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APS for tactical planning in a steel processing company

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Abstract

Purpose – The main purpose is to describe and analyse the impact that the implementation of an advanced planning system (APS) has on the tactical planning level at a steel processing company. This is done in terms of analysing changes in the tactical planning processes, effects on company performance, and how the APS is used in a practical planning context.

Design/methodology/approach – This research is based on a longitudinal case study in the process industry. The case company, a high-end steel producer, has been studied during several years using a combination of data sources: literature reviews, interviews, archival records, and also attendance at meetings, workshops, seminars, etc.

Findings – This case study points to the fact that implementing an APS and reorganizing the planning department and the planning processes are mutually dependent. The positive effects at the tactical planning level (in terms of service levels, fast and reliable order promises, more accurate forecasts) could not have been realized without the APS. On the other hand, the APS could not have been effectively utilized without the organizational change.

Research limitations/implications – The results presented in this paper are based on a single case study, but in the context of our literature review and other case studies the findings are still valid and an important step towards better understanding of the practical use of APSs.

Practical implications – The process descriptions, lessons learnt, and issues encountered in case studies like this should be helpful to practitioners on their way to implement APSs, and companies seeking new ways to improve their planning can use this research to investigate the use of an APS.

Originality/value – Studies on the practical use of standard APS software are still scarce. As such this paper provides enhanced knowledge and understanding on the use of APSs in industry settings.

Keywords Business planning, Process planning, Demand management

Paper type Case study

Introduction

Increasing pressure on supply chain performance has for many years encouraged companies to take action to improve their overall competitiveness. This pressure stems from increasing customer demands on high-quality products at a low price plus higher expectations on accurate deliveries and customer service. Advanced planning systems (APSs) have been put forward as a tool to meet the ever increasing demands

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on effectiveness that put new pressures on swift and efficient planning and control of the supply chain (David *et al.*, 2006). APS as a commercial off-the-shelf (COTS) decision-support system (DSS) for production and distribution planning is still a fairly new and unexplored tool, even though advanced planning and scheduling techniques have been around for more than two decades (McKay and Wiers, 2003). During the last decade, companies that sell enterprise resource planning (ERP) systems have started developing and implementing standard APS modules, which by the aid of sophisticated mathematical algorithms and optimization functionality, support planning of complex systems such as supply chains (Stadtler and Kilger, 2008; Lin *et al.*, 2007; Wu *et al.*, 2000).

The planning and scheduling task is important for most companies, and planners do need decision support in these areas. A lot of the scientific work on production planning and scheduling in process industries focus on designing dedicated algorithms for a specific situation, or a specific part of the process. However, in practice, companies tend to implement commercially available standard software packages (Wiers, 2002), wherefore there is a need for further analysis of the practical use of these standard systems. Yet, APSs as such, their effects on planning and planning processes, and implementation aspects are largely ignored by academia (Wiers, 2009; Lin *et al.*, 2007; McKay and Wiers, 2003). Wiers (2009) furthermore states that the majority of APS implementations are in the production scheduling domain (operational planning), whereas Gruat La Forme *et al.* (2009) in their small survey find support for that APSs are most common in tactical planning environments. However, there are few accounts on documented studies describing how APSs support specific planning processes (Kjellsdotter and Jonsson, 2010), and especially on the practical aspects of APS implementations in the manufacturing industry (Gruat La Forme *et al.*, 2009). This study focuses on the implementation and use of a standard APS for tactical planning in the process industry through a longitudinal case study.

The main purpose of this paper is to describe and analyse the impact that the implementation of three APS modules has had on the case company's tactical planning. As such, the research questions in this study are the following:

RQ1. How have the tactical planning processes changed due to the APS implementation project?

RQ2. What effects have the APS implementation project had on the company's performance?

RQ3. What are the advantages and disadvantages with the case company's way of using the system?

Previous research on the use of APSs is scarce, and case study papers discussing actual APS implementations are crucial to gain real insight for actual implementations (McKay and Black, 2007). Our case company, SSAB Plate, is the largest Nordic manufacturer of heavy steel plates and has implemented standard APS software for tactical planning. The results are promising, but there is still room for improvements in many areas. For SSAB Plate, capacity constrained planning is of uttermost importance, and three APS modules from i2 Technologies have been implemented: demand planner (DP), supply chain planner (SCP), and demand fulfilment (DF). It has been argued that the promises of APS suppliers are not realized (Fontanella, 2001; McKay and Wiers, 2003), but both the systems and the users have evolved since these studies were carried out. Through this longitudinal case study we hope to increase the knowledge and understanding of the practical use of a COTS APS, and also how APSs can enhance the planning effectiveness for tactical planning in process industries.

The subsequent sections present the methodology and the literature review with a special focus on APSs and supply chain master planning, where after the main part of the paper is devoted to the case study. The case is then analysed and managerial implications are provided before the paper is concluded.

1. Methodology

From a methodological perspective, this research is based on a literature review and a case study. The literature review is founded in the fields of supply chain management, operations management, and APSs. The case study is based on data gathered through semi-structured interviews and onsite visits at the plant, as well as on data from the company's information system database and internal documentation. The authors also had access to primary data in terms of company reports describing processes, performance data, etc. Typically, interviews were carried out with DPs, master planners, and members of the implementation team. One of the authors also interviewed system users and participated in user training sessions to get a firm understanding of both the system itself and how it is perceived by the users. Several people at the case company and also representatives from the consultant company were interviewed, with the responses compared to ensure that correct data had been gathered. Drafts were sent to the interviewees after the interviews to minimize the risk of misinterpretations. Validation of the data was also done on continuing meetings and by having managers at the company read and comment on the research several times during the process. The researchers have also done their best to make sure that the chain of evidence is kept, for instance, by ensuring the possibility to trace the results backwards with the aid of the case study protocols.

The case analysis is a comparison between "before" and "after" the implementation of the APS suite at the case company. This approach was selected in order to capture the results of the APS implementation as well as the changes in working methods and organization, which were a part of the total implementation project. The "before" situation covers the planning processes and methods that were used before the APS modules were implemented, and since the researchers did not have direct access to the company during this period, data are mainly based on information from interviews and project documentation. The "after" situation covers the planning processes and methods that have been used after the APS modules were implemented. The researchers have followed the case company, its APS use, and its continual improvement of the system from late 2006 until the beginning of 2010, but the bulk of data gathering was conducted during 2007 and 2008. During this period, the planning organisation, the planning processes, and the system settings have been fairly intact facilitating the possibility of providing a representative picture of the company's use of the APS modules in question for this study.

Owing to the fact that there are few documented cases on the use of standard APSs in tactical planning, this research is of an exploratory nature, which also explains the use of a single case study. Yin (2009) lists five rationales for conducting single case studies, of which two are present in this research: the case is considered "typical" for its industry segment and the study is "longitudinal", revealing the effects of the APS implementation.

2. Advanced planning systems

2.1 The APS structure

During the last decade not only APS niche vendors, but also ERP vendors have more aggressively started developing and implementing advanced planning modules, with the aim to support complex planning problems. Nowadays, APS modules are often a part of larger software suites and work as add-ons to existing ERP systems (Stadtler and Kilger, 2008; Lütke Entrup, 2005; Dickersbach, 2004). An APS does not replace the ERP; it extracts data from the ERP database, makes its calculations and sends the resulting plans back for distribution and execution. Often, solver engines based on linear programming and mixed integer programming are used to unravel the large amount of data. To cut computing time, heuristics are used built on operations research knowledge (De Kok and Graves, 2003). APSs, consequently, tries to automate and computerize the planning through simulation and optimization. Still the decision making is done by planners who have insight in the particular supply chain, know about the system constraints and also have a feeling about the feasibility of the plans that are created.

Considering the complex environment that most companies have to cope with, most decision-support systems advocate a hierarchical distribution of the decision-making processes, where the next upper level coordinates each lower level (Stadtler and Kilger, 2008). Strategic decisions (long horizon and periods) cannot be based on the same level of detail in the information as is the case for operational decisions (short horizon and periods). Hence, decisions made at a high hierarchical level are normally based on aggregated information (in terms of product families, factories, etc.) and aggregated time periods. Thereafter, these high-level decisions form the context for the decision-making processes at lower-level decision centres, where decisions are disaggregated into more detailed information and time periods, also the considered horizon is made shorter (Wiers, 2002). Decisions are thus exploded through the hierarchical structure until the lowest level is reached and detailed decisions are executed. One way to classify standard APS is by categorizing different modules depending on the length of the planning horizon (and thus the level of aggregation) on the one hand, and the supply chain process that the module supports on the other. Meyr *et al.* (2005) categorize the most common standard APS modules according to these two dimensions, which is also a module segmentation that is commonly used among software vendors. The tactical planning, which is the focus of this study, is at the centrefold of many companies' planning processes, and also the planning level where many APS-specific features and functionalities (optimization, simulation, capable-to-promise (CTP), etc.) are possible to use on a regular basis. In this study, the tactical planning includes demand planning, multi-site master planning, and DF (for further information on the module segmentation, please refer to Meyr *et al.*, 2005).

2.2 Tactical planning in an APS

Tactical, or mid-term, planning concerns rough quantities of material supplied, workforce requirements, production quantities and seasonal stock and use of distribution channels. To be able to optimize the mid-term supply chain model, production, inventory, and distribution must be regarded concurrently. Tactical planning uses data on products and material in aggregated product groups. Inputs are demand data and network constraints in terms of a model that defines capacity and dependencies between different processes. The tactical planning results in a common supply chain plan regarding production, distribution, inventory, procurement, and materials requirements (Rohde and Wagner, 2005). This tactical supply chain plan is thereafter on the one hand exploded down the product structure to be used in the detailed planning and scheduling, and on the other hand used as basis for DF and order promises. In the context of this study, tactical planning is considered to include demand planning, master planning, and DF, which are described in the following.

The "demand planning" module in an APS does not differ much from good demand planning modules in traditional ERP. The main purpose is of course to improve decisions affecting demand accuracy and the calculation of buffers to reach a predefined service level (Stadtler and Kilger, 2008). Demand planning includes sophisticated statistical forecasting methods, possibilities to aggregate and disaggregate forecast in terms of product groups, geographical regions and time periods in a multi-user environment, and also to establish a consensus-based forecast within the company. The multi-site master planning module with its fairly long planning horizon in most instances needs forecast information to perform the planning task.

In traditional ERP, "master planning" is often done by infinite MRPII systems (Steger-Jensen and Svensson, 2004), or by simple calculations using spreadsheets without considering capacity limitations (Fleishmann and Meyr, 2003). In an APS, master planning is typically based on linear programming striving to minimize costs (or maximize profit) while meeting demand and taking constraints (e.g. capacity) into consideration as an integrated part of the planning process (Chopra and Meindl, 2004). As such, multi-site master planning aims at synchronizing the flow of materials along the supply chain, and thereby balancing demand and capacity. It supports the tactical decisions concerning efficient utilisation of production, distribution, and supply capacities (Stadtler and Kilger, 2008). The planning not only balances demand with available capacities, but also assigns demands (production and distribution amounts) to sites and resources in order to avoid bottlenecks, wherefore it typically covers one full seasonal cycle, or at least 12 months in terms of weekly or monthly time buckets. Owing to the complexity and details required in the model, normally only potential bottleneck and/or critical resources are modelled in detail.

To determine how actual customer demand (orders) should be fulfilled, the "demand fulfilment" module, including available-to-promise (ATP) and CTP functionality, books orders against the capacity constrained master plan (Neumann *et al.*, 2002). As such, order lead times, suitable supply locations, available transportation resources, and available supplier material capacity can be established and communicated to the customer in a swift way (Steger-Jensen and Svensson, 2004). The customer order decoupling point (CODP) is of utmost importance to determine how the ATP process in DF should be set up and how orders are booked against the master plan (Rudberg and Wikner, 2004; Wikner *et al.*, 2007). Using ATP/CTP functionality in an APS to determine when an order can be delivered makes the order promising more accurate and reliable (Steger-Jensen and Svensson, 2004).

2.3 APSs in practice

Supply chain planning has in the recent years been developed to be supported by optimization and simulation tools, especially concerning "higher" planning levels. Complex trade-off analysis can be calculated with the aid of optimization models and solution heuristics in relatively short computing time (De Kok and Graves, 2003; Chopra and Meindl, 2004). Cost minimization and profit maximization are the two most common ways to control the solution (Stadtler and Kilger, 2008). Many supply chain planning modules stem from in-house developed DSS that aid planners at various levels in the decision hierarchy (De Kok and Graves, 2003). There are reports on some successful implementations of DSS in either special supply chain planning situations or optimization models regarding the entire chain. Gupta *et al.* (2002), for example, describe a DSS that helps Pfizer to plan their distribution network. The model is useful in both strategic and tactical planning situations. Brown *et al.* (2001) present a large-scale linear programming optimization model used at Kellogg Company to support production and distribution decision making on both strategic and tactical levels.

Jonsson *et al.* (2007) and Rudberg and Thulin (2009) both report on process industry companies using standard APS software at the mid-term tactical planning level, with the aim to enhance supply chain planning. Kjellsdotter and Jonsson (2010) study the potential benefits that could be reached by using APSs in the sales and operations planning process, also here for a process industry company. Zoryk-Schalla *et al.* (2004) describe a project where the case company, an aluminium manufacturer, implements three i2 modules for tactical and operational planning. Their major focus is, however, not on the effects of the implementation *per se*, but on the modelling of the planning processes and how the hierarchical planning structure can be captured in APS. David *et al.* (2006) analyse the practical use of APS in the aluminium conversion industry, whereas Wiers (2002) presents a study on the integration of an APS and an ERP system in a steel processing plant. Our research reports on a longitudinal case study analysing both the tactical planning processes, and the effects from the APS implementation at the company. As such, we are able to determine the differences before and after implementing the APS system. Similar approaches have been used in the ERP domain (Plant and Willcocks, 2007).

3. Case study: SSAB Plate

3.1 The steel industry

From a general perspective, process industries include firms that deal with powders, liquids, or gases that become discrete during packaging. They include the pipeline industries such as refining, chemical processing, pulp and paper, food processing, textiles, and metals. Process manufacturing is defined by Cox and Blackston (2002) as "Production which adds value by mixing, separating forming, and/or chemical reactions. It may be done in either batch or continuous mode". Process industries make up a large proportion of the manufacturing operations in the early stages of the overall production cycle of converting raw materials into finished products. Most process industries can be classified as either "basic producers" or "converters", and sometimes a combination of the two (Finch and Cox, 1987). A basic producer is a manufacturer that produces materials from natural resources to be used by other manufacturers, whereas a converter changes these products into a variety of industrial and/or consumer products. As such, process manufacturers would be positioned in the lower right-hand corner of the product-process matrix (Hayes and Wheelwright, 1979), typically producing commodities in high volume/limited variety. Whereas "fabricators" and "assemblers" (the two other categories in Finch's and Cox's classification) can be labour intensive, process industries rather have a high cost of capital invested in facilities. The steel industry that we are investigating is a combination of a basic producer and a converter, but apart from many other process industries, steel processing is in many parts based on discrete/batch processing (David *et al.*, 2006; Wiers, 2002). Parts can be accumulated in queues, processed together in batches (e.g. for heating, quenching or ageing), or processed separately (e.g. rolling and machining). Therefore, the possible benefits from using APSs are most likely larger in steel industries, than what it is in more continuous processing (David *et al.*, 2006). For our case company, which is a niche producer, the functional layout of the production process is even more noticeable.

3.2 Company background

SSAB Plate is part of the group Swedish Steel AB, which is a niche producer of high-strength steel with a yearly turnover of approximately SEK 48 billion during 2007 (1 SEK ≈ 0.11 EUR). In 2007 (the reference year for this study), SSAB Plate employed almost 2,500 persons and produced 586,000 tonnes of steel plate, which led to sales at SEK 9,941 million and a profit of SEK 2,193 million. SSAB Plate is the largest Nordic manufacturer of heavy steel plate, with brands such as HARDOX and WELDOX, and runs a fully integrated steel mill from cooking plant to finished end products (Figure 1). Approximately, 90 per cent of the production is exported worldwide. SSAB Plate has about 10,000 customers, with only two of them accounting for more than 10,000 tonnes annually, which in this context means that most of their customers are fairly small. The customers are served by about 200 regional sales managers (RSMs) and the mill is producing 24 hours a day, seven days a week. Yet, the company is not able to satisfy the customers' demand wherefore the company needs an extra focus on coordinating sales with production capacity.

The tactical planning, which is in focus for this study, is organisationally located at the Marketing Department at SSAB Plate, managing the demand planning, master planning, and DF processes. The Production Department controls the operational planning levels, including detailed production and materials planning, scheduling and sequencing, and transportation planning. The two departments naturally interact, but since this study focuses on the tactical planning processes, we are mainly concerned with the Marketing Department. The Marketing Department is run by a marketing manager (MM) and the two

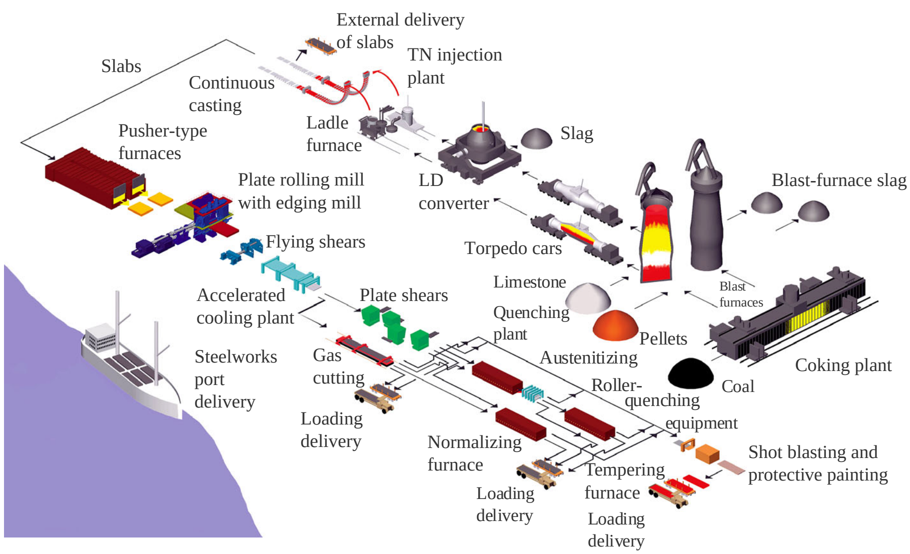

Figure 1.
Schematic production layout at the manufacturing site at SSAB Plate

main functions involved in the tactical planning are "sales" and "master planning". The sales function, responsible for the demand planning process, is organised in different business areas, which in general are different geographical areas. Every business area has a business area manager. The business areas are divided into smaller geographical sales areas which are divided into even smaller sales regions, each with their own managers; area sales managers and RSMs. The organisation of the sales function has not changed due to implementing the APS modules, but the organisation of the master planning function has changed. The master planning function is responsible for the master planning and DF processes and is after the APS implementation constituted by a small group of planners and system technicians. Before the implementation, the master planning responsibilities were divided between many functions and planners, making the process slow and cumbersome with poor visibility. In the following, we provide a background to the planning situation and planning problems triggering the search for better decision support in terms of APSs.

3.3 Planning situation and planning problems

There are two kinds of planning units at SSAB Plate; stock keeping units (SKUs) that are made to stock and kept at warehouses around the world, and so-called Externalgrade Thickness Groups (ETGs) that are made to order and based on customers' specifications. There are about 370 SKUs roughly accounting for 40 per cent of the production capacity. Demand for SKUs is mainly triggered by re-order points in the approximately 80 stock points spread around the globe. The ETGs, which are a sort of product groups based on products with similar production characteristics, occupy the other 60 per cent of the production capacity. There are some 160 ETGs and all are made to order with an order horizon of 12 weeks. The CODP is situated halfway through the production process where the slabs are finalized (Figure 1). The slabs are possible to store and a CODP buffer is placed at this location. After this point in the production process all orders are "unique" in terms of being linked to a specific SKU replenishment order or an ETG customer order.

3.3.1 Demand planning. In the beginning of the 2000, SSAB Plate's demand planning process was organised as follows. Every August, the RSMs made an estimate of their sales in tonnes for the forthcoming year and a half, because of an 18-month budget horizon. As time went by, the sales managers had no possibility to change their forecast. The approximately 200 RSMs made their forecasts in various spreadsheets, with different layouts and non-standardized product names, just to mention a few of the experienced problems. One DP was responsible for merging the individual forecasts into one and another person was responsible for acting as a mediator between sales and production, to match the forecasted sales with the production capacity and allocate tonnes to the different RSMs. This meant that every RSM did get an upper limit, in tonnes, for their future sales, but to increase the possibilities of getting enough allocations the RSMs frequently overestimated their forecasts. It is easy to see several problems in this process considering there are about 200 RSM and a huge amount of products. Therefore, the demand planning process was fragmented with low forecast reliability.

3.3.2 Master planning. The "master planning" process was mainly a manual process, based on the consolidated yearly forecast, the current order stock (both SKUs and ETGs), and the stated available capacity. The balancing of demand and supply was done by matching lists from different legacy systems and spreadsheets, with the aid of personal experience and a multitude of phone calls. There were a few persons responsible for the balancing process, but the planning process *per se* involved a multitude of people from many departments and functions. The planning process as such was not clearly defined (e.g. in terms of workflows, activities, persons) and had no clear objective, leading to low accuracy and plans that neither satisfied demand nor were feasible in terms of production capacity.

The most severe problem was maybe that all planning (both sales and production) was based on tonnes of steel produced. Using tonnes as a unit for production is problematic because the required production capacity differs a lot depending on, for example, the specific plate and its thickness. To give an example; one plate of 6 mm HARDOX 400 uses roughly the same production capacity as one plate of 25 mm HARDOX 400, which implies that the 6 mm plate uses about four times as much capacity per tonne. This used to result in overbooking of capacity, since there were no other sales limits than the tonne allocations, which in turn caused delays in delivery of ETGs and unplanned stock out situations in terms of SKUs.

3.3.3 Demand fulfilment. To estimate delivery times, the company compared order requests (both ETGs and SKUs (stock orders)) with lists from the production planning systems used at the plant showing available capacity. The production planning system is a finite scheduler originally implemented as PMSIM, but later upgraded (through a series of vendor acquisitions) to Lawson M3 Advanced Production Planner (APP). The APP lists were showing total available capacity in the bottlenecks and orders were normally matched with the available capacity on a first-come-first-served basis. These APP lists were only updated every Monday, which meant that the available capacity could change and hence be overbooked at any time during the week without anyone noticing it. Furthermore, the problem of using tonnes as a unit of planning in production further enhanced these problems. The overbooking caused delivery delays and the rigid and ineffective planning process made the RSMs overestimate their future sales just so that they would not run out of allocations. This in turn made the acceptance of the sales forecast low in production, i.e. there was a conflict between production and market and sales.

The planning situation at SSAB Plate was virtually impossible to handle and to get it working effectively. Therefore, the company decided that they needed to improve their overall planning, both in terms of decision support and in terms of reinventing their planning processes. The key goals at the time were to handle the increasing demand the company faced and to be able to give the customers accurate delivery promises, or alternatively turn orders down if there were not enough capacity. The later also highlighted the need to prioritize between customers and orders to be able to accept "the right" orders in times of demand surplus.

3.4 Planning solution

In 2001, SSAB Plate initiated a project focusing on streamlining the tactical planning and finding a DSS that could help straighten out those complicated master planning processes. At the beginning of the project they evaluated ten different APSs, of which three vendors were invited to demonstrate the systems on real data in the final round. The main focus was on the demand management, which was the function that later made them chose a product suite from i2 Technologies (from now on i2). This led to the implementation of three modules from i2's suite; DP, SCP, and DF, which were up and running by the end of 2002 (Figure 2).

Figure 2 shows the implemented APS modules at SSAB Plate as of 2002. Besides the i2 modules and the Lawson M3 APP (that was already in place before the i2 project was initiated), a set of legacy systems also supported the tactical planning process and the APS. Figure 3 shows a schematic overview of the new tactical planning process.

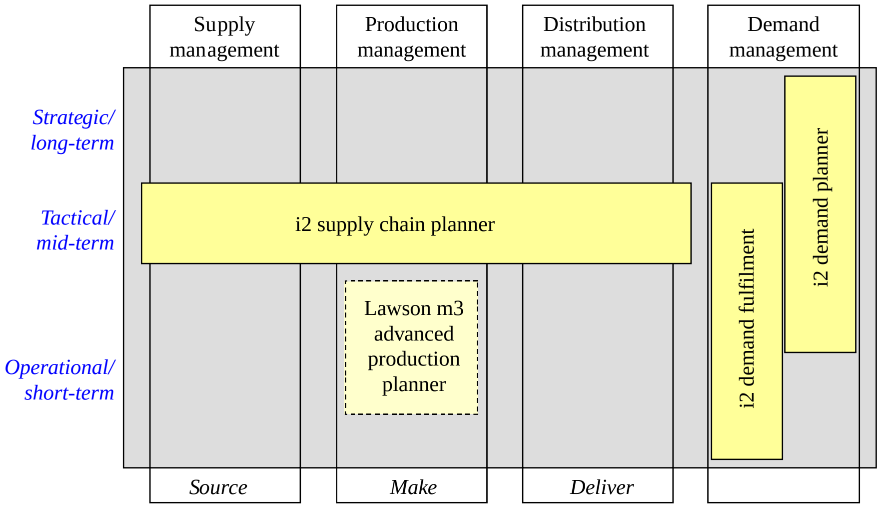

Figure 2.
APS modules at SSAB Plate after the implementation of i2's modules in 2002

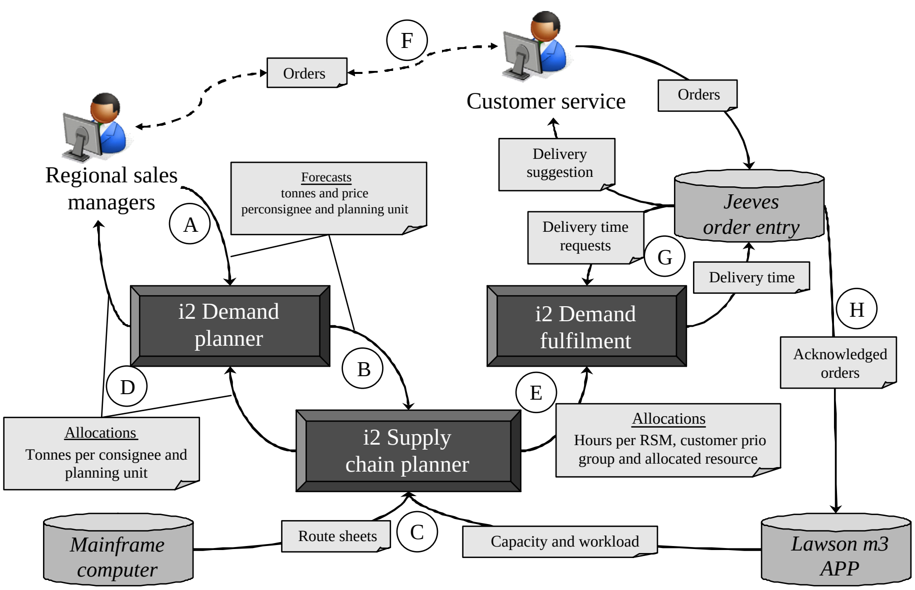

Figure 3.
SSAB Plate's tactical planning process and related APS modules

The following sections will describe the new planning processes and how they are supported by the APS modules (referring to Figure 3 throughout the description).

3.4.1 Demand planning. In DP, about 1,000 of the largest customers are listed, with the smaller customers bundled together under each RSM as "others". This grouping is done partly because they are small customers and it would take too much time and effort to place individual forecasts for each and every one of them, and partly because it is too difficult to estimate these customers' demand, as it tends to be very irregular.

The current planning process starts with a manual forecast, as the RSMs use their experience to forecast the future demand and the future price per product and customer ("A" in Figure 3). The database includes three years of historical data, but this is seldom used to create statistical forecasts. SSAB wants 18 months forecast data in DP, and they require that the first six months are of good quality with high forecast accuracy. Every August, just before the budget period starts, the RSMs are requested to update the entire 18 months of forecast. Except for this time it is up to the individual RSM to decide when to update the forecast, as long as the next six months is of good quality. In general, the RSMs update their forecast once a month, leading to an 18 months rolling planning horizon. SSAB uses an order horizon of 12 weeks and in this near future the forecast is not to be changed. Beyond this 12 weeks time fence, the RSMs are allowed to change their forecast whenever they want. On the 15th of every month, the RSM forecast is transferred to what SSAB calls the final forecast, which is exported to SCP ("B" in Figure 3).

The RSM forecast is unconstrained, which means that they forecast what they could sell if they were allowed to sell as much as possible. This is important since the demand widely exceeds the supply and SSAB wants to use the demand instead of future sales in the planning process. Forecasted volume per month is entered into DP per consignee in tonnes per planning unit. Also the prices of the different combinations are forecasted, which is partly due to the profit optimizing objective that is explained in the sections below.

3.4.2 Master planning. The forecast information in DP is imported into SCP ("B" in Figure 3), where the first three months are disaggregated from monthly to weekly time buckets. SCP uses route sheets from an in-house developed mainframe computer system to calculate the needed capacity for each of the forecasts, and uploads available capacity and current workload from APP ("C" in Figure 3). To provide a description of the magnitude of the forecasting process, consider the fact that there are some 200 persons making forecasts in DP. Each of them forecasting for, typically, 20 customers specified so that all planning units (SKUs and ETGs) are forecasted for every customer (both in terms of demand and selling price). This is specified per month, with the first three months disaggregated to weeks, which makes a lot of combinations and data to organise and process. In SCP, each individual forecast (RSM, consignee, planning unit, price and time bucket) is kept intact and matched with current available production capacity for the most critical 15-20 resources. The aim of the matching is to create an optimal product mix, based on profit maximization and a set of business rules that are decided upon by the company management.

The objective function in SCP is set to maximize profit, but SSAB controls the solution through a set of business rules that have priority over the profit maximization objective. In principle, there are three sets of rules. The first set is of a geographical "fair share" type, ensuring a predefined minimum level of supply to different business areas. The second set of rules controls the ETGs and SKUs by prioritizing between customers and between ETG and SKU orders. The third set is basically the profit optimization objective, leading to that the orders with the highest contributing margin are prioritized so as to ensure that SSAB is using the limited capacity in the most profitable way. The second set of rules is worth describing into somewhat more detail. These rules are based on a segmentation of the customers into three groups according to their importance, where Group 1 contains the most important customers and Group 3 the least important. There is also a fourth group which contains the stock orders from SSAB Plate's own warehouses around the world. The general rules regarding which customers that should belong to the most important group is decided by the MM, the other groups are determined by each business area manager exclusively for each business area. Within the first three groups, a further division is made, which is based on an ABC classification of the forecasted revenue. The forecasted demand within each group is classified in terms of gross margin multiplied by tonnage, so that the forecast which generates most revenue within each group gets the highest priority. SSAB Plate typically uses three revenues classes within each group where the first class should account for approximately 20 per cent of the total sales value within that group.

According to the explained business rules and the current production data from APP, SCP creates the constrained and optimized sales plan, which is a time-consuming process that takes somewhere between 6 and 10 hours. The constrained plan is then exported from SCP back to DP in terms of allocated tonnes per planning unit (ETGs and SKUs), consignee and time bucket ("D" in Figure 3), so that the RSMs can use DP to check their current allocations. As before there are problems with using tonnes as a unit, as it does not relate to the needed production capacity, but it is a well-known unit that everyone understands.

3.4.3 Demand fulfilment. The constrained master plan is also exported from SCP to DF ("E" in Figure 3), but here it is done in hours per allocated resource, RSM, priority group, and time bucket. At the time of the study, there were approximately 120 defined resources in the system, but only 15-20 of these are critical in terms of capacity and used as allocated resources. When an RSM gets an order request it is sent by e-mail or fax to the customer service department ("F" in Figure 3). Here, the orders are entered into the order entry system (Jeeves) and further transferred to DF, which searches for available capacity for the RSM in the needed resources and time buckets. The allocated resources get a workload between 98 and 99 per cent because they are the resources limiting the production throughput, but they are also the ones important not to overbook since that unconditionally will cause delays.

DF is used to give accurate and fast order promising, with the use of the allocations planned in SCP. Information in DF is updated daily with the latest allocations from SCP and the current capacity and workload from APP. When DF gets an order request, it searches for available allocations to consume in the constrained resources according to the order routings that have been attached to the order. In the ATP/CTP search, the DF seeks for available capacity based on an appropriation system, which is based on the customer classifications as described in Section 3.3.2. All customers are prioritized from one to four (SKUs making up the fourth class), where prio one are the most important customers. For a specific order request, DF first tries to find available capacity for the RSM in the customer's prio group. If this does not exist, DF seeks for capacity in lower prio groups for the RSM. As a third step, and only for customers with prio three and above, DF seeks for available capacity, first in other RSMs prio four groups (in the same sales area) and then in other sales areas' prio four groups. This method is used to level out the fluctuations in individual sales and the description above is the standard setting. Every business area manager can decide exactly how and which appropriation rules that should be applied in their own business area. If DF finds available capacity a delivery promise is returned to Jeeves, which is thereafter sent to the RSM ("G" in Figure 3). If DF does not find available capacity within the requested delivery lead time, a search for available capacity with delayed delivery is conducted. However, SSAB Plate does not normally accept orders beyond the 12-week time fence, wherefore order requests might be turned down. If orders are acknowledged they are loaded into the APP, hence consuming available capacity ("H" in Figure 3). The whole DF process is automatic from the time when orders are entered into the order entry system (Jeeves) and takes about 3 minutes for a "normal" order.

4. Case analysis and discussion

The general opinion at SSAB is that the new tactical planning process and the implementation of the three APS modules were necessary in order to get control of the diversified demand and master planning functions. Yet, even though the APS modules provide many positive effects, there are still a lot of areas were both the planning processes in itself, and the use of the software, can be improved. Some of them will be highlighted in the analysis below. Table I provides a short summary of the main issues that are analysed.

4.1 Planning processes

4.1.1 Demand planning. The problem with the former demand planning process was the main reason triggering the APS implementation project. SSAB's many RSMs did their work without any support from neither a standardised forecasting process nor any forecasting software. After implementing DP the process has been streamlined, but it was hard to make the autonomous RSMs accept the new forecasting procedures, which goes in line with what Wiers (2009) reports regarding shop floor autonomy and APS success. Hence, the SSAB management considered it impossible to also force them to use statistical forecasts as a basis for their input to the planning process. This is why all forecasts still are based on personal judgement alone, concerning both demand and selling price. The main difference with the new planning process is that it is standardised and that it is possible for the central management (i.e. the master planners) to overview the process, and that forecasts are updated regularly on an 18 months rolling horizon. It is also possible to give the RSMs a reliable feedback via the optimization in SCP. As such, the SCP provides a constrained forecast to all RSMs with the same granularity as was the case for the original forecast. This procedure guaranties that the RSMs are controlled in terms of available sales volumes which is extremely important considering the demand surplus for SSAB's products. Still some RSMs are using spreadsheets to create their forecasts, since they do not work in DP more than a couple of hours a month and by that do not get comfortable in using DP. Although they are using these spreadsheets they need to transfer the information into DPs standardized form, which is a big improvement compared to before.

4.1.2 Master planning. An interesting feature of SSAB's master planning process is that they do actually use profit maximization as the objective function in the SCP master planning. Otherwise most companies tend to use cost minimization

Table I. Case analysis highlighting the main issues before and after the APS implementation

Analysis issue	Before APS (prior to APS implementation)	After APS (when APS was implemented)
Demand planning		
Decision support	Various individual spreadsheets	i2 Demand Planner
No. of persons involved	About 200 RSMs, one DP consolidating forecasts	About 200 RSMs, consolidation in DP for informational purposes only
Model design	Manual judgement of demand and price	Manual judgement of demand and price
Planning horizon/period	18 months	Rolling 18 months (six months "good quality")
Planning frequency	Updated once a year	Updated once a month
Planning process	Fragmented, low visibility	Streamlined, high visibility
Main objective	Consolidating forecasts	Establishing reliable forecasts
Forecast accuracy	Overestimated forecast/low reliability	Constrained forecast/high reliability
Master planning		
Decision support	Manual based on Excel-made budget	i2 Supply Chain Planner
No. of persons involved	Many, but three with main responsibility	Three master planners
Model design	Manual balancing to find feasible plan	Plant loading based on a set of business rules, incl. profit maximization, to find an optimal plan
Planning horizon/period	18 months	Rolling 18 months, weekly buckets for first three months
Planning frequency	Monthly	Updated weekly, with a major replanning every month
Planning process	Fragmented, low visibility	Centralised, high visibility
Main objective	No clear objective	Max. throughput in bottlenecks and to prioritize profitable customers
Planning accuracy	Low	High
Run time (planning cycle)	N/A	6-10 hours
Planning output	Sales/production plan in tonnes	Constrained and optimized plans in tonnes (for DP) and in hours (for DF)
Demand fulfilment		
Decision support	Manual lists of available capacity (from APP)	i2 Demand Fulfilment
No. of persons involved	One	Automatic process
Model design	Overloading possible due to allocations in tonnes	ATP/CTP functionality based on a set of priority rules (allocations in hours)
Planning horizon/period	N/A	12 weeks/real time
Planning frequency	Real time	Real time/daily
Planning process	Fragmented, undefined	Streamlined, automatic
Main objective	Accepting orders	Providing reliable order promises
Planning accuracy	Low	High
Response time	Long and unreliable	Acknowledged order in less than 3 minutes

(Stadtler and Kilger, 2008; Wiers, 2002; Brown, 2001). However, due to the business rules used, there are only a few percent of the total demand that is actually affected by the profit maximization objective. Yet, SSAB has realized that in a world of capacity shortages it is of utmost importance to use the scarce capacity in the best possible way. The use of profit optimization is not uncontroversial at the company, and there are several opinions on how to calculate sales cost for different sales offices in different countries and there are managers claiming that profit optimization is a short-term approach that makes the company more vulnerable in the long run. Concerning the planning process as such, the master planning has changed from being fragmented with no clear objective to become centralised with high visibility and a clear focus on maximizing both the throughput in bottlenecks and the company's profitability. The plans resulting from SCP is also of higher accuracy and more easily accepted within the organisation, making the whole tactical planning process more reliable.

On the downside, it is worth mentioning that SSAB struggles with long run times in the SCP. This is partly due to that all forecasts for each single RSM and product group is kept as an individual "order" in the planning process. This makes the planning cumbersome and slow (6-10 hours per run), but the use of profit optimization requires every order to be considered individually. SSAB also wants to communicate the constrained forecast after the SCP run to the forecasters, which also makes it impossible to consolidate the forecasts. As such, the main positive effects from the APS implementation lie not in reducing the planning staff and run times, but rather in the possibility to better plan the constrained resources and to provide detailed feedback to the forecasters/RSMs.

4.1.3 Demand fulfilment. The DF process is controlled through the constrained plan that the SCP provides. The DF output from SCP is based on allocations in hours (as compared to tonnes in the DP feedback). As such, SSAB is able to provide reliable delivery promises based on the constrained master plan, and also to search for alternative sourcing points and delivery dates, should a shortage occur. This was not the case prior to the APS implementation, when this process was based on manual lists from APP. Combining the DF with the constrained SCP plan also forces the company to keep within their capacity limits, and not overloading the resources as was done prior to implementing the APS. The DF is now an automatic process and consumes allocations and capacity in real time, even though a major update is done weekly, right after the SCP run. Instead of accepting orders to whatever cost, SSAB has adjusted the process so that they only accept orders that they actually can deliver, hence increasing the delivery reliability of accepted orders. Also, the new DF process is fast with an order acknowledgement (or reject) within 3 minutes.

4.2 Company performance and areas to improve

The most important performance indicator for SSAB is delivery performance, and delivery performance has been kept on a stable level, although demand has almost doubled during the time from the implementation of the APS modules. The workload has thereby hit the roof and the initial improvement in delivery performance has diminished. Yet, SSAB has been able to assimilate this increase in demand and still been able to deliver on time, which is an indicator of a well functioning tactical planning processes. One should keep in mind that the production process in itself is far from stable, and there have been numerous severe breakdowns during the last few years that of course affect the tactical planning process and planning accuracy. The most constrained resources are loaded to 98-99 per cent which obviously makes it practically impossible to catch up after a breakdown in the manufacturing process. Yet, in spite of these problems, SSAB has been able to keep deliveries on close-to-acceptable levels, which according to the company is thanks to the new centralised and visible planning processes and the new system support from the APS. In terms of cost, no big differences have been noted. The number of planners is approximately the same, but they are treating almost twice the number of orders without increasing the planning work force.

Company performance has been hard to measure during this study. This is partly due to the fact that SSAB has not kept track of performance indicators during the project, and partly due to that the changes in market and an unstable production process make it almost impossible to isolate the effects from the APS implementation. Rather than "hard" performance indicators, the benefits lie in "soft" issues, such as better visibility, higher planning accuracy, better customer service (more reliable and faster information to customers), and more standardised planning processes. Similar results have been found in other studies on APS implementations (Kjellsdotter and Jonsson, 2010; Gruat La Forme *et al.*, 2009; Rudberg and Thulin, 2009; Lin *et al.*, 2007). Finally, and maybe the most important effect from the APS implementation – SSAB has established a standardised way to:

- use their limited capacity; and
- prioritize between customers and orders in accordance with the company's long-term strategy.

This would have been impossible without the APS support in terms of the SCP and DF modules. In many cases, limited decision support makes it difficult to prioritize orders and customers, which is an important function for manufacturers with limited capacity and a high customer focus (Steger-Jensen and Svensson, 2004).

Even though the APS implementation overall is regarded to be successful at SSAB, there are many areas still to improve. SSAB strives for continuous improvement, and the demand planning process has once again triggered an APS upgrade project that is currently ongoing (not covered in this study). An upgraded demand planning module has been implemented (i2 Demand Manager) and upgrades of the other modules are planned in the near future. In these upgrade projects, the following issues are the most important to consider in terms of improvement:

- The use of statistical forecasts as a starting point in the demand planning process.
- The reduction of run times for the master planning process.
- The establishing of procedures for the profit maximization method, and to gain acceptance for this throughout the organization.

4.3 Summary and answers to research questions

The main purpose of this paper has been to describe and analyse the impact that the implementation of three APS modules has had on the case company's tactical planning. Related to this purpose, we raised three research questions in the introduction of this paper.

The *RQ1* concerned how the tactical planning processes have changed due to the APS implementation. First and foremost, SSAB has managed to turn three manual and fragmented planning processes into more standardised processes with a higher degree of automation. Also, the former unreliable planning processes have now been turned into centralized, controlled, and visible processes. The new processes also give central management better possibilities to overview these processes and to control both the plans and the planners (e.g. in terms of forcing the RSM to stick to the limits of the constrained forecast). All processes also have clearly defined objectives leading to that all planners are working towards the same goals. Even though the planning processes and the planning tasks have changed, the actual planning organisation has not. This could be a missed opportunity for the company, but the possibilities to also change the organisation in this case needs further research. Gruat La Forme *et al.* (2009) also highlights that many companies implementing APS have experienced a better overview of the supply chain. In this study, this is also true, but more important is that the central planning function has got a better overview and visibility of the planners involved in the tactical planning process, and of the plans (forecasts) that they deliver.

The *RQ2* highlighted the effects that the APS had on company performance. First of all, it should be stated that the results from our research only reveals few effects on company performance that affects the bottom line. Measurable effects are that the forecast accuracy is higher, a relative improvement in service levels, a faster response time concerning order acknowledgement, and more reliable order promises. Similar effects have also been identified in earlier studies on APS (improved forecast accuracy in Gruat La Forme *et al.*, 2009; Stadtler and Kilger, 2008; increased customer service levels in Gruat La Forme *et al.*, 2009; Stadtler and Kilger, 2008; Jonsson *et al.*, 2007; and improved ontime delivery in Gruat La Forme *et al.*, 2009; Stadtler and Kilger, 2008; Lütke Entrup, 2005). Costs have not been reduced and we have not been able to detect any significant changes in revenues or profits due to the APS, which is contradictionary to results in other studies (Rudberg and Thulin, 2009; Stadtler and Kilger, 2008; Jonsson *et al.*, 2007). However, the performance of the tactical planning function has been improved in a number of ways; the plans are more frequently updated (also found in Stadtler and Kilger, 2008) leading to accurate planning data and better decision making, the plans consider actual (rather than planned) lead times and takes capacity constraints into account at all levels, and the company has also been able to find efficient means to prioritize between customers orders and to force the RSMs to adhere to this prioritization.

Finally, *RQ3* was directed towards the advantages and disadvantages with the case company's way of using the APS. Some of the advantages with the SSAB way of using the APS, is that the DF process, in terms of planning, is a fully automated process with a fast response time (which is also supported by the findings in Stadtler and Kilger, 2008). SSAB has also used the system as the means to force planners to adhere to the standardised processes. Without the system support this would have been virtually impossible. The disadvantages lie mainly in the fact that SSAB has created a rule-based system, replicating parts of the old planning approach, overriding the true optimization. As such, the company does not use the full potential in the system to prioritize between orders and maximize profits. They have also kept their tactical planning on a detailed level with a long planning horizon, leading to long run-times in the system. Finally, SSAB has missed out on the possibilities to integrate the APS modules in the tactical planning with the APS module at the operational planning. This means that SSAB are not able to optimize the operational schedules in accordance with the CTP calculation, which in turns leaves the company with far from optimal production schedules, sometimes leading to inefficient use of the limited production capacity (e.g. in terms of unnecessary changeover between orders).

One main reason explaining many of the disadvantages with the system use that have been experienced at the case company is the lack of understanding of both the APS system as such, and the possibilities that APS offers in terms of efficient planning and establishing effective planning processes. One could argue that better training would solve this problem, but training without the practical experience from using APS on a regular basis is no guarantee for avoiding the most severe disadvantages and mistakes with using the system. The coming upgrade project at the case company will address these disadvantages to further improve their planning and their use of the APS, but without the experience from the last few years of using APS the company would not have been able to address these issues. The general implication from this is that companies must be humble enough to realise that it takes time to establish effective and efficient planning processes, and to get the most out of the DSS.

5. Concluding remarks

This research points out the main lessons learnt from a longitudinal study at SSAB Plate, analysing the implementation of three APS modules for tactical planning in the process industry. Internally, the project is regarded to be successful and this research shows several positive effects, even though many of them are not measurable in terms of performance indicators. One of the measurable effects of the project is that the production almost doubled but the delivery performance stayed stable. Besides, this a lot of "soft" effects has been noticed, such as better control and higher visibility in the planning processes, a fast and reliable order promising process, and more standardised forecasting process leading to more accurate forecasts, to name but a few.

The reorganization of the planning function and the new planning processes are factors that also affect the performance, but the current situation could not have been realized without the APS. On the other hand, the APS could not be effectively utilized without the organizational change. Lin *et al.* (2007) reveal that APSs should not be used to drive business process reengineering; rather process changes should precede APS implementations to overcome typical implementation pitfalls. In this case, the APS implementation project triggered the changes of the planning processes, but the APS did not drive the reorganisation. Lin *et al.* (2007) furthermore notice that effective management of processes in supply chains requires the use of APSs. On the downside of the project results are the fact that there are still some problems with the usage of the APS modules. This is partly due to that several of the company's about 200 RSMs do not know the system well enough to handle the demand planning module properly. Also there are a lot of functions and possibilities offered within the APS that are not in use. One reason for this is that the MM and the sales function want to keep control of how planning is done within the company. Therefore, the rule-based planning structure is dominating, even though master planners want to give the APS more "freedom" in creating optimal plans with a higher degree of profit maximization.

The results from this case study may not be applicable to other situations. However, the process descriptions, lessons learnt and issues encountered in case studies like this may be helpful to practitioners on their way to implement APSs, and for academics studying APS implementations and their effects (Wiers, 2002). Companies seeking new ways to improve their planning can use this research to investigate the use of an APS at

SSAB and make comparisons with their own situation. As such, they will get better insight into what is to be expected from an implementation project, both in benefits, but also in what efforts it takes to avoid pitfalls and create a stable solution. Managers will hence be able to use this paper, both as guidelines and as a comparison during and after their own project.

SSAB is in the middle of a number of upgrade projects and future research on the subject will focus on how planning is improved further in this context. Also, there is a need to analyse "hard" figures concerning planning and delivery performance as a result from implementing APSs, with the changing of planning processes and organisation as a major influencing factor. From a general perspective, future studies could also focus more on the implementation process *per se*, and how it affects the possibilities to realise the expected effects from using APSs. For example, Plant and Willcocks (2007) investigates how critical success factors in ERP implementation influence the outcome of the implementation. Similar studies are needed for APSs implementation. User training may be a factor contributing to the challenges in implementing an APS, and so are top management support and leadership. All of these factors are worth investigating in further research on APSs.

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