Sales and operations planning in the process industry

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Abstract
This paper provides a systematic review of sales and operations planning (S&OP) in process industries (PIs). The aim is to investigate the present state of S&OP in PIs and then to identify the desired future state of the S&OP process based on the specific characteristics of PIs. The findings of this paper show that this issue has not received much attention in the academic world. Hence there is a need for conceptual models with focus on specific characteristics of PI. In particular, characteristics upstream of the discretization point are investigated and implementation of S&P in the PI context is stressed.

Keywords: Sales and operations planning, Process industry, Discretization point

Introduction
The process industry (PI) plays an important role in terms of GDP in many countries. Yet, operations management research has not paid much attention to PIs until the 1980s (Van Donk & Fransoo, 2006). Process industries have been defined as a kind of firms that “produce products by mixing, separating, forming and/or performing chemical reactions” (Blackstone Jr., 2010, p. 115). Process industries partly deploy continuous production, implying specific characteristics which differentiate them from discrete manufacturing (DM) companies. These characteristics affect the adoption of an appropriate manufacturing planning process for these companies (Dennis & Meredith, 2000). Despite these facts, Sales and operations planning (S&OP) has been mostly treated as a generic process (Proud, 1999) in the sense that it is not dependent on specific characteristics of a particular industry.

S&OP is the second highest level in the planning hierarchy and has a role of balancing demand and supply plans at an aggregate level (Jacobs, et al., 2011). APICS dictionary defines S&OP as “a process to develop tactical plans that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain” (Blackstone Jr., 2010, p. 133). In order to achieve the balance, it is essential to integrate people from different related areas both within and outside the company and provide a platform for inter/intra-company discussion and decision making (Affonso, et al., 2008) (Jacobs, et al., 2011). Hence, integration is the essential part of a successful S&OP process.

S&OP has, to a large extent, been developed by practitioners in industry (Grimson & Pyke, 2007) and despite the growth of academic literature about this subject during the
recent years, the gaps between industrial needs and academic research still exist. This paper, hence, aims at identifying these gaps and to highlight their importance in PIs.

**Purpose**

The purpose of this review is to study S&OP in PI. Due to the fact that there is not much written about this subject in the literature, we aim to first investigate the present situation of S&OP is in PIs and second, the desired future status of this process based on the identified gaps as well as specific characteristics of PIs.

We have defined two research objectives. The first is to investigate how advanced the implementation of S&OP processes have been in PIs based on the literature and which parts of the supply chain that this process covers. Second, we identify the operations characteristic of PI, which may substantially affect the functionality/architecture of S&OP. So far, S&OP process has been considered as a generic process (Grimson & Pyke, 2007). The authors of this paper do, however, think that the specific characteristics of PIs should influence the design and implementation of S&OP in PIs.

The rest of the paper is as follow. We continue this section with a short explanation about PIs. The second section contains the literature review methodology. In the third section we have gathered the papers about S&OP/Production planning) in PIs. The paper ends with the analysis, conclusions and further research in sections four and five.

**General characteristics of process industry**

Process industries have been defined as kind of firms that “add value by mixing, separating, forming and/or chemical reactions by either batch or continuous mode” (Fransoo, 1993, p. 187). If the demand is high in this type of industry, continuous production can be applied, however in case the low quantities are demanded continuous production would be very expensive and hence, batch production would be more feasible (Fransoo & Rutten, 1994).

Here we focus on characteristics other than production processes since they are thoroughly discussed in the following part. Fransoo & Rutten (1994) mention 15 characteristics for PIs including variable yield, quality, quantity (availability) and recipe; divergent flow and BOM (by-products); and price of raw materials (Fransoo & Rutten, 1994, p. 50). Ashayeri, et al. (1996) mention 28 features classified under four groups: relationship with the market, production process, quality, production and control. They name environmental demands, danger and quality measurements under the quality group which are considered to be highly important for PI but of less importance for DM companies (Ashayeri, et al., 1996).

**Discretization point**

Traditionally the PI companies have been considered as one integrated entity with one set of characteristics. However, there is a point in the production process of PIs where “process production turns into discrete production” and discrete products are produced which is referred to as “discretization point” (DiPo) (Pool, et al., 2011, p. 194) (Abdulmalek, et al., 2006). Hence, the production process in PIs is divided into process flow production (PPr) and discrete production (DPr) as illustrated in Figure 1.

In the PPr part, almost all products have similar routings which result in a flow of material through the process stages with minimal interruptions in the process (Blackstone Jr., 2010).
Figure 1: Discretization point in a PI company

The layout of the PPr part is designed in a way to facilitate the products’ flow through specialized equipment which implies lower degree of flexibility and since there is a production line, the capacity of the line is restricted to the capacity of the bottleneck process. (Taylor & Bolander, 1994). Differences between these two types of production systems are compiled from Fransoo & Rutten (1994), Ashayeri et al. (1996) and Taylor & Bolander (1994) in Table 1.

Table 1: Differentiating characteristics of PPr and DPr

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Process flow production (PPr)</th>
<th>Discrete production (DPr)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labor intensity</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Capital intensity</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Lead-time to increase capacity</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td><strong>Production facility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Routing</td>
<td>Fixed</td>
<td>Variable</td>
</tr>
<tr>
<td>Material handling equipment</td>
<td>Fixed-path</td>
<td>Variable-path</td>
</tr>
<tr>
<td>Layout</td>
<td>Process-based</td>
<td>Product based</td>
</tr>
<tr>
<td>Production equipment</td>
<td>Specialized</td>
<td>Flexible</td>
</tr>
<tr>
<td><strong>Capacity utilization</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Priority to preventive maintenance</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Equipment failure effect</td>
<td>On the whole factory</td>
<td>On a machine</td>
</tr>
<tr>
<td>Changeover time</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>Work-in-process inventory</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Added value</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Production volume</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

As outlined above, PIs are hybrids (Abdulmalek, et al., 2006) and both these groups of characteristics in Table 1 are expected in them. Usually it is considered that the bottleneck is positioned in the PPr part and a stock is located at the DiPo to decouple PPr and DPr (King, 2009). As Pool, et al., (2011) suggest, DiPo can be used as a point of reference in the planning processes i.e. in the implementation of appropriate planning approaches based on the characteristics of each side of the DiPo.

Methodology

This paper provides a systematic review of S&OP in PIs which includes planning the review, conducting the review and reporting and dissemination (Bryman & Bell, 2007). The analysis of the found sources has been done based on “meta-ethnography”. A synthesis is defined and different studies are translated and compared to each other in a way to create value for the audience (Bryman & Bell, 2007, p. 102). The synthesizing can be done in one of three ways: “refutational synthesis can be used when reports give conflicting representations of the same phenomenon, reciprocal translations can be used where reports address similar issues and lines of argument synthesis can be used if different reports examine different aspects of the same phenomenon” (Tranfield, et al., 2003, p. 218). Due to the nature of this study which is based on reviewing different studies regarding S&OP process, the reciprocal translation has been used.
After reviewing all papers, we have suggested an integrated framework. The framework is based on the best-in-class companies’ practice of S&OP covering all types of industries. We have gathered the papers about S&OP which are not specific for a particular industry or related to DM under the heading of generic S&OP and distinguished them from the papers with explicit focus on PI. The papers are also divided based on their methods into two groups of qualitative and quantitative in order to better understand the context of the available literature on this subject and to find out which types of papers are missing for the future studies.

Three databases were selected which contain a large body of literature being published in areas related to operations management/research and industrial studies including peer-reviewed full-text articles: ScienceDirect, Emerald, and Taylor and Francis. The keywords used were “sales and operations planning” for preparing the framework, for PI part “sales and operations planning” and “production planning” in combination with “process industry”, “chemical”, “steel”, “food”, “pulp and paper” and “forest” which were searched in the title, abstract and keywords of the papers from 1980-2012. Since searching S&OP in PI returns very few results, the keyword “production planning” has been added in order to cover the terminology which has been already used in PIs literature referring to medium-term planning. Where appropriate, the reference lists of the previous studies have been used in order to dig into specific areas related to the topic of the study (Croom, 2009). These articles form the core of the study. In addition, articles from professional and business journals have been reviewed in order to identify the recent developments (Rowley & Slack, 2004) in this area. Two journals of this type were selected according to other researchers’ recommendation. All articles about S&OP in “Supply chain management review” magazine from 2000-2012 and “Supply chain quarterly” from 2007-2012 were reviewed.

All the articles were first reviewed according to their abstract and conclusion in order to exclude the non-corresponding ones and yet to reduce the risk of losing the related ones due to misinterpretation and bias. The filtering criteria were: focus on S&OP/production planning or demand/supply planning considering the medium-term planning horizon on the tactical level. As a result of this process, 107 papers were reviewed based on their full-text. Due to the page restriction, the generic S&OP part of the study is excluded from this paper. The full reference list can be provided upon request.

**Sales and operations planning**
In the beginning of this section, the generic S&OP and its outcomes are discussed and the synthesis of the paper is introduced.

**S&OP process**
The advent of S&OP goes back to 1950s when Holt, Modigliani, Muth and Simon started working on aggregate production planning and forecasting. This process has later evolved into S&OP, almost the way we know it today (Singhal & Singhal, 2007) (Feng, et al., 2011). Some other authors though believe that S&OP has emerged from MRPII and been improved since 1970s (Basu & Wright, 2008). In recent years the fierce competition, tough economic situation (Atkinson, 2009), globalization complexities (Jonsson, 2011), and the ongoing trend of outsourcing (Klappich, 2012) have put more emphasis on the importance of S&OP process (Cecere, 2005) with an extended scope as we discuss further in *The synthesis*.

Most of the authors suggest that S&OP is a monthly process which aims to create balance or integration between demand and supply plan at an aggregate level (Wallace
& Stahl, 2008) (Jonsson, 2011) while some researchers suggest that if needed, the balance can be sought on SKU level too (Grimson & Pyke, 2007). The suggested planning horizon lower and upper limits for this process are three months and three years (Gianesi, 1998) (Grimson & Pyke, 2007), while more emphasis is on a horizon between 12-18 months (Wallace & Stahl, 2008) especially for companies with seasonality profile (Grimson & Pyke, 2007) (Jonsson & Mattsson, 2009).

As Wallace & Stahl (2008) emphasize, S&OP implementaton is first and foremost about people who participate in the process rather than just a set of models or software. Hence, realization of the benefits of this process is bound to the cultural context of the organization, integration of various functions involved in decision making process and breaking down the organizational silos (Shobrys & White, 2002). Different benefits have been mentioned as the result of the S&OP process which can be divided into two categories: soft and hard (Wallace, 2006). The first group payoffs are hard to measure and include improved visibility (Kjellsdotter Ivert & Jonsson, 2010) (Muzumdar & Viswanathan, 2009), better cooperation between personnel and management (Jacobs, et al., 2011) and between different functions in a company (Gianesi, 1998) and improved organizational behavior, better decisions with less effort (Wallace, 2006). These aspects of S&OP are very important in the performance of the companies (Basu, 2001) but hard to achieve (Shobrys & White, 2002).

The second group (hard benefits) includes benefits such as customer satisfaction (Muzumdar & Fontanella, 2006), improved inventory turns, improved service (Basu & Wright, 2008), better forecast accuracy (Grimson & Pyke, 2007), reduced out-of-stock (Prokopets, 2012), improved operational performance (Gianesi, 1998) and optimized customer service vs. inventory level and cost (Thome, et al., 2012a).

The synthesis
As mentioned above, the main aim of the S&OP process is to create balance or integration. The proposed framework in this paper aims to focus on S&OP in the supply chain context considering the integration issues. Integration can be considered in two directions, vertical and horizontal. Vertical integration refers to linking the strategic plan, business plan, financial plan and long-term objectives to short-term operational plan while horizontal integration is concerned with the “cross-functional” integration considering both inter- and intra-company’s activities (Thome, et al., 2012a, p. 2). While inter-company supply chain has been widely studied, intra-company supply chain integration still needs more focus in the body of literature (Statlter & Kilger, 2010).

Figure 2 shows the focal company and the perspective of its supply chain. Within the company, the formal S&OP process is performed as suggested by several authors such as Wallace & Stahl (2008) and Jacobs, et al. (2011). This process starts with data gathering for demand planning and supply planning and in the next step a demand plan is prepared. Demand planning is mainly focused on forecasting the demand for present and new products based on history, competitors’ activities, management directives and economic situation. This plan is then sent to the supply planning step where capacity planning is performed based on the demand plan, available capacity and inventory levels. In order to achieve the balance between these plans, two final steps are designed to gather people from different related areas in the company and to provide a platform for cross-functional discussion and decision making (Wallace & Stahl, 2008).

Outside the focal company’s boundaries in Figure 2, different tiers of suppliers, customers and competitors interact with the company through e.g. the flow of information and/or materials which implies the horizontal integration in the intra-company context. Suppliers provide goods/service for the company and the customers
are defined as “a person or organization which receives goods, service or information” (Blackstone Jr., 2010, p. 34) Subcontractors are considered as suppliers which provide capacity for the focal company. The competitors’ products prices, new products and release dates are important information for demand planning in S&OP (Wallace & Stahl, 2008).

![Figure 2: Sales and operations planning in the supply chain context](image)

Due to the great importance of integrated supply chain in the recent years, some authors have suggested the involvement of main customers and suppliers in the S&OP process. (Grimson & Pyke, 2007) The best-in-class companies, in their S&OP process, consider also scenario and risk management (Kjellsdotter Ivert & Jonsson, 2010) as shown in Figure 2, in order to confront the unknown future’s economic situation with more knowledge about different scenarios/alternatives and their consequences on the company’s performance. Scenario management also enables company to shape the demand rather than just balancing supply and demand which leads to profitability increment (Cecere, 2005) and is significantly important in tough economic times (Atkinson, 2009). In addition, they integrate the budgeting and financial planning (Kallrath, 2002) at this level in order to properly evaluate the assets investments, revenues, costs and profits for different scenarios for a robust decision making process (Prokopets, 2012).

Sales and operations/production planning in process industry

Searching the literature for S&OP in PI returns few results which are specifically focused on this subject since S&OP has usually been considered a generic process.

In order to figure out how long/medium-term planning has been done in PIs, the keyword production planning (PP) has also been included. PP is defined as “aggregate plans for material, equipment, labor, energy and any other critical resources. The plans, linked to annual business plan, generally have monthly or quarterly time intervals and cover a range of one to two years. Resource levels are set to match demand expectations, and products are assigned to plants based on cost, quality, customer service and labor consideration” (Taylor & Bolander, 1994, p. 57). David, et al. (2005) suggests that the assigned time of production capacity to each market segment should also be decided in this process.

Table 2 is prepared according to the framework that is depicted in Figure 2. In this table, strategic (business) and operational plans are included under vertical integration.
It should be noticed that in this table DiPo papers are a subset of all PI papers. Also according to the definition of financial integration in The synthesis, quantitative papers with objective functions of maximization of profit or minimization of cost are not considered as financial integration.

Table 2: The number of the reviewed references about S&OP/PP in PI classified under the framework

<table>
<thead>
<tr>
<th>Integration aspect</th>
<th>Qualitative</th>
<th>Quantitative</th>
<th>DiPo</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horizontal integration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suppliers</td>
<td>3</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Focal company S&amp;OP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand planning</td>
<td>15</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Supply planning</td>
<td>15</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Balance of demand &amp; supply</td>
<td>15</td>
<td>28</td>
<td>9</td>
</tr>
<tr>
<td>Customers</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Competitors</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Vertical integration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>18</td>
<td>5</td>
</tr>
<tr>
<td><strong>Financial integration</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Risk/Scenario management</strong></td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

Results
Figure 3 shows the result of the review with regard to the percentage of qualitative (L), quantitative (N), and DiPo related papers in relation to the total number of reviewed papers in PIs. By DiPo related we mean the papers which have considered different characteristics for PPr and DPr at each side of DiPo. DiPo related papers are all quantitative and hence, discussed under the quantitative papers below.

As mentioned above, searching for S&OP in PI has generated very few results and hence the keyword “production planning” has also been used to cover the concept. As the results show in Figure 3, in all areas the quantitative papers outnumber the qualitative ones in PI except for financial integration and risk/scenario management. One reason for lack of risk/scenario management is that usually the demand and capacity data are considered deterministic in PIs (Fransoo, 1993). Regarding the financial integration, almost all quantitative papers consider cost/benefit optimization
but in this paper, we did not consider this approach as financial integration based on the presented definition in *The synthesis*

Regarding the quantitative papers several issues can be observed. These papers usually consider the demand rate as deterministic (Fransoo, 1993) while considering maximum capacity as a restriction. These characteristics are related to PPr part of DiPo as stressed in Fransoo (1993). However, the DiPo as a concept has been explicitly considered only in a few number of the reviewed papers. In many cases it can be noticed that the author(s) has considered a hierarchical model.

Regarding the integration issue and due to the modeling and model solving restrictions, they usually have considered a multisite company with several distribution centers and aim to integrate the distribution planning between the company and its distribution centers, see e.g. Feng et al., (2008).

The drawback with some of these papers is that they do not consider the soft benefits of S&OP process as discussed in *S&OP process*. In addition, these papers do not give a vivid view about how medium-term planning should be implemented in PIs.

**Specific characteristics of PIs affecting S&OP/PP**

As illustrated in Figure 3, only 21% of the papers, all quantitative, have taken the PPr part of the production into account. DiPo has been considered in these papers in three ways: S&OP has been done on the bottleneck(s) when the bottleneck is located in the PPr part, DiPo is in packaging so the whole line is of PPr type or DiPo has been specifically distinguished and different models/formulas were used on each side of DiPo. The specific characteristics of PI with this regard are maintenance plans integration, inventory capacity restriction energy provision and consumption (Yin, et al., 2003), and yield percentage (Biswal & Acharya, 2012).

Compared to Table 1, these characteristics are related to resource/capacity utilization which is in line with the significant importance of resource management in PIs. Specialized equipment, capital intensity, extensive effect of equipment failure, long lead-time for capacity increase and relatively low WIP put an emphasis on resource management in PIs which also implies less flexibility in responding to demand fluctuations. Other features mentioned in Table 1 such as routing and changeover time are more of concern in short-term planning.

Yield percentage in addition to variable recipe and divergent material flow (Taylor & Bolander, 1994), and staff planning (Singhal & Singhal, 2007) are related to features of PI other than production system. The only exception is staff planning since PIs usually are not labor intensive. It can be argued that PIs are capital intensive and usually try to follow a level production on both capital and labor. On the other hand, the operators in PIs should be highly specialized and well-trained to work with the specialized equipment (Taylor & Bolander, 1994). Therefore, the hiring/fireing and the training process are crucial for them.

Yield percentage, variable recipe and divergent material flow might not be of interest for all PIs but they might be considered e.g. in steel, aluminum and chemical industries.

**Conclusion and further research**

In this paper we have provided a systematic review about S&OP in PIs. According to our findings, there is not much written on this issue in the literature. Our objectives have been to investigate the present situation of S&OP in PIs and whether their specific characteristics have been included in S&OP process.

Regarding the first research objective, we found out that the number of the quantitative papers outnumbers the qualitative ones and the papers are more focused on
the traditional definition of S&OP rather than newly added aspects such as risk management and financial integration as well as integration in the supply chain.

Following the second research objective, we have scrutinized the definition of process industries through the DiPo concept and looked into the PI papers to figure out if they have distinguished the differences between PPr and DPr in S&OP. The results show that maintenance plans integration, inventory capacity restriction, energy provision and consumption, and yield percentage have been included in the S&OP quantitative models. The first three issues are mainly of interest at the PPr side of DiPo.

Further research might answer the question whether a tailored S&OP framework should be defined with DiPo as the point of reference which matches the specific needs and characteristics of PIs and more specifically PPr.

In addition, it can be said that the implementation and the soft benefits of S&OP related to organizational context for PI have not been well-covered in the literature since the main focus has been on quantitative modeling of the process. It implies the need for more conceptual models to define the needs and the boundaries of PI as the first step for further improvements.

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