs and priorities, and the APS system tended to be relied upon to solve cross-organizational issues.

3 Research methodology

In this article we address a managerial problem, i.e. the problem of fulfilling S&OP aims by proposing the use of APS systems. Integration of the S&OP process with use of an APS system has attracted little research attention, and no theoretical concept of how APS systems might support the S&OP process has been advanced. Thus, our research could be characterized as early theory-building in nature. Handfield and Melnyk (1998) opine that exploratory and descriptive approaches are appropriate for research topics of this type. One exploratory approach that can be used to explore and explain emerging operations management practice is *design science* (Holmström et al., 2010). This focuses on discovery and problem-solving; a design scientist is not content with merely explaining and predicting phenomena, but also assumes an active role in shaping the phenomena of interest (Holmström et al., 2009). Design science is an appropriate model for the present study, because our intention is not only to understand how APS systems can be used in an S&OP process but also to define when this is in fact appropriate (a matter of problem-solving). In the field of management, design science methodology uses design propositions; these are the means needed to reach desired ends (Holmström et al., 2010). Denyer et al. (2008) present the 'CIMO' logic, which can be used for developing design propositions. The CIMO logic is constructed as follows: in a problematic Context (C), Intervention types (I) are used to invoke generative Mechanisms (M), to deliver Outcomes (O). Design propositions thus contain information on what to do, when, to produce what effect, and explain why this happens. We apply CIMO in a qualitative case study context; we frame a problem and generate rudimentary design propositions. The case study approach is appropriate; we need to investigate APS system-supported S&OP processes in detail to understand how APS systems may support planning tasks, and we explore how APS system usage could be facilitated. A qualitative case study can be used to explore and better understand emerging phenomena, particularly when human factors are critical (Barratt et al, 2011). Literature from different domains of IS and Operations Management was used to help shape the initial research design (Barratt et al, 2011) and to analyze and develop design propositions in greater depth and detail. We do not conduct empirical testing and we do not develop a formal theory. Rather, our academic contribution is generation of CIMO-related propositions (Holmström et al, 2010).

3.1 Research site and unit of analysis

Our research site is a chemical company that manufactures, markets, sells, and distributes surfactants. The 1,100 employees work in America, Asia, and Europe. The European division was selected because of the rather challenging planning situation and as APS systems have been implemented to cope with the situation. The division installed two different APS systems under different circumstances, the first in 2001 and the second in 2007. Also, the European division enthusiastically shared data and employees participated in interviews.

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The unit of analysis is the two APS system-supported S&OP processes. Both in 2001 and in 2007, the planning situations were complex, featuring both dynamic and detail complexity. Although the S&OP aim in both years was quite ambitious, that in 2001 was much less clear than that in 2007. APS system usage and ITO dimensions differed greatly between 2001 and 2007; the first APS system installation was regarded as unsuccessful whereas the second was, in general, successful.

3.2 Interview protocol

We had an informal dialogue with the supply chain manager prior to data collection. Thus, we were able to develop an explicit protocol [as proposed by Eisenhardt (1989)] of site visits. The protocol outlined subjects to be covered at interview, the questions to be asked, and the specific data required. The aim of interviews was to understand how the APS systems supported S&OP processes. In spite of that, we wanted to understand how the context and ITO dimensions affected the use of APS systems in supporting S&OP aims. The protocol also included direct observations of monthly planning meetings, the daily work of the formal S&OP team, and that of site schedulers, at two of the three production sites of the European division.

3.3 Informant selection and data collection

Data were collected between 2007 and 2010 via 30 semi-structured interviews 60 to 90 minutes in duration with those from all functional areas involved in the S&OP process and/or affected by the process, as well as those involved in the APS system implementations. We sought to identify those who had been involved in both APS system implementations and APS system-supported S&OP processes. Many interviewees had worked at the company from before 2001 and their information on events of that year was thus considered trustworthy. The formal S&OP team helped us identify such persons. Some people were interviewed twice. Table 2 is the list of interviewees.

We conducted most of the interviews at the headquarter and the production sites, but some follow-up interviews were conducted by telephone. Notes were taken during interviews and some interviews were recorded. Interviews were transcribed and copies sent to interviewees, to enhance validity (Voss et al., 2002). Each response was triangulated with the answers of others and follow-up interviews were used to clarify differences. We also examined archival data including blueprints of APS system-supported S&OP processes (showing individual responsibilities, work flows, and the goals of sub-processes); PowerPoint presentations on company APS system implementations and usage; intranet data on company history; and annual reports. We observed monthly planning meetings and the daily work of the formal S&OP team and site schedulers. Also, one author participated in an educational session on the 2007 APS system modules to get to know the system.

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Table 2: Data collection methods.

Data collection methods	**2001**	**2007**
Interviewees	CEO, operations manager, supply chain manager, supply planner, project members involved in APS implementation (2), production manager, site scheduler, business manager	CEO, operations manager, supply chain manager, supply planners (2), APS vendor, production managers (2), site scheduler (2), business managers (3), contract manufacturer representatives (2), member of the APS implementation team
Observations		Two production sites, demand planning meeting, supply planning meeting, S&OP planning meeting, educational session on APS modules
Archival sources	Blueprint of APS system implementation, intranet presentation, PowerPoint presentation, case story written by the APS system vendor	PowerPoint presentations

Note: (2) and (3) indicate that two and three different persons were interviewed.

3.4 Data analysis

We summarized our field notes and recorded interviews in the form of detailed case stories. Key interviewees were asked to review these data to enhance validity (Yin, 1991). Within each case story we mapped the sequence of activities that constituted the S&OP processes and the roles played by various people. We then moved to *within-case analysis* to understand how APS systems were used to support the S&OP process and to document the personal experiences of those using APS functionalities. A proposal for how it all was coherent was identified as a result of the within case analysis. The CIMO logic (Denyer et al., 2008) is as follow: the complex planning environment of the S&OP process made it difficult to accomplish the more ambitious S&OP aim (C). The use of an APS system (I) supported the S&OP process in fulfillment of the S&OP aim (O). The ITO dimension was the mechanism (M) influencing the use of the APS system in that context. Within each case, we sought to understand how a fit between context and an APS system affected the fulfillment of S&OP aims and how APS system use in combination with (M) affected this process. We then moved to *cross-case analysis* where the combined impact of (I) and (M) on (O) was compared in a more-or-less similar context (C). The design of our within- and cross-case analyses is outlined in Figure 1.

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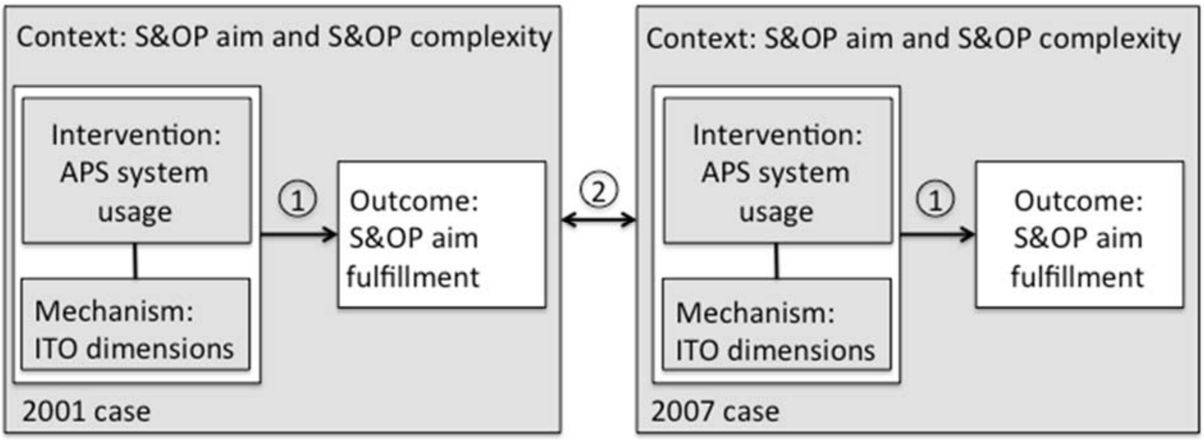

Figure 1. Case analyses: (1) Within-case analyses of CIMO relationships. (2) Cross-case analysis.

4 Case description

This section describes the two APS system-supported S&OP processes. The case context is first given, followed by details of how APS functionalities were used to support S&OP processes. Last, the experience of using APS systems is described.

4.1 Case context

The company had been formed by merger of two other companies prior to the first APS system implementation in 2001; the merged companies managed operations differently. It was thus sought to unify procedures. This required establishment of an S&OP process, integration of several production sites and sales departments, and effective control of financial resources. There were four production sites, in part interdependent, restrictions on critical capacity, about 15 sub-contractors, 100 suppliers, 1,000 customers in different market segments, over 800 products, and 1,050 stock keeping units (SKU). Earlier, every production site planned individually and inefficiencies were common. Sales managers (around 40) called production sites each time they received an order because they lacked information on inventory and capacity. Production sites lacked reliable sales forecast figures. *"We had to get a global perspective on planning in the organization as it was impossible to handle customers locally. Besides, the production sites were very much dependent on each other as products are produced in several steps, often involving many production sites*" (CEO). A central planning organization was introduced to establish and run an S&OP process. Shortly thereafter, an APS system was introduced to support establishment of that process. *"The central planning organisation needed a tool that could create an integrated production plan and more accurate forecast data."* (person involved in the APS system implementation in 2001). However, the APS system project team and others in the organization did not agree on what the S&OP process should accomplish. The CEO had a vision of a supply chain focus; capacity could be changed within production sites. Europe was divided into different sales regions and it was considered appropriate to decide which production site could cost-efficiently produce which products and serve which markets (geographical optimization). However, the planning people thought that the most important aim was creation of a platform allowing cross-functional cooperation, delivery of consensus on a single set of goals, and generation of feasible delivery and production plans. The planning organization thought it was important to identify and analyze possible future scenarios, using the S&OP process to support mid- and long-term decisions.

Many problems developed and, after a few years, it was clear that the system needed to be extensively upgraded or replaced*. "Although the organisation gladly received the APS system, it soon became a creak as the system delivered strange output as a consequence of incorrect model design"* (person involved in the APS system implementation in 2001). The company chose to replace the APS system in 2007. The planning environment was similar to that of 2001, except that one production site had been shut down and the numbers of products and SKUs had been reduced slightly. The aim of the S&OP process was to integrate production sites and sales departments, generate feasible delivery and production plans, and identify and analyze possible future scenarios. The previous aim of geographical optimization became less important as the new strategy was to maximize capacity utilization at a single production site and use other sites for the rest of the products.

4.2 The use of APS systems in the S&OP processes

In 2001, the S&OP process consisted of two sub-processes led by a central planning organization; these were a demand planning process to identify customer needs and a supply planning process to meet these needs. The S&OP process was conducted monthly with a planning horizon of 18 months. The APS system supported sales managers in creating forecasts by suggesting forecasts based on historical data. Thereafter, sales managers were able to manually adjust the forecasts. Business managers responsible for several sales managers were supposed to examine the forecast figures before the central planning organization aggregated these figures into a delivery plan. In reality, the business managers rarely controlled forecast figures and sales managers rarely updated the figures. The central planning organization collected capacity figures from production managers and added these figures to delivery plans; these were now converted into optimal production plans, taking account of required materials, stocks, production times, transportation times, and cost. A lot of master data had to be manually typed as integration between the APS and ERP systems was defective. The output of a production plan was when, where (at what production site and which reactors), and what products (volumes) would be produced at the lowest possible cost. The delivery and production plans were sent as Excel sheets to production sites, manufacturing contract representatives, and some suppliers. An executive S&OP meeting was held to discuss the appropriateness of the production plan with representatives of different departments. However, in reality, this forum *"became a forum were everything was discussed in the absence of other forums and the things of importance was neglected"* (person involved in the APS system implementation in 2001). No measure was used to evaluate S&OP performance, and the plans were not well accepted at production sites or by contract manufacturing representatives. *"Many sales managers continued calling production sites and some production managers still conducted their own forecast"* (Production Manager).

In 2007, monthly demand and supply planning meetings were introduced. In terms of demand planning, business managers and the central planning organization got together before a delivery plan was created. Thus, a delivery plan was based not only on historical data but also on meeting outcomes. During the meeting, issues such as forecast accuracy, possible increases in sales, and specific customer profitability, were discussed. *"The communication with the central planning organization works very well. Still they do not always listen to the indications from us and trust the system too much*" (Business Manager). The agreed delivery plan was, thereafter, automatically converted into a preliminary production plan, taking master data and capacity figures into account. The preliminary plan was generated using a two-pass approach. In addition, what-if simulations were run to analyze different scenarios. *"One problem with what-if simulation is that it takes a few hours if we use all data in the model. This makes it impossible to generate scenarios during meetings."* (Supply planner). The preliminary production plans were used as the basis for the supply planning meeting attended by representatives of the central planning organization, operations managers, production managers, and manufacturing representatives. They discussed whether it was possible to meet demand; capacity; bottlenecks; and inventories. Based on these discussions, and actual stock balances, a final production plan was created. This suggested what volumes to produce where, and when, at the highest contribution margin. Every second month, an executive S&OP meeting was held involving the CEO, operations managers, and representatives of central planning organizations. The focus was on accessibility issues and identification of risks. The S&OP process was evaluated by measuring forecast and delivery accuracy. The ERP system transferred data to the APS system on a daily basis and the APS system could be accessed by all parties concerned. "*I would not be able to manage my job without the use of the APS system. I use the APS system almost everyday to see how the customer demand looks like and to plan for the purchasing process of internal and external contract manufacturers"* (Contract manufacturing representative). *"We use the production plan to produce our weekly and daily production plan"* (Site scheduler).

4.3 Experiences of APS system supported S&OP processes

There were many problems with the 2001 APS system. *"Being the second player, it is easy to see that everything was done in the wrong order. The model was designed before data was collected and parameters known. There was no feeling for the organization as a whole and everyone wanted to leave one's mark on the implementation"* (Supply Chain Manager). The personnel at production sites did not update capacity figures frequently and forecast figures were not accurate, resulting in low quality of basic data. *"An important factor to successfully use our APS system is the input. If not the input is of a good quality, then the results is not of a good quality"* (Operations Manager).*"The APS system requires an incredible carefulness by its users, carelessness by one person and the whole system is collapsing"* (member of the APS system implementation team of 2001). The APS system was not properly integrated with the ERP system. *"Every month we had to report capacity figures to the central planning organization. It was not possible for us to make changes directly in the ERP system as the APS system and ERP system lacked integration"* (Production Manager). The project team lacked knowledge of production constraints, leading to unrealistic assumptions and development of a complex model. *"It is important to understand which bottlenecks that are existing in reality. The central planning organization was looking at the filling rate at the reactors but the bottleneck was to manage to empty the reactors as fast as possible"* (Production Manager). Besides, many thought that the system was not user-friendly and demanded much time and effort. *"It is difficult to find time and motivation to learn yet a new system"*

(Sales Manager). Still, many were of the opinion that the APS system supported a comprehensive view that was absent before implementation. *"The APS system was a tool for making the S&OP process working"* (Operations Manager). The production sites started to communicate, and did not view each other as rivals. *"We got better in forecasting and production planning meaning better capacity management, reduction of staffing and cost. In particular, the war in the corridors was minimized"* (member of the APS system implementation team of 2001).

The second implementation of an APS system was smoother. The project team knew more and the APS model was more realistic. *"In 2001, the planning object in the production plan was product which was wrong as customers requested SKU. This was changed in the 2007's model*" (Supply planner). The quality of meetings improved and the general impression was that "beliefs" were replaced with facts. Those involved in the process stressed that they had been given a tool that allowed them to better understand what would happen in future; they could be one step ahead. Even though the sentiments were positive, it was felt that the entire potential of the APS system was not used. *"It would be interesting to integrate contract manufacturers in the model to support capacity decisions, but it is difficult to receive planning data from contract manufacturers"* (Supply Chain Manager*). "Next step is to create detailed production plans with less imposition of hands*" (Production Manager). The opinion among many was that data management could be improved. "*Many times it is difficult to make the production sites understand the value of updating the parameters in the ERP system"* (CEO). *"I think we need to understand that it is impossible to get a 100 percent forecast accuracy. In fact, I believe that it is difficult to become better in forecasting than we are now"* (Business Manager).

5. Case analysis

Case analysis was conducted as shown in Figure 1. The 2001 and 2007 cases were structured using CIMO logic (Table 3) followed by within-case analysis of the two cases. Finally, five empirical observations were generated, by comparing and contrasting APS system usage, ITO dimensions, and S&OP aim fulfillment, in 2001 and 2007.

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Table 3: A CIMO-dictated breakdown of APS-supported S&OP processes (2001 & 2007)

	Context	**Intervention**	**Mechanisms**	**Outcome**
APS-supported S&OP processes in 2001	Detail complexity 4 production sites; 15 contract manufacturers; 1,000 customers; >800 products; >1,050 SKU. Dynamic complexity Uncertainties in terms of raw material supply; low forecast accuracy; capacity restrictions.	Activities 1 and 2 Statistical forecast methods. Activities 3 to 5 Immediate creation of an integrated and optimized model.	I-variables *Knowledge and understanding*: No experience of APS systems; did not know what to expect or how to use such systems. T-variables *Integration between APS and ERP systems*: The APS model was updated twice a month. Much manual work was required. *Quality of input data:* Master data were of low quality. *Modeling:* A complex model was used; many assumptions were wrong. O-variables *S&OP structure*: Formal S&OP team. *Meeting and collaboration*: S&OP meeting.	Aim one (fulfilled to some extent): Creation of cross-functional co-operation; establishment of consensus on goals; generation of balanced and feasible delivery and production plans. Aim two (fulfilled): Integration of production sites. Aim three (not fulfilled): Identification and analysis of future scenarios supporting mid- and long-term decisions. Aim four (not fulfilled): Geographical optimization.
APS-supported S&OP processes in 2007	Detail complexity 3 production sites; 15 contract manufacturers; 1,000 customers; 800 products; 1,050 SKU. Dynamic complexity Uncertainties in terms of raw material supply; low forecast accuracy; capacity restrictions.	Activities 1 and 2 Statistical forecasting methods. Activities 3 to 5 A two-pass approach was used to create an integrated and optimized plan. Also, what-if simulation was used.	I-variables *Knowledge and understanding*: Had experience of APS functionalities; knew what to expect and how to make use of functionalities. T-variables *Integration between APS and ERP systems*: The APS model was automatically updated daily with master data. *Quality of input data*: The quality of sales and capacity figures was acceptable. *Modeling:* The model was realistic. O-variables *S&OP structure*: Formal S&OP team; executive participation. *Meeting and collaboration*: Executive S&OP meeting, demand planning meeting, supply planning meeting.	Aim one (fulfilled): Creation of cross-functional co-operation; establishment of consensus on goals; generation of balanced and feasible delivery and production plans.. Aim two (fulfilled): Integration of production sites. Aim three (fulfilled to some extent): Identification and analysis of future scenarios supporting mid- and long-term decisions.

5.1 Within-case analysis

The 2001 case

The aim of the S&OP process in 2001 was rather ambitious as a consequence of the complex planning situation and high ambition by the management. In terms of planning, the interdependence of the four production sites and the unstructured nature of forecasting and planning created a need for cross-functional cooperation

and goal consensus, and generation of feasible plans (Aim 1) with integration of entities involved in the same process (Aim 2).
The high level of demand uncertainty created a need for identification and analysis of future scenarios to support mid- and long-term decisions (Aim 3). Management envisaged development of a supply chain focus allowing capacity to be changed in both internal and external production sites; geographical optimization was desired (Aim 4). An APS system was implemented to support the S&OP process of fulfilling these aims. Examination of the APS functionalities used toward achievement of the desired aims reveals a fit between the use of forecast methods and some elements of Aim 1; forecasting methods are structured and seek to minimize forecast errors; this aids delivery and production. A fit is evident between Aim 2 and integral planning; such planning makes it possible to include several entities. However, no fit between the functionalities used and Aim 3 is evident. In 2001, no function was used to identify and analyze future scenarios. Aim 4 fits with optimization.

Based on the argumentation above there should be good prerequisites for fulfilling parts of Aims 1, 2 and 4, but not Aim 3. In practice, Aim 1 was part-fulfilled, Aim 2 fulfilled, and Aims 3 and 4 unfulfilled. The APS system became the truth rather than a tool supporting the S&OP process. The APS system-generated forecast was more-or-less accepted to create a delivery plan, which was automatically converted into a production plan without further analysis. Although optimized and integrated production plans were generated, the logic of creation went missing, creating distrust. Consequently, consideration of feasibility under Aim 1 was not fulfilled. In addition, most of those involved did not embrace the strategy of geographical optimization. Thus, even though the APS system generated "optimal" plans, these were not really used. The fact that production plans integrating the four production sites were provided, and that these were based on forecasts from many sales managers, did, however, make those involved feel that they were part of a process. This created a comprehensive view, and reduced infighting. Thus, that part of Aim 1 targeting co-operation and consensus was fulfilled to some extent; Aim 2 was fulfilled.

The lack of knowledge of how to use APS functionalities is probably an important explanation for why the APS system was used with little influence of human experiences. The organization thought, or at least wished, that implementation of an APS system guaranteed fulfilment of S&OP aims. Besides, the APS system implementation began before an established S&OP process with defined aims had been formed; no meetings, collaboration, or measures of progress had been defined and no formal S&OP team with executive participation existed. Inadequacy of modelling, poor integration of ERP systems and the APS system, and low data quality, further explain why the plans generated were simply ignored.

<u>The 2007 case</u>
In 2007, the planning environment was characterized by geographically dispersed production sites and sales departments, restrictions on capacity, and critical demand uncertainties. The aim of the S&OP process was to create a platform for cross-functional co-operation, establishment of goal consensus, and generation of feasibility plans (Aim 1); integration of production sites (Aim 2); and identification and analysis of future scenarios to support mid- and long-term decisions (Aim 3). The APS functionalities used corresponded well with S&OP aims. Integral planning,

statistic forecast methods, and constraint based planning should support the generation of feasible plans. Integral planning also makes it possible to integrate all production sites. What-if simulation aids in identifying and analysing future scenarios, and can be used to support mid-term decisions. In other words, it would be expected that fulfilment of S&OP aims would be aided using the APS functionalities available in 2007. Experiences among the users show that Aims 1 and 2 were fulfilled and Aim 3 partly fulfilled.

APS functionalities were used to support those involved. Thus, sales managers complemented the APS generated forecast with their judgement, and business managers and the central planning office became involved in creation of a delivery plan. Preliminary production plans were set using a two-pass approach. What-if simulation was used by central planning to identify and analyze future scenarios. Such scenarios were not used, however, to support mid- and long-term decision-making. Thus, Aim 2 two was only part-fulfilled. Preliminary plans were run past experienced production managers, representatives of contract manufacturers, and the operations manager, before a final plan was created. As those involved in the S&OP process had input into the delivery and production plans, confidence was created. Consequently, the plans were considered feasible, thus fulfilling a part of Aim 1. Those involved experienced "communication", "understanding", and "belonging to the same process", indicating that the Aim 1 component of co-operation and consensus, and Aim 2, were fulfilled.

The actors had a lot of experiences of APS systems and a good notion of how APS functionalities should be used in S&OP processes. The introduction of planning meetings created collaboration including manual adjustments and sharing of experience in generation of delivery and production plans. The APS model reflected reality. However, some data updating problems were evident and scenario generation was slow, which is probably why what-if simulations were not used to support mid- and long-term decision-making during meetings, rather becoming a duty of the planning organisation.

5.2 Cross-case analysis

The complexity of the planning environment was more-or-less identical in 2001 and 2007, and the aims of the S&OP processes very similar. Fulfillment of S&OP aims improved over time, because APS functionalities were better used and appropriately mediated by ITO dimensions. S&OP aim fulfillment in 2001 and 2007 is compared:

- Feasible plans was not made in 2001 but were in 2007. Use of statistical forecast methods, and constraint-based and integral planning, were valuable. These approaches were successfully used in 2007, because the I (knowledge and understanding of APS systems, APS functionalities and the S&OP process); T (correct modelling, system integration, data quality); and O (S&OP process with planning meetings) dimensions were incorporated.
- The aim of creating a platform facilitating cross-functional co-operation and consensus on goals was not fully fulfilled in 2001 but was in 2007. Installation of an APS system with statistical forecast methodology, optimization and integral planning, was helpful. The success of the 2007 APS system may be explained by development of the O-dimension (a mature S&OP process

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featuring planning meetings and establishment of a formal S&OP team with cross-functional involvement).

- The aim of integrating production sites was fulfilled in both 2001 and 2007; integral planning was critical. This aim was heavily supported by the O-dimension (a formal S&OP team with cross-functional involvement).
- The aims of identifying and analyzing possible future scenarios and supporting mid- and long-term decision-making were not fulfilled in 2001 but partly fulfilled in 2007. In 2007, the use of what-if simulation in combination with the O-dimension (an S&OP process with planning meetings and a formal S&OP team with executive and cross-functional involvement) was important, but the what-if approach was too slow.
- The aim of plan optimization was paramount, especially in 2001, but cannot be considered fulfilled. In order to fulfil the aim, the functionality optimisation was required. Immature O (formal S&OP team with executive involvement) and imperfect T (correct modelling, system integration, and data quality) dimensions are possible reasons for the not successful APS system usage.

6 Discussion

The discussion is divided into two parts. The first generates propositions concerning relationships among CIMO logic derived from case analysis and the literature. The second explores managerial implications and suggests when it is appropriate to use APS systems in S&OP processes.

6.1 CIMO propositions

<u>The impact of the context on successful APS system use in S&OP processes</u>

The case analysis showed that a complex environment demands APS functionalities. In APS system related literature it is the complexity in form of complex trade-offs between competing priorities that is particularly emphasised (de Kok and Graves, 2003; Gen et al., 2008, Rudberg and Thulin, 2008). Although the S&OP processes studied have inevitable constraints (due dates, capacities, transportation costs, set-up costs, and limited resources), detail and dynamic complexity were the principal problems requiring APS functionality. To generate balanced and feasible delivery plans, it is probably adequate to use statistical forecast methods and constraint-based planning; these functionalities are features of most planning systems. However, in our case study, the detail complexity (many interdependent sales departments and production sites) demanded integrated planning to yield feasible plans. Dynamic complexity (unpredictable and fluctuating demand) required scenario analysis, in which what-if simulation was helpful. The value of using the what-if approach to deal with uncertainties has been identified by, for example, Van Eck (2003). Not only did the detail and dynamic complexity place a need of APS functionalities, so did also the ambition by management and the resulting S&OP aims. The need of APS functionalities in order to fulfil highly ambitious aims has been identified in previous studies as well (Grimson and Pyke, 2007).

How well does APS functionality support the S&OP process? Optimization of APS functionality, integrated planning, and what-if simulation, afforded good progress. Although the APS system implementation failed once, the use of APS systems made people understand that they belonged to the same process (Aim 2) and provided some information on what to expect in future (Aim 3). What could be discussed is if an APS system is needed to fulfil the traditional and less ambitious aims of creating co-operation and goal consensus, and feasible plans (Aim 1)? The cases studied here are rather complex meaning that APS systems are needed to fulfil these traditional aims. However, we found that less ambitious aims do not involve as many APS functionalities as do highly ambitious aims and that the maturity of the S&OP process was of greater importance than use of APS systems to fulfil less ambitious aims. As previously found (Setia et al. 2008; Ivert and Jonsson, 2011), it was also found that successful APS system usage was demanding of the organization and employees.

Based on the discussion we propose that: "*APS system usage is appropriate to support an S&OP process. This is especially the case when the aims are ambitious and the planning environment complex."*

Impact of the I-dimension on successful APS system use in S&OP processes

The case analysis supports contentions in the IS literature to the effect that addressing the I-dimension is critical to successfully use the system (Cox and Clark, 1984; Guimaraes et al., 1992; Petroni, 2002). Lack of knowledge and understanding of the APS system and the S&OP process contributes to development of over-confidence in an APS system. In one case, implementation of an APS system was seen as a tool for establishment of an S&OP process. In practice, this meant that the S&OP process was more-or-less forgotten and the APS system supplanted human planning; planning was now automated. However, an APS system cannot generate optimal plans without human input; an APS system has no experience of the behavior of customers, suppliers, or production systems; this information is critical in planning. Lack of knowledge of constraint-based planning and optimization also caused the central planning team to generate a supposedly optimal production plan as a first step, without first creating an infinite plan as a baseline. This made it difficult to evaluate plan feasibility and to explain why production was distributed in the manner outlined. Retracing the results of planning systems is difficult (Wiers and Van Der Schaaf, 1997; Lin et al., 2007; Kreipl and Dickersbach, 2008). Our case study identified this problem and we found that the problem is exacerbated when the I-dimension receives inadequate attention.

Our case findings further support the notion that the I-dimension is particularly critical when the planning environment is characterized by detail and dynamic complexity. Individual knowledge and understanding is essential when feasible plans are to be formed in such environments. This conclusion is supported by Lin et al. (2007) who found that it was impossible to implement an automatic and optimized planning process in a complex and uncertain environment, because human input is necessary. It may be possible to operate an automatic planning process if the planning situation is stable, thus characterized by minimal detail and dynamic uncertainty. However, even in such cases, it is important to not ignore the I-dimension. We found that people trust plans if they have been involved in formulation.

We propose: *"Knowledge and understanding of APS systems, APS functionalities, and the S&OP process allow successful APS system usage in S&OP processes. This is especially important in complex environments".*

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The impact of the T-dimension on successful APS system use in S&OP processes

In agreement with previous findings, our case data confirm that model design affects how well a system handles complexity and fulfils the aim of the S&OP process (Zoryk-Scalla, 2004). We also found that system integration and access to accurate data were critical (Wiers, 2002; Günter, 2005; Viswanathan, 2010; Lin et al., 2007; Jonsson et al., 2007). For example, in 2001, much manual input was needed whenever the APS system was used, frustrating users. Accurate APS modelling, system integration, and high-quality data are of great importance in generation of delivery and production plans that actually work. These issues are important even when the "only" aim of an S&OP process is to generate feasible plans. The importance of the T-dimensions, even when APS systems find only "simple use", has been emphasized in the literature (Wiers, 2002; Günter, 2005; Stadter and Kilger; 2005; Lin et al., 2007). However, if the aim is to obtain optimal plans, these factors are even more important. Such plans require more-or-less perfect modelling and integration, and a very high level of data quality (Wiers and Van Der Schaaf, 1997; Lin et al., 2007; Kreipl and Dickersbach, 2008).

We found that the low speed of plan generation using the APS system constrained what-if analysis activities. This may be attributable to limited APS functionality, as also identified in earlier studies (Grimson and Pyke, 2007; Lin et al, 2007). We consider the complexity of our cases to be high and therefore difficult to model. This, consequently, also lengthen computational time (Stadtler and Kilger, 2005; Jonsson et al, 2007). However, such complexity is not unique; many other firms are more complex. This raises questions whether existing APS systems lack the functionality required to support S&OP processes in highly complex environments where management has ambitious aims? How much of what type of complexity is it actually possible to model while still planning efficiently and feasibly?

We, accordingly, propose: *"Model design, integration of ERP and APS systems, and high data quality are essential for successful APS system usage in S&OP processes. This is particularly important in terms of the generation of high-quality plans, especially if these plans are to be optimal."*

The impact of the O-dimension on successful use of the APS system

In line with previous results, our case analysis found that both a mature S&OP process and advanced IT are required to ensure success (Clause and Simchi-Levi, 2005) and to fulfil highly ambitious aims (Grimson and Pyke, 2007). To identify and analyze future scenarios in support of mid- and long-term decision-making, it is important that the S&OP process and the APS system work in tandem. Pre-meetings, with cross-functional and executive involvement, are necessary to evaluate APS system-generated plans and to confirm feasibility. The same was true when optimal plans were to be fulfilled. If such plans were to be used, then the giving of a top management mandate to the S&OP team, and continued executive involvement, were of the greatest importance.

We identified the importance of the O-dimension even when less ambitious aims are to be fulfilled with the support of APS systems. In one instance, the extent of focus on the O-dimension was low. The planning organization did not have a mandate, or didn't manage, to focus the organization on the S&OP process. The S&OP process became important to only the planning organisation. The absence of planning meetings with cross-functional involvement of accountable people weakened commitment to APS system-generated plans; the plans were neither trusted nor used. Although the case analysis shows that the O-dimension is very important for successful use of APS systems, no matter how lofty the aim, we also found that use of APS systems is less important when aims are not ambitious. Also, previous studies have clearly revealed the importance of the O-dimension in the S&OP process, whether IS is or is not used (e.g., Lapide, 2005). Companies that have low expectations of their S&OP processes normally do not use APS systems (Viswanathan, 2010). We found that a high degree of focus on an APS system may weaken the attention that must be paid to the O-dimensions with the result that not even non-ambitious S&OP aims are fulfilled. Lin et al. (2007) came to a similar conclusion; the tendency was to rely on APS systems to resolve inter-organizational issues and the suggestion was that business process re-engineering should precede APS system implementation. However, we do not deal with S&OP processes that do not involve APS systems, and it is clear that maturity of the S&OP process, thus development of a formal S&OP team and the holding of planning meetings, is critically important in the successful use of APS systems, no matter what the aims or extent of complexity.

We accordingly propose: *"an S&OP process with planning meetings and a formal S&OP team with executive and cross-functional involvement are essential to ensure successful APS system usage in S&OP processes."*

5.2 APS system appropriateness in S&OP processes

Here, we explore when it is appropriate to use APS systems to support S&OP processes. The relevant variables are the ambitiousness of S&OP aims, the complexity of the planning environment, and the ITO dimensions:

- When the aims of an S&OP process are not ambitious the need is to create a platform balancing demand and supply, obtaining goal consensus, and generating feasible plans. If the level of ambition is high, optimal plans must be created, possible scenarios identified and analyzed, and/or planning extended beyond intra-organisational boundaries.
- Low-level complexity of the planning environment corresponds to a situation characterized by a single production site, very few customers and suppliers, predictable market demand, stable lead times, and reliable production processes. High complexity includes detail complexity (several interdependent components) and/or dynamic complexity (unpredictable market demand, uncertain supplier lead times, and unreliable production processes).
- Low-level individual (I) and organisational (O) maturity correspond to a system characterized by placement of low-level emphasis on both the I and O-dimensions. No S&OP planning meetings take place; there is little or no collaboration between sales and operations departments; and no formal S&OP function. Knowledge and understanding of the S&OP process, and the functions and utility of an APS system, are low. High-level I and O maturity are present when the S&OP process is mature, featuring planning meetings, a

formal S&OP team with cross-functional and executive participation, and collaboration in development of delivery and production plans.

- Low-level technological (T) maturity is present when the APS system is not well integrated with existing IT infrastructure, when APS models poorly represent reality, and when master data are of low quality. High-level T maturity features an APS system well-integrated into existing IT infrastructure, corresponding to reality and fed accurate data.

Sixteen combinations of context and generative mechanisms may be identified; each represents one S&OP scenario. Table 4 and the text below summarize the appropriateness of each combination. It is possible to describe the features of all combinations although not all cells in the Table have been "populated" with empirical data. Our case analysis allowed us to understand the generating mechanisms in context. Thus, we present our theoretical deductions with reference to the literature.

Table 4: Appropriate use of APS systems in S&OP processes.

<table>
<tr><td rowspan="6">Generative mechanisms: Individual (I), Organizational (O), and Technological (T) dimensions</td><td rowspan="2"></td><td colspan="4">Context: Aim (A) and Complexity (C)</td></tr>
<tr><td>A: Low
C: Low</td><td>A: Low
C: High</td><td>A: High
C: Low</td><td>A: High
C: High</td></tr>
<tr><td>IO: Low
T: Low</td><td>1. Not appropriate because T-dimension is immature</td><td colspan="3">2-4. Not appropriate because the I-, O-, and T-dimensions are immature.</td></tr>
<tr><td>IO: Low
T: High</td><td>5. Possible but support is absent or marginal</td><td colspan="3">6-8. Not appropriate because the I- and O-dimensions are immature</td></tr>
<tr><td>IO: High
T: Low</td><td colspan="4">9-12. Not appropriate because the T-dimension is immature</td></tr>
<tr><td>IO: High
T: High</td><td>13. Possible but only marginal support is available</td><td colspan="2">14-15. High-level, high-quality support</td><td>16. Good support</td></tr>
</table>

Note: White cells represent situations wherein APS system support is appropriate. Light grey cells represent situations wherein APS system support is possible but support may be lacking. Dark grey cells represent situations wherein APS system support is not appropriate.

APS systems offer no support to an S&OP process in combinations 2–4 and 6–8: Mature I and O dimensions are prerequisites of successful APS system usage. Our case studies clearly emphasized the importance of empowered personnel and a well-established planning process if aims of all types are to be fulfilled in a complex environment. Combination 6 is the only one of the seven combinations wherein an APS system could give useful support, because the T dimension is high and this is combined with low S&OP aims and high-level planning complexity. However, as the I and O dimensions are low, a rather automatic process is favored; no particular focus can be placed on either the process or human involvement.

APS systems offer no support to S&OP process combinations 1 and 9–12: A mature T dimension is a prerequisite for successful APS system usage, no matter what the levels of aims and complexity. It is therefore difficult, if not impossible, for an APS system to support S&OP aim fulfilment when the T dimension is immature. Our case studies revealed that an immature T-dimension rendered it impossible to create feasible plans, which in turn made it difficult to create goal consensus, make optimal plans, or support mid- and long-term decision-making.

APS system use is possible but such a system offers no or marginal support to the S&OP process in combination 5: This combination is a typical IT project; all dimensions except the T dimension are low. A company with such an S&OP process may generate high-quality plans using an APS system, but as the I and O dimensions are immature (low), it will be difficult to successfully support the S&OP process. As the S&OP aims and the level of planning environment complexity are low, any need for APS functionality is also relatively low. A recommendation for such organizations would be to focus more on I and O dimensions and consider use of a less-advanced planning system.

APS system use is possible but only marginally supports the S&OP process of combination 13: The high maturity levels of the I, O, and T dimensions make it likely that APS functionality will effectively support the S&OP process. However, as the S&OP aims and planning environment complexity are low, the need for APS functionality is not very high. The context of our case studies was quite different, but other studies have found that companies characterized by low complexity and low ambitiousness may find that implementation of APS systems is undesirable; additional effort is required to manage such tools (Setia et al., 2008). As the full potential of an APS system is not used in the environment under consideration, we believe that less-advanced planning systems could be considered.

APS system support is appropriate and important in S&OP process combination 14: The high level of planning environment complexity poses a need for many APS functionalities. The level of detail complexity, for example, renders it impossible to generate feasible plans without the use of advanced functionalities. The high maturity levels of the I, O, and T dimensions create a likelihood that existing complexity will be effectively accommodated, and an APS system will support fulfillment of the aim of an S&OP process.

APS system support is appropriate and important in S&OP process combination 15: In this combination, the I, T, and O dimensions support the ambitious S&OP aim. The chance that an APS system-supported S&OP process will succeed is thus high. This process probably requires a less complex model as the planning environment complexity is low (Günter, 2005; Jonsson et al., 2007). This is in contrast to the S&OP process combination 14, which probably requires a more complex model.

APS system support is appropriate and required in S&OP process combination 16: In combination 16, the aim is ambitious, the environment complex, and the ITO dimensions mature. It is difficult to fulfill S&OP aims without the support of an APS system, but the necessary prerequisites exist. Grimson and Pyke (2007) and Viswanathan (2010) consider that IT tools (e.g., integrated S&OP optimization software, a full interface with the ERP platform, good accounting and forecasting, and the availability of real-time solutions) will most likely be required to attain a mature S&OP process featuring profit optimization for the entire company. Our case studies show that the APS system per se lacks some functionalities allowing the system to deal with planning environment complexity, indicating that not even a very advanced system may be adequate to control a very complex environment.

6 Conclusions

This study takes a pragmatic approach toward research. The work describes and explains how APS systems can be used in S&OP processes, but also identifies when it is appropriate to use APS systems in various S&OP scenarios. In addition, this study shows how a form of structured logic (CIMO) can be used in case study research to structure the analysis and to make findings accessible. The work fills some knowledge gaps. It explains how APS functionalities can support S&OP processes and how individual (I), technological (T), and organisational (O) dimensions mediate successful APS system usage. A comparative analysis of two APS system implementations supporting S&OP processes revealed that the ambitiousness of the S&OP aim, and the type and extent of complexity within the planning environment, directly influenced the effective use of APS functionalities. Also, ITO dimensions affected the ability of an APS system to support the S&OP process. The following propositions are advanced:

- APS system usage is appropriate to support an S&OP process in fulfilment of its aim, especially when those aims are ambitious and when planning environments are complex in terms of dynamics and detail.
- Knowledge and understanding of APS functionalities and S&OP processes are separate issues that influence successful APS usage in S&OP processes, especially within complex planning environments.
- Accurate APS modelling, effective system integration, and a high level of data quality are technological issues that influence successful APS system usage in S&OP environments. These features are of particular concern when high-quality or optimal plans are sought.
- A mature S&OP process, featuring planning meetings and formation of an S&OP team with cross-functional powers and including executive involvement, are important organizational issues affecting successful APS system usage in S&OP processes.

In terms of managerial implications, the suggestions made indicate when it is appropriate to use APS systems in the context of different aims and degrees of complexity, and at varying levels of maturity of the ITO dimension. APS system-supported S&OP processes are not considered appropriate when the aims are not ambitious and the levels of individual and organizational maturity low. Nor is it considered appropriate to offer APS system support to processes characterized by low-level technological maturity. S&OP processes with ambitious aims, operating in an environment of high planning complexity, are considered difficult if not impossible to handle without the support of APS systems.

Only one company was included in the empirical study; this means that the findings may be valid only in this context. However, the case company is representative of quite a "wide" context. The company has installed two APS systems, on different occasions, and under different circumstances. We studied the different aims of S&OP, in situations characterised by high levels of detail and major dynamic complexity, and in circumstances where different levels of ITO maturity were in play.

Therefore, the work is applicable to the concerns of other similar companies. The logic underlying the mechanism and the context of APS system-supported S&OP processes encourages theoretical application of our findings in other situations. Although the study explores several aspects of S&OP and APS systems, more detailed work is needed to further develop our understanding of the unique relationships that exist between the aims of S&OP, institutional complexity, ITO dimensions, and successful use of APS functionalities. Some questions that need further research are: How high must the level of complexity be before an organization can benefit from an APS system implementation? Is there a limit on the level of complexity with which an organization can cope even if an APS system is introduced? Do functionalities other than the five identified APS functionalities exist that support the S&OP process, and if so, how? Another obvious object of future research is empirical testing of the propositions generated. This would be a useful first step on a deductively oriented research path seeking to develop a more general framework for work in this area, and for the drawing of more general conclusions.

References

Affonso, R., Marcotte, F. and Grabot, B. (2008), "Sales and operations planning: the supply chain pillar," *Production Planning and Control*, Vol. 19, No. 2, pp. 132-141.

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

Barratt, M., Choi, T.Y. and Li, M. (2011). "Qualitative case studies in operations management: Trends, research outcomes and future research implications", *Journal of Operations Management,* Vol. 29, pp. 329-342.

Berglund, M. and Karltun, J. (2007). "Human, technological and organizational aspects influencing the production scheduling process", *International Journal of Production Economics*, Vol. 110, No. 1-2, pp. 160-174.

Bower, P. (2006), "How the S&OP process creates value in the supply chain," *Journal of Business Forecasting*, Vol. 25, No. 2, pp. 20-29.

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.

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.

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.

Denyer, D., Tranfield, D., van Aken, J.E., 2008. "Developing design propositions through research synthesis". *Organization Studies,* Vol. 29, No. 3, pp. 393–413.

Full reference to this article: Ivert, K.L. and Jonsson P. (2014), "When should advanced planning and scheduling systems be used in sales and operations planning?", International Journal of Operations and Production Management, Vol. 34, No. 10, pp.1338-1362. DOI: http://dx.doi.org/10.1108/IJOPM-03-2011-0088

Eisenhardt, K.M. (1989). "Building theories from case study research", *Academy of Management Review*, Vol. 14, No. 4, pp. 532-550.

Feng, Y., D'Amour, 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 recourse," *International Journal of Production Economics*, Vol. 15, No. 1, pp. 189-209.

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

Gen, M., Cheng, R. and Lin, L. (2008) *Network Models and Optimization Multiobjective Genetic Algorithm Approach*, Springer, London.

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.

Graut La Forme, F.A., Botta-Genoulaz, V. and Campagne. J.P (2005), "Advanced Planning and Scheduling System: An overview of gaps and potential sample solutions", International Conference of Industrial Engineering and System Management, 16-19 May, Marrakech, Available at http://hal.archives-ouvertes.fr/docs/00/39/51/07/PDF/2005_IESM_-_FAG_VBG_JPC_PAM.pdf, (downloaded 24 September 2012).

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

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.

Handfield, R.B., Melnyk, S.A., (1998). "The scientific theory-building process: a primer using the case of TQM". *Journal of Operations Management* Vol. 16, No. 4, pp. 321-33.

Holmström, J., Ketokivi, M., and Hameri, A., (2009). "Bridging practice and theory: a design science approach", *Decision Sciences,* Vol. 40, No. 1, pp. 65-87

Holmström, J., Främling, K., and Ala-Risku, T. (2010), "The uses of tracking in operation management: Synthesis of a research program", *International Journal of Production Economics*, Vol. 126, pp. 267-275.

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

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

Jonsson, P. and Mattsson, S.A. (2009), *Manufacturing Planning and Control*, McGraw-Hill Education, Berkshire, 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. 27, No. 19, pp. 816-834.

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.

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

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

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 business with sales and operation planning,* John Wiley and Sons, New York.

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

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

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

Rudberg, M. and Thulin, J. (2008). "Centralized supply chain master planning employing advanced planning systems," *Production Planning and Control*. Vol. 20, No. 2, pp. 158-167.

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.

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

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

Viswanathan, N. (2010), *Sales and operations planning: Strategies for managing complexity within global supply chains*, Aberdeen Group Publications, Boston (MA).

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. 105-219.

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

Wiers. V.C.S. and Van Der Schaaf, W.T. (1997). "A framework for decision support in production scheduling tasks, *Production Planning and Control,* Vol. 8, No. 6, pp. 533-544.

Wiers V.C.S. (2002). "A case study on the integration of APS and ERP in a steel processing plant," *Production Planning and 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. (1991). *Case Study Research. Design and Methods*, 7th revised ed., Sage Publications, Newbury Park (CA).

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.