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A modularized framework for sales and operations planning with focus on process industries

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ABSTRACT
This paper suggests a modularized sales and operations planning (S&OP) framework, consisting of content and process. The framework’s content is based on a typology of decoupling points in which the effect of decoupling points on the decision variables in S&OP is studied. The framework’s process takes a step back and addresses the need for a more elaborate design to precede the operational use of S&OP content for different production contexts. The framework supports both process industries (PIs) and discrete manufacturing industries (DIs), and recognizes their specific requirements and reflects them in their S&OP. The differentiating characteristics of PIs and DIs are emphasized through three different decoupling points, namely: discretization decoupling point, control mode decoupling point, and customer order decoupling point. The suggested framework aims to fill the gap in the literature regarding the lack of aggregate planning processes that match the PIs’ specific requirements by reflecting the differentiating characteristics of PIs in S&OP.

1. Introduction

Process industries (PIs) and discrete manufacturing industries (DIs) have different characteristics regarding their production processes. From an industry perspective, the DIs and the PIs have therefore been considered as mutually exclusive. There are, however, some properties that are similar and Abdulmalek, Rajgopal, and Needy (2006) developed a concept showing that PIs can in fact be seen as hybrids, meaning that they usually deploy both continuous production and discrete production. Continuous production implies producing ‘with minimal interruptions in the actual processing in any one production run or between production runs of similar products’ and discrete production means producing discrete items (Blackstone, 2010). DIs only deploy discrete production and do not use continuous production, whereas PIs may actually deploy both types of production processes in a hybrid fashion. Not only the different key properties of the production processes imply that DIs and PIs require different planning and control systems, but also that the common discrete production of PIs and DIs can help in identifying similarities between these two types of
industries. This concept has been used as a point of reference for improved planning processes in PIs (see e.g. Pool, Wijngaard, & van der Zee, 2011) which emphasize the specific characteristics of PIs while providing the possibility of learning from the analogies with DIs.

Manufacturing planning and control for PIs have been under study for around 40 years (Van Donk & Fransoo, 2006). PIs were traditionally considered as producers of commodity products in high volumes and long lead-times (Taylor & Bolander, 1994). This picture has changed for PIs in recent years due to their need to also be flexible and responsive to demand to stay competitive in the market (Kopanos, Puigjaner, & Georgiadis, 2012), which puts more emphasis on planning and integration of supply chains (Oliva & Watson, 2011). Nevertheless, PIs have been lagging behind DIs in the implementation of more generic planning processes which match their specific needs (Dennis & Meredith, 2000b). This issue is specifically noticeable at strategic and tactical planning levels, including sales and operations planning (S&OP), due to the long planning horizon and wide decision-making scope (Noroozi & Wikner, 2013; Proud, 1999). S&OP has mostly been seen as a generic process, implying that it is a one-size-fits-all process, independent of the industry in which it is implemented. Considering the unique properties of PIs, in comparison to DIs, the authors of this paper find strong reasons to believe that PIs would benefit if these specific characteristics were integrated into their S&OP. Ivert et al. (2015) employed a similar approach but focused on food industries. Since different types of PIs have similar characteristics from a production point of view, the intention here is to provide a more general perspective, including other types of PIs and their supply chains.

From a supply chain perspective, S&OP is known as an integrator (Basu & Wright, 2008), concerned with both horizontal and vertical integration of the supply chain (Affonso, Marcotte, & Grabot, 2008). S&OP usually affects supply chain performance through the management of resources (referring to cost), output (customer responsiveness), and flexibility (responsiveness to changes and uncertainties), which are vital components to supply chain success, see e.g. Beamon (1999). Different parts of the supply chain may, however, emphasize different types of performance and this is supported by a modular approach to capture the requirements of the supply chain. The importance of a modularized supply chain, based on market, product, and process characteristics, has been long emphasized in the literature to achieve competitiveness, see e.g. Fisher (1997). Considering the importance of S&OP in supply chain management, it is essential for S&OP to recognize, reflect, and manage the different modules of the supply chain. While consideration of market segmentation in S&OP has been partly covered in the literature (see e.g. Burrows, 2012), the integration of all three aspects (market, product, and process) in terms of, for example, market driver, product properties, production repetitiveness, and their interrelations have not been thoroughly covered. In order to fill this gap, the typology introduced by Wikner and Noroozi (2014) is used as the baseline for the suggested S&OP framework in this paper. This typology is based on modularizing the supply chain through key decision categories and the decoupling points – the discretization decoupling point (DDP), the control mode decoupling point (CMDP), and the customer order decoupling point (CODP) – each related to a specific criterion such as the flow driver. The criterion has different properties, related to, for example, forecast driven or customer order driven, for different parts of the flow, and the point where the property changes represents a discontinuity, which is here associated with a decoupling point. The flow pattern changes at the decoupling points (Wikner & Noroozi, 2014), and, accordingly, different managerial approaches and planning decisions
are required at each side of a decoupling point (Giesberts & Tang, 1992; Soman, Van Donk, & Gaalman, 2004; Van Donk, 2001). The decision categories can involve several different aspects, such as driver, product, transformation mode, customization, and controllability. In the current paper, the focus is on entities that can be managed as one integrated system, such as an individual production facility or a production network of integrated facilities. Hence, three types of decision categories are of particular significance: the type of object being transformed in the system, the mode applied in the transformation, and the driver of the transformation. Among these three decision categories, the object type plays the main role in distinguishing between PIs and DIs, that is whether continuous and/or discrete production is involved. The emphasis of the S&OP framework in the current paper is on PIs. The integration of flow driver in S&OP is a common practice (see e.g. Wallace & Stahl, 2008) and the control mode is included in the framework because of the importance of the level of transformation repetitivity in planning processes. This approach leads to inclusion of more detailed information about the supply chain than in the generic S&OP process.

The purpose of this paper is to outline a framework for S&OP that is applicable to PIs as well as DIs and to cover both the content that is the constructs of the framework, and the process used for its implementation, thus including both the design phase and the actual performance of the monthly S&OP. The framework is based on a modularized approach so that the modules of S&OP can be standardized and used across different companies.

The focus on S&OP is due to the crucial role of S&OP in supply chain management as the integrator of inter-firm and intra-firm activities, and its ability to link companies’ strategic and operational levels. The suggested framework emphasizes the need for a more elaborate design to precede the operational use of the S&OP process for different production contexts, and leads companies to reflect on and manage the specific characteristics and requirements of their supply chains based on a modularized approach. A modularized typology is hence used as a point of departure for S&OP, which highlights the generic properties that are in common between PIs and DIs while recognizing their differences through the type of objects involved.

The rest of the paper is as follows. In the next section, the methodology is explained, followed by a review of the selected literature. It then continues with the application of the typology to S&OP and introduces the S&OP framework’s content and process. The paper ends with the application of the framework to a case company, concluding discussion, and some ideas for further research.

2. Methodology

This paper suggests a framework for S&OP that makes a distinction between PIs and DIs through differentiation of continuous production and discrete production. The focus is therefore on ‘what’ to consider in the S&OP and is referred to as the framework’s content as presented in Section 4 and Table 6. In addition, the paper provides guidelines on the implementation of the suggested framework’s content. The focus here is on ‘how’ to implement the content and is referred to as the framework’s process which is presented in Section 5 and Figure 2. Since the paper is of a conceptual nature, the conceptualization process and literature review are further explained.
2.1. Conceptualization process

The research in the current paper is conceptual in nature and thus it is based on theory-building research (Wacker, 1998). According to Wacker (1998), a theory should have four parts: a definition of terms, a domain of when or where the theory is applicable, a description of the relationships between the terms, and predictions. Meredith (1993, pp. 7–8) introduced seven methodologies for conceptual research ranked in ‘explanatory power: conceptual description, taxonomies and typologies, philosophical conceptualization, conceptual induction, conceptual deduction, conceptual systems, and meta-frameworks.’ These seven methodologies are divided into three groups. The first three belong to the conceptual models group, the second three to the conceptual frameworks group, and the last one belongs to the theories group (Meredith, 1993). According to this classification, the current paper belongs to the conceptual frameworks group.

As shown by Noroozi and Wikner (2013), there is a lack of conceptual models that scrutinize the specific requirements and boundaries of PIs. The current paper aims to reduce this gap and provide a foundation for S&OP that highlights the unique properties of PIs compared to DIs. First, the relationship between S&OP and each dimension of the typology is studied separately; second, the cross hybridities between the different dimensions are taken into account; and, finally, the influence of cross hybridity on S&OP is studied. The result is the conceptual framework’s content, which combines the modularized supply chain idea (through decision categories and decoupling points) into S&OP (see Table 6). The differentiation between PIs and DIs is based on object type, related to the physical properties of the product, which is the result of an extensive literature review on S&OP in PIs considering only the object type, see Noroozi and Wikner (2013). In line with Meredith (1993), the framework suggested in this paper is conceptual deduction. Conceptual deduction suggests a framework and provides detailed predictions that can be used for comparison with reality, and also provides managerial insights and guidelines (Meredith, 1993). It should be noted that in conceptual deduction, the relationship between different concepts and predictions is based on logical reasoning and deduction (ibid.). The current paper uses conceptual deduction since it provides a conceptual framework of several concepts (i.e. object type, control mode, and flow driver, as well as S&OP) and the relationships between them. The suggested S&OP framework distinguishes the specific needs of PIs (through continuous and discrete production) and DIs (through discrete production). However, since the emphasis of this paper is on PIs, the one time mode of control mode (which is mainly used in DIs, e.g. in the construction industry) is excluded from this study. In other words, only PIs and DIs with continuous and intermittent mode are in the scope of this paper. For further simplification, the hybrid driven part of flow driver is excluded from this study. The paper also includes managerial insights on the implementation of the framework through the framework’s process, see Figure 2. Consequently, the framework consists of two parts: the framework’s content (presented in Table 6) and the framework’s process (presented in Figure 2) for S&OP. The framework is then applied to secondary data from a steel company in order to illustrate the application of the framework to a case company (Section 6). Following Wacker (1998), this study intends to cover the parts of theory related to the description and the definition of the framework, and partly the explanation, the understanding, and the predictions. The reason is that the existing literature does not thoroughly cover all the aspects of the framework, for example, the hybridities and cross hybridities; and such aspects are instead
logically developed in this paper. The framework has been applied to the secondary data of a case company and has not yet been implemented in a company.

### 2.2. Literature review process

The use of a conceptual method usually implies that a literature review is a fundamental part of the research. This is based on the view that the aim of conceptual models is to provide new insights through logical reasoning into the conventional problems present in the body of literature (Wacker, 1998). Thus, even though the current paper is not a literature review paper *per se*, it uses this method as the basis for data collection. In line with Wacker (1998), the literature review provides the relevant definitions, the existing relationships between variables, and their importance, and the prediction of results. Where needed, new definitions in line with the purpose are suggested and new relationships (e.g. related to hybridities and cross hybridities) are logically developed. Based on both existing and newly developed definitions and relationships, the results are logically predicted where possible based on the literature. The results from the literature are summarized in Tables 2–4, and the interrelations are discussed in Tables 5 and 6 as shown in Table 1. For example, the papers about S&OP in make-to-stock (or speculation driven, SD) and make-to-order (or commitment driven, CD) are reviewed, and the properties which affect the S&OP decision variables are extracted and the results are presented in Table 4. The same procedure has been followed in Tables 2 and 3.

### 3. Literature review

The main focus areas of this paper, i.e. the decoupling points (related to the decision categories), PIs, and S&OP, are investigated from a literature review perspective. The decoupling points provide the conceptual foundation for the framework and are covered first. Next, the PI is briefly described and, finally, the key properties of S&OP are outlined.

#### 3.1. Decoupling points

Flow management is based on decisions about how to design and manage flow as effectively and efficiently as possible. The decision maker faces a wide set of alternatives where some

<table>
<thead>
<tr>
<th>Properties of object type, control mode and flow driver affecting S&amp;OP</th>
<th>Speculation driven (SD): effects of SD on S&amp;OP decision variables (Table 4)</th>
<th>Commitment driven (CD): effects of CD on S&amp;OP decision variables (Table 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous object (CO): effects of CO on S&amp;OP decision variables (Table 2)</td>
<td>Continuous mode (CM): effects of CM on S&amp;OP decision variables (Table 3)</td>
<td>Intermittent mode (IM): effects of IM on S&amp;OP decision variables (Table 3)</td>
</tr>
<tr>
<td>Discrete object (DO): effects of DO on S&amp;OP decision variables (Table 2)</td>
<td>Continuous mode (CM): effects of CM on S&amp;OP decision variables (Table 3)</td>
<td>Intermittent mode (IM): effects of IM on S&amp;OP decision variables (Table 3)</td>
</tr>
<tr>
<td>Effects of hybridities and cross hybridities on S&amp;OP decision variables (Tables 5 and 6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. The S&OP framework’s content structure.**
decision categories are of particular importance. Wikner (2014) showed that the flow based decision categories are related to decoupling points, which imply the recognition of flow discontinuities. The flow pattern changes at a decoupling point and different decisions are required at each side of the decoupling point. The framework developed here is based on this flow logic, but involves a slightly different set of decision categories (onetime mode and hybrid driven are excluded) in comparison with the typology suggested by Wikner and Noroozi (2014). Their typology enables a general modularized approach to the supply chain and can improve understanding of a companies’ supply chain with regard to the flow characteristics that can be used in different contexts, such as planning and control, and resource management in different industries. This paper is focused on S&OP covering PIs (through continuous production in combination with discrete production) and DIs (through discrete production). The approach in the current paper is quite general and does not target a particular type of PI.

The typology involves three decision categories/flow dimensions that have been suggested as important factors in planning and control by researchers such as Constable and New (1976) and Finch and Luebbe (1995). These three flow dimensions are here referred to as object type, control mode, and flow driver, which are key in flow management and thus appropriate for the purpose of this paper. The importance of flow driver has been emphasized in the literature, see e.g. Hoekstra and Romme (1992), Hofmann and Knébel (2013) and Wikner (2014). Flow driver is related to the CODP where flow driver can be either speculation, commitment, or hybrid. Note that CD also is referred to as customer order driven (Giesberts & Tang, 1992) or demand driven (Heikkilä, 2002) in the literature. The object type is essential since it distinguishes PIs and DIs (Noroozi & Wikner, 2013; Pool et al., 2011) through the DDP, which refers to the product properties (continuous or discrete). The control mode is important due to the view it provides on production planning with regard to the repetitiveness of production (MacCarthy & Fernandes, 2000) where the control mode decoupling point (CMDP) is used to identify different levels of repetitivity of the flow in terms of onetime, intermittent, or continuous.

Wikner and Noroozi (2014) refers to continuous production as continuous object (CO) and discrete production as discrete object (DO) and this terminology is used below. For simplification and due to the emphasis on PIs, the hybrid driven-based modules and the onetime mode of their typology are excluded. The result is a three-dimensional matrix with eight modules and three decoupling points as illustrated in Figure 1. The modules are numbered from 1 to 8 and these numbers will be referred to in Table 6 as well.

In PIs, the production process in one site by nature starts with CO and is typically followed by DO (Abdulmalek et al., 2006), meaning that, for example, once packaging has been performed, the package will not be broken before the package leaves the site. In a similar manner, SD precedes CD since once a customer order is received, that particular flow is not changed back to forecast driven. Considering the control mode, having intermittent prior to continuous mode is not common in PIs. Usually continuous production is run in a continuous mode or intermittent mode and then discrete production is run in an intermittent mode. As an example, a liquid is produced in a continuous mode and then goes through a reactor in batches for a particular period of time, and finally the product is packaged in discrete production using batches of different sizes. In some cases, the continuous production is in intermittent mode using, for example, campaigns, and the discrete production may be run in continuous mode but this case is not further included. Therefore,
three fundamental module sequences or hybrid conditions can be identified, where the notation implies ‘upstream–downstream’, according to the material flow. For the object type, the transition is from continuous to discrete (CO-DO), for control mode from continuous to intermittent (CM-IM), and for flow driver from speculation to commitment (SD-CD).

These three dimensions of the typology underline the hybridity inherent in the production process i.e. hybrid CO-DO, CM-IM, SD-CD, or a combination of two or three dimensions. Although different authors, directly or indirectly, have discussed how hybridity within each dimension influences S&OP, the combination of different dimensions or cross hybridity, see Wikner and Noroozi (2014), and its effect on S&OP has not been covered in the literature, despite its significance for planning and control.

3.2. Process industry

PIs consist of production facilities that ‘produce products by mixing, separating, forming and/or performing chemical reactions’ (Blackstone, 2010). PIs are traditionally considered to deploy process flow production, referred to in this paper as continuous production (or CO). However, it has recently been suggested that they actually are hybrids, i.e. in their production process there is a point where COs turn into DOs and hence discrete final products are produced (Abdulmalek et al., 2006). This point is referred to as the point of discretization by Pool et al. (2011, p. 194), but in this paper we refer to it as the DDP in order to stress its nature as a decoupling point.

The flow of materials (from a time perspective), which is referred to as control mode, in the PIs can be either intermittent (batch) or continuous (Dennis & Meredith, 2000a; Fransoo, 1993; Woodward, 1965). It should be noted that DIs can also use intermittent and/or continuous modes. Thus, while discussing the differentiating characteristics of process production and discrete production, the influential factor is the continuity of the object, which affects the choice of production processes and resources (Fransoo & Rutten, 1994). These characteristics, for example, long set-up time, divergent material flow, and high capital intensity (for more information, see Noroozi & Wikner, 2013), influence the manufacturing planning and control processes of PIs (Dennis & Meredith, 2000b).
3.3. Sales and operations planning

S&OP emerged from manufacturing resource planning (MRPII) (Wight, 1984) and has been improved since the 1970s (Basu & Wright, 2008). S&OP has a limited direct impact on the material plans of the enterprise and mainly focuses on identifying the capacity required to fulfill expected future demand. This is frequently referred to as establishing a 'game plan' for the company, and since it is inherently cross-functional, the process of defining the plans has received considerable attention. This process is usually considered to be generic (Grimson & Pyke, 2007) and is defined as:

a process to develop tactical plans that provides management the ability to strategically direct its businesses to achieve competitive advantage on a continuous basis by integrating customer-focused marketing plans for new and existing products with the management of the supply chain. (Blackstone, 2010)

From a content perspective, S&OP targets aggregate data, such as product families and clusters of resources. The process of S&OP is usually monthly and aims to create a balance, or integration, between demand and supply plans at the aggregate level (Ling & Goddard, 1988; Wallace & Stahl, 2008). The planning horizon can be between three months and three years (Gianesi, 1998; Grimson & Pyke, 2007); however, most researchers focus on the horizon of between 12 and 18 months (Wallace & Stahl, 2008) in order to cover the whole marketing cycle for companies with a seasonal profile (Grimson & Pyke, 2007; Jonsson & Mattsson, 2009).

Traditionally, the S&OP process seeks a balance between demand and supply plans. Advanced S&OP, however, includes a balance between strategic and operational plans, and the integration of financial plans, risk and scenario management, and customers, suppliers, and competitors in this process (Noroozi & Wikner, 2013; Viswanathan, 2011). S&OP is a cross-functional process, and during the process different functions, including sales and marketing, production, finance, human resources, purchasing, and product development, should cooperate and come to an agreement on the final plan (Wallace & Stahl, 2008). It is also worth mentioning that even though S&OP is mainly considered to be located at the tactical level, it has extensions towards the strategic level, for example, when it deals with capacity expansion (Thome, Scardava, Fernandez, & Scardava, 2012) or risk management (Wallace & Stahl, 2008).

Such a cross-functional process may be performed in several different ways, but a quite established and generic S&OP process has developed over time as a result of the work of several authors such as Wallace and Stahl (2008) and Jacobs, Berry, Whybark, and Vollmann (2011). The process has five steps: data gathering, demand planning, supply planning, pre-meeting, and executive meeting. First, the process is about gathering data for demand and supply planning. Next, a demand plan is prepared which is mainly focused on forecasting future demand for present and new products. This plan is sent to the next step where capacity planning is performed based on the demand plan (required capacity), available capacity and inventory/backlog levels. In the two final steps, people from different related areas in the company gather and discuss issues related to the balance between the demand and supply plans and come to an agreement on a final game plan for the company (Jacobs et al., 2011; Wallace & Stahl, 2008). These five steps are used as a baseline to unify the presentation of the results of this paper and are divided into three groups: demand planning, supply planning, and balancing. This is due to the fact that the first step of the
process provides information for other parts and the last step is mainly concerned with confirmation of the game plan.

4. **S&OP framework’s content based on the decoupling typology**

The framework consists of two parts related to content and process, respectively. The process is developed once the content is established. The framework’s content is developed in three steps. First, each dimension of the typology is investigated separately in terms of how it affects S&OP. In this context, the hybridity within each dimension is also studied. Then the focus is on cross hybridity at the intersection between the two dimensions and its influences on S&OP. Finally, the integrated framework’s content for S&OP in PIs is developed, see Table 6, which is the result of integrating all three dimensions. It should be emphasized that each manufacturing entity falls into at least one of the eight modules in Figure 1 based on the positions of the decoupling points. Thus, all entities are cross hybids of object type, control mode, and flow driver.

4.1. **S&OP and the three dimensions of the modular typology**

In order to understand the effect of the typology on S&OP, it is crucial to first scrutinize the influence of each dimension separately. This part deals with the interaction between S&OP and object type, control mode, and flow driver one at a time as presented in Tables 2–4. It should be noted that Table 2 is the result of a literature review by Noroozi and Wikner (2013) but Tables 3 and 4 are new contributions of the current paper.

The properties related to the three dimensions of the typology can be considered as decision variables *per se* as they are or as an influence on other decision variables in S&OP. Some examples of decision variables in a generic S&OP are sales volumes and production quantities of product families, inventory and backlog levels, set-up time between product families and cycle time for each family, capacity allocation, and the need for new investments (Feng, D’Amours, & Beauregard, 2008; Wallace & Stahl, 2008).

4.1.1. **S&OP and object type**

As mentioned above, an important difference between PIs and DIs is the continuity of materials/products. Therefore, all PIs are either of type pure CO or hybrids of CO-DO. A pure DO system (and the corresponding S&OP) has already been discussed in the literature review on S&OP for discrete manufacturing. Note that CO and DO here indirectly refer to continuous production and discrete production, where the objects are of type CO and DO, respectively. The main goal of S&OP is to balance demand and supply plans. Important factors to consider in S&OP, here referred to as generic S&OP, plus the properties which are of specific interest to CO, and hence PI, are gathered in Table 2 (for more information about the generic S&OP, readers are referred to, for example, Grimson & Pyke, 2007; Thome et al., 2012; Viswanathan, 2011; Wallace & Stahl, 2008).

It should be noticed that the generic S&OP attributes have mainly been defined for DIs or are considered to be industry generic (Noroozi & Wikner, 2013), thus DO characteristics are included in the industry generic S&OP column. Specific CO properties gathered in Table 2 are the result of a literature review about S&OP in the process industry by Noroozi
Table 2. Generic/discrete object and specific continuous object properties (decision variables) to be considered in S&OP (Noroozi & Wikner, 2013; Wallace & Stahl, 2008).

<table>
<thead>
<tr>
<th>S&amp;OP attributes</th>
<th>Important factors regarding the object type</th>
<th>Process industry specific properties related to continuous objects (COs)</th>
<th>Industry generic properties related to discrete objects (DOs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand planning</td>
<td>Demand forecasting</td>
<td>New product introduction (higher frequency of new product development and demand uncertainty)</td>
<td>Forecast based on sales plan, marketing plan, new products and customers</td>
</tr>
<tr>
<td>Resources</td>
<td>Variable yield's effect on the throughput</td>
<td>Bottlenecks (inventory capacity restriction, laboratory capacity restriction)</td>
<td>Bottlenecks (mainly production capacity restriction)</td>
</tr>
<tr>
<td>Capacity utilization</td>
<td>Supply uncertainty (seasonality of raw material and dependency on nature)</td>
<td>Inventory/backlog level Maintenance plans integration</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td>Supply capacity restriction</td>
<td>Long lead-time materials</td>
<td></td>
</tr>
<tr>
<td>Balancing</td>
<td>Balance of demand and supply</td>
<td>--</td>
<td>Integration of different parties involved in the process</td>
</tr>
</tbody>
</table>

and Wikner (2013). These properties have been considered by different researchers to be important before the DDP.

Most of the issues related to CO in Table 2 are of interest to all PIs except yield percentage, variable recipe, divergent material flow, and perishability. These factors might be specifically considered, for example, in the steel, aluminum, food, and chemical industries. The table also highlights the significance of supply planning in PIs (Noroozi & Wikner, 2013). The results from Table 2 are used to shape the S&OP framework’s content in Table 6. It should be noted that since the generic S&OP attributes have mainly been defined for DIs, these attributes are presented once in the fourth column of this table to avoid repetition and this is used as the basic model for S&OP.

S&OP and hybrid CO-DO: As mentioned earlier, most PIs are hybrid CO-DO; sometimes referred to as ‘semi-process industries’ (see, e.g. Pool et al., 2011) or pure CO. All factors related to industry generic S&OP in Table 2 are also valid for PIs since they provide the foundation of S&OP. While some of the CO properties in Table 2, such as maintenance plan integration, energy provision and consumption, and demand and supply uncertainty, can be of interest for DO, some others, such as yield percentage, variable recipe, or seasonality of raw materials, are relevant to CO. Inventory capacity restriction can also be applicable for DO through consideration of a tight maximum inventory level in case, for example, the inventory cost is high or in a lean environment where inventory levels are explicitly constrained by, for example, physical means. In general, however, these characteristics are of greater importance and more relevant for CO than for DO and thus are emphasized in the S&OP for PIs.

4.1.2. S&OP and control mode

PIs can apply intermittent mode (campaign or batch) or continuous mode (Woodward, 1965). The difference lies in the set-up time which affects the choice of the planning system
In most PIs (referring to CO/continuous production), set-up time has a great influence on the planning process since set-ups are usually long and partly sequence-dependent (Taylor & Bolander, 1994; Van Donk, 2001). Cleaning is an important part of the set-up time in PIs. Based on the type of industry, for example, in food or pharmaceutical industries, it can account for up to 50% of labor losses per set-up (McIntosh, Matthews, Mullineux, & Medland, 2010).

Olhager and Rudberg (2002) suggest that in comparison to market and product characteristics, the flow of material and the process choice is less influential at the S&OP level. Nevertheless, they consider that the level and chase S&OP strategies would be appropriate for CM and IM, respectively.

In the case of CM, it is assumed that it is possible to neglect the set-up times, and hence this issue does not have any influence at the S&OP level, and only the production volume may need to be configured. This situation can exist in dedicated production lines, where no set-ups are required, or in lines where the set-up time is insignificant. In case of IM, and due to the fact that S&OP is performed at an aggregate level, the set-up time between two subsequent product families are usually taken into account while the set-up times within the product families are neglected. Consequently, the objective is to minimize the set-up costs, see e.g. Neureuther, Polak, and Sanders (2004), Omar and Teo (2007) and Feng et al. (2008). The control mode properties affecting S&OP are gathered from Taylor and Bolander (1994), MacCarthy and Fernandes (2000), Olhager and Rudberg (2002), and O’Reilly, Kumar, and Adam (2015) in Table 3.

For IM companies, cyclic planning through campaigns has been suggested as an effective way to deal with the fill rates, the inventory level, and the utilization of equipment. At the S&OP level, decisions should be made on the length of the cycle time for each product family, which is based on the set-up times, available capacity, and the desired inventory level (Fransoo, 1993; Pool et al., 2011; Soman et al., 2004). The results from Table 3 are used to shape the S&OP framework’s content in Table 6.

S&OP and hybrid CM-IM: As discussed earlier, the main issue concerning the control mode is the set-up time. In the case of a hybrid CM-IM system, the issue that can cause problems is the meaningful difference between the capacities of the CM-based part and the IM-based part of the flow. If the capacity of the CM-based part is more than the IM-based part, either a buffer is required between them (Kopanos et al., 2012) or the production process of the CM-based part would eventually be halted if all capacity is used. If a buffer is used, the buffer capacity and the perishability of intermediate products should be considered. If no buffer is used, then eventually the CM part will have to stop and the start-up of the continuous processes should be considered, which might be very expensive, and thus an alternative might be to eventually produce in batches instead (Pool et al., 2011; Taylor &

### Table 3. Continuous mode and intermittent mode properties (decision variables) to be considered in S&OP.

<table>
<thead>
<tr>
<th>S&amp;OP attributes</th>
<th>Important factors regarding the control mode</th>
<th>Continuous mode (CM) properties</th>
<th>Intermittent mode (IM) properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand planning</td>
<td>–</td>
<td>–</td>
<td>Cycle time (campaign) for product families</td>
</tr>
<tr>
<td>Supply planning</td>
<td>Production planning</td>
<td>Production rate</td>
<td>Set-up time (sequence dependent)</td>
</tr>
<tr>
<td>Balancing</td>
<td>Planning strategy</td>
<td>Level</td>
<td>Chase</td>
</tr>
</tbody>
</table>
In case the capacity of the CM-based part is less than that of the IM-based part, then the IM processes might be starved, resulting in lower utilization of production processes which usually is very expensive in PIs, especially in relation to CO. Regarding the S&OP, the balance of production in the two parts, the buffer/inventory levels and the start-up or set-up time/costs, should be taken into account.

4.1.3. S&OP and flow driver

Three main demand/supply strategies are defined based on flow driver: SD (MTS), CD (MTO), and finish-to-order (FTO). FTO is considered a hybrid of SD and CD and is therefore discussed in the next section.

SD dominated systems usually compete on low prices, so performance measures such as cost and productivity are important and they follow the S&OP level strategy (Olhager, 2003), which implies mass production, economies of scale, and high utilization of the equipment. In addition, due to market expectations of very short lead-times, these companies keep inventories of end products to fulfill demand (Pagh & Cooper, 1998). Such inventories are used to absorb demand fluctuations as well. Therefore, in these companies, decisions about the level of production, lot sizes, and the inventory of product families are important in S&OP (Soman et al., 2004; Wallace & Stahl, 2008).

In CD dominated systems, on the other hand, companies compete on design, flexibility, and delivery speed and precision. The important performance measures for these companies are flexibility and delivery lead-times. Hence, they follow the chase S&OP strategy (Olhager, 2003), which implies keeping free capacity and consequently lower utilization of equipment. Based on the expected delivery lead-time from the market, and in order to keep utilization at an accepted level, these companies usually focus on the backlog level instead of the inventory level (Olhager, Rudberg, & Wikner, 2001; Olhager, Selldin, & Wikner, 2006). The production and backlog levels are the focus of S&OP in these types of companies (Soman et al., 2004; Wallace & Stahl, 2008). Flow driver properties affecting S&OP from the above mentioned authors are summarized in Table 4.

Olhager et al. (2001) took this a step further and linked the planning strategies (level, chase, and mix) with capacity strategies, i.e. lag, lead, and track. They suggest that lag and lead strategies should be matched with level and chase, as used in S&OP, respectively. This link is important since S&OP is located between the tactical and strategic levels in the planning hierarchy (Olhager & Rudberg, 2002; Thome et al., 2012; Wallace & Stahl, 2008). In addition, decisions regarding supply planning in S&OP are used as an input (or feedback) to strategic planning (Jacobs et al., 2011). A level planning strategy implies high utilization of equipment, which is in line with the capacity to lag behind the demand changes. A chase strategy implies a high level of flexibility or keeping capacity cushions which are aligned with the capacity to lead the demand changes (Olhager, 2003; Olhager et al., 2001). Mix strategy, also known as hybrid/combined strategy (Arnold, Chapman, & Clive, 1998), is further discussed below in the section on cross hybridity of control mode and flow driver. The results from Table 4 are used to shape the S&OP framework’s content in Table 6.

S&OP and hybrid SD-CD system: The planning and control of PIs in a hybrid SD-CD system is intuitive yet challenging. In general, the CODP is associated with a stock point (Hoekstra & Romme, 1992), but stock points in PIs are usually constrained due to both product characteristics and the sheer volume often involved in PIs, and in particular in relation to COs. The challenges for PIs hence include the cost of low utilization of equipment before
the CODP, the possibility of decoupling the production process and adding to the CODP stock point, the capacity of the stock point, and the selection of intermediate products, see e.g. Caux, David, and Pierreval (2006), and Kilic, Akkerman, Van Donk, and Grunow (2013).

The CODP divides the production process into one SD-based part and one CD-based part with fundamentally different characteristics (Olhager, 2003). Before and after the CODP, lean and agile approaches are respectively suitable (Mason-Jones, Naylor, & Towill, 2000; Wikner & Rudberg, 2005). While the lean approach is focused on efficiency and a low inventory level, the agile approach values flexibility and responsiveness in planning (Maskell & Baggaley, 2004; Naylor, Naim, & Berry, 1999; Sabri & Shaikh, 2013). A level S&OP strategy is therefore suitable before the CODP, and a chase strategy after this point (Olhager et al., 2006). The objective here is to integrate the SD-based part and CD-based part into a framework. There are two papers (Rafiei & Rabbani, 2012; Soman et al., 2004) which have considered a similar issue for S&OP. In these papers, the discussion is based on products rather than modules but the analogy is clear and SD products are produced in SD-based parts and CD products in the corresponding CD-based parts. The SD-based and CD-based parts are however performed by the same resource and hence both these cases actually correspond to hybrid driven of the decision category flow driver, which is not included in this framework. Giesberts and Tang (1992) also mention this type of hybridity but also this case is hybrid driven.

### Table 4. Speculation driven and commitment driven properties (decision variables) to be considered in S&OP.

<table>
<thead>
<tr>
<th>S&amp;OP attributes</th>
<th>Important factors regarding flow driver</th>
<th>Speculation driven (SD) properties</th>
<th>Commitment driven (CD) properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demand planning</td>
<td>Demand</td>
<td>&amp;OP based on forecast</td>
<td>S&amp;OP based on customer orders and forecast</td>
</tr>
<tr>
<td>Supply planning</td>
<td>Capacity strategy</td>
<td>Lag</td>
<td>Lead</td>
</tr>
<tr>
<td></td>
<td>Buffering policy</td>
<td>Safety stock level</td>
<td>Safety capacity level</td>
</tr>
<tr>
<td></td>
<td>Hedging</td>
<td>Inventory level</td>
<td>Backlog level</td>
</tr>
<tr>
<td>Balancing</td>
<td>Planning strategy</td>
<td>Level</td>
<td>Chase</td>
</tr>
</tbody>
</table>

4.2. **S&OP and cross hybridity**

Most manufacturing companies are cross hybrids in terms of applying a mixture of CO-DO, CM-IM, and SD-CD. The planning process of these cross hybrid systems has been a challenge for many researchers and companies (Giesberts & Tang, 1992; Soman et al., 2004; Van Donk, 2001). In this part, the cross hybridities between the dimensions are discussed. The main focus is still on the PIs.

#### 4.2.1. S&OP and cross hybridity of object type and control mode

From an S&OP perspective, the two dimensions – object type and control mode – are independent since PIs can practically use both CM and IM regardless of the position of the DDP. In the case of IM, both the CO-based part and the DO-based part should consider the set-up times and lot-sizing problem. Still, it might be problematic in the context of a CO-based part to apply the chase strategy due to the importance of high utilization. This issue is discussed further in the section on S&OP and cross hybridity of the control mode and flow driver.
4.2.2. **S&OP and cross hybridity of object type and flow driver**

A main point in this cross hybrid situation is that the DDP and the CODP cannot be positioned at the same place during the production process since the DDP is related to a transformation process (Abdulmalek et al., 2006) and the CODP to a stock point (Hoekstra & Romme, 1992). Hence, there are two possible relative positions of the DDP and the CODP. Having the CODP before the DDP in the production process requires specific attention in S&OP regarding the possibility of decoupling the production process and adding buffers in the CO-based part, the capacity of the buffers, and the selection of intermediate products (Akkerman, Van Der Meer, & Van Donk, 2010; Caux et al., 2006; Kilic et al., 2013; Sharda & Akiya, 2012; Van Hoek, 1999). PIs have a divergent material flow (Fransoo & Rutten, 1994) and the variety of stock keeping units (SKUs) usually depends on the packaging options which may be based on customer orders and are, therefore, related to the CODP to a large extent. On the other hand, packaging is always at or after the DDP since packaging implies creating discrete, packaged objects. This implies that the variant explosion in the material flow is highly connected to the position of the DDP and the CODP. As mentioned earlier, decoupling the production process and adding buffers before the DDP is not always possible. This implies that the CODP in PIs is more prone to being positioned after the DDP. Also considering the properties related to flow driver, keeping capacity buffers and following a chase strategy are economically more reasonable in DO than CO.

4.2.3. **S&OP and cross hybridity of control mode and flow driver**

This cross hybridity, as illustrated in Table 5, indicates mismatches when a mixture of CM-CD or IM-SD exists in a production process since they imply two contradictory production strategies: level and chase.

PIs are traditionally considered to apply a pure level and lag strategy due to the importance of high utilization and low cost (Taylor & Bolander, 1994). One option to address this problem could be to apply a mix strategy, that is change the production level several times during the planning horizon but not as often as in the chase strategy. The application of the chase and the mix strategy is, however, limited in PIs (related to CO/continuous production) due to the importance of high utilization and long lead-times to increase capacity; however, they are both applicable in the DO/discrete production.

Mix strategy is in line with the track manufacturing strategy, which implies the acquisition of capacity in small steps. PIs, specifically in relation to the CO part, are restricted in the implementation of this strategy since, for example, working overtime or changing the staff level is usually not possible for them. Nevertheless, other options – such as subcontracting, inventory building, or short-term control of demand by, for example, initiating sales programs – can be considered (Maskell & Baggaley, 2004; Olhager et al., 2001).

<table>
<thead>
<tr>
<th>Table 5. Control mode and flow driver cross hybridity.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speculation driven (SD) (Level)</td>
</tr>
<tr>
<td>---------------------------------</td>
</tr>
<tr>
<td>Continuous mode (CM) (Level)</td>
</tr>
<tr>
<td>Intermittent mode (IM) (Chase)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

(Ability to ignore the table and mention the content can be helpful in case it’s not needed for the question)
Table 6. The S&OP framework’s content in terms of the eight modules of the typology.

<table>
<thead>
<tr>
<th>Properties of object type, control mode, and flow driver affecting S&amp;OP</th>
<th>Speculation driven (SD)</th>
<th>Commitment driven (CD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous object (CO)</td>
<td>Demand planning: forecast-based</td>
<td>Demand planning: customer order-based</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Supply planning: lag strategy, inventory and safety stock level</td>
<td>Supply planning: lead strategy, safety capacity and backlog level</td>
</tr>
<tr>
<td>Demand planning: --Supply planning:</td>
<td>Module 1</td>
<td>Module 2</td>
</tr>
<tr>
<td>Production rate</td>
<td>CO-CM-SD</td>
<td>CO-CM-CD</td>
</tr>
<tr>
<td>Balancing: level prod.</td>
<td>Match</td>
<td>Mismatch, refer to Table 5</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Module 2</td>
<td>Module 4</td>
</tr>
<tr>
<td>Intermittent mode (IM)</td>
<td>Demand planning: cycle and set-up time</td>
<td>CO-IM-SD</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Balancing: level prod.</td>
<td>Mismatch, refer to Table 5</td>
</tr>
<tr>
<td>Demand planning: production rate</td>
<td>Module 3</td>
<td>Module 4</td>
</tr>
<tr>
<td>Balancing: level prod.</td>
<td>CO-IM-SD</td>
<td>CO-IM-CD</td>
</tr>
<tr>
<td>Intermittent mode (IM)</td>
<td>Mismatch, refer to Table 5</td>
<td>Match</td>
</tr>
<tr>
<td>Discrete object (DO)</td>
<td>Module 5</td>
<td>Module 6</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Demand planning:</td>
<td>Demand planning:</td>
</tr>
<tr>
<td>Demand planning: production rate</td>
<td>--Supply planning:</td>
<td>customer order-based</td>
</tr>
<tr>
<td>Balancing: level prod.</td>
<td>Production rate</td>
<td>Supply planning:</td>
</tr>
<tr>
<td>Intermittent mode (IM)</td>
<td>--Supply planning:</td>
<td>lead strategy, safety</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Cycle and set-up time</td>
<td>capacity and backlog</td>
</tr>
<tr>
<td>Demand planning: production rate</td>
<td>Balancing: chase prod.</td>
<td>level</td>
</tr>
<tr>
<td>Continuous mode (CM)</td>
<td>Module 7</td>
<td>Module 8</td>
</tr>
<tr>
<td>Demand planning: --Supply planning:</td>
<td>DO-IM-SD</td>
<td>DO-IM-CD</td>
</tr>
<tr>
<td>Production rate</td>
<td>Mismatch, refer to Table 5</td>
<td>Match</td>
</tr>
<tr>
<td>Balancing: chase prod.</td>
<td>Module 8</td>
<td>Match</td>
</tr>
</tbody>
</table>
4.3. The S&OP framework’s content

The S&OP framework’s content studies the integration of all three decision categories illustrated by the three dimensions of the typology and its effect on S&OP. All companies are recommended to consider the generic S&OP properties presented in Table 2 as the foundation of their S&OP. A summation of the issues discussed so far is illustrated in Table 6 with regard to each of the eight modules shown in Figure 1 and are numbered accordingly. The results from Tables 2–4 regarding demand planning, supply planning, and balancing are presented in the first two columns and the first row of Table 6.

Thus, in addition to generic S&OP, the issues presented in Table 6 should be given further consideration and be integrated into the five steps of the S&OP process. Mismatches happen in modules 2, 3, 6, and 7, where a mixture of CM-CD or IM-SD exists since CM and SD imply level production and CD and IM imply chase production (see Table 5). As an example, a company with a part of the flow characterized as CO-IM-SD (Module 3 in Table 6 and Figure 1) is assumed to consider the CO properties corresponding to the first column of the table (e.g. energy costs), IM properties in the second column, third row of the table (e.g. cycle and set-up time, and chase production), and SD properties in the third column, first row of the table (e.g. lag strategy and level production) in the decision-making in S&OP. In case of a mismatch, as in this example, the discussion relating to Table 4 can provide further guidelines.

According to the market, products, and processes of a company, the related supply chain can be a combination of one or more of these modules, identified by numbers 1–8 in Table 6 and Figure 1. For such supply chains, S&OP should be based on the specific properties of each module as well as being able to combine two or more of the modules in a unified process. In the case of cross hybridity, balance of capacity between CM and IM and capacity allocation between SD and CD parts should be considered in the S&OP. An example from a case company is provided below, but first the framework’s process is outlined.

5. S&OP framework’s process based on the decoupling typology

In the previous section, the main factors relating to each module of the typology and the hybridities and cross hybridities were scrutinized. Based on that discussion, a guide for the implementation of the framework’s content is suggested below. In Figure 2, the framework’s process for implementation starts with product families identification and segmentation.
(Burrows, 2012; Sabri & Shaikh, 2013) and continues with the positioning of the decoupling points per product family (Pool et al., 2011; Rafiei & Rabbani, 2012), assigning the product families to the modules, performing S&OP, and ends with a follow-up step for evaluation and improvement (Jacobs et al., 2011; Wallace & Stahl, 2008).

It can be noticed that in these steps, the process is extended to also cover the design of the S&OP to be performed. As indicated with a frame in Figure 2, the first three steps belong to the design phase when different product families are assigned to the appropriate modules of the typology. There can be several iterations between the first three steps until a design that is useful in practice is achieved. In step 4, the monthly S&OP is performed and the results evaluated, and in step 5 the feedback is provided to the previous steps. In the case when a redesign is required, the design phase is performed again and accordingly the monthly S&OP.

5.1. Step 1: identify and segment the product families

This step is based on the properties of the products and the markets. Each product might have various realized values (Latamore, 2001) as well as different CODPs at different markets, which affect the demand planning phase of S&OP (Sabri & Shaikh, 2013). Therefore, the first step is to define the product families based on the markets they serve. However, S&OP should be based mainly on volume level and if possible avoid detailed mix issues (Wallace & Stahl, 2008). Thus, the individual product levels of the assumed mix in the product family should be aggregated with each other in a way to provide the most consistency between marketing (demand) and production (supply) (Sabri & Shaikh, 2013). One way to address this issue is to define the product families based on the production process and divide it further into sub-product families based on market characteristics (Burrows, 2012). The other way round would be to consider market segmentations based on geographical location (Jacobs et al., 2011) and then translate this classification into production product families (Wallace & Stahl, 2008). The point is that product segmentation based on market characteristics helps companies to remain focused on their key products/customers and strengthen their competitive position (Latamore, 2001). It also implies that in each segment, different strategies and managerial decisions are required, which should also be reflected in the S&OP since S&OP is the bridge between the company’s strategies and its operations.

The segmentation into product families does not need to be updated every month as the criteria that affect the segmentation do not change frequently (Soman et al., 2004). The suggestion is to update these criteria quarterly (Godsell, Diefenbach, Clemmow, Towill, & Christopher, 2011), but it can be considered as an event-driven task, based on, for example, the feedback from step 5, as well as in cases when significant changes influencing the segmentations occur. This strategy helps companies to be proactive rather than reactive (Grimson & Pyke, 2007).

5.2. Step 2: position the decoupling points per product family

Besides CODP, which is related to product and market properties, the two other decoupling points are affected by the production process. In this step, the position of the decoupling points for each product family should be determined since it influences the specific design of the S&OP process according to the framework. The CM-based and IM-based parts, and the
position of CMDP, must be identified due to their importance in the supply planning part of S&OP. Identifying the DDP is straightforward since it is related to the physical attributes of the products and is given by the design of the physical flow. In addition, it is most probably the same for different products in a product family or for all families being produced on a production line due to the effect of object continuity on the production processes and resources. A similar reasoning is valid for the CMDP. Positioning the CODP, on the other hand, could be more complex since the CODP can be positioned in different parts of the flow for different products and markets and sometimes shifts over time. In this paper, it is considered that the products in a product family have the same CODP. Note that customization is different from flow driver (CODP). After the CODP, a product may be either standard or customized, but this distinction is not included in the discussions in this paper.

It should be noticed that the position of the CODP is an input from strategic planning to S&OP (Rafiei & Rabbani, 2012; Willems, 2013) and the positions of the two other decoupling points are mainly based on properties of the production process. Therefore, step 2 is out of scope for performing the S&OP, but still a fundamental part of the design phase of the framework and an important input to the S&OP.

5.3. Step 3: assign the product families and process steps to the modules

This step brings the market, the product, and the process aspects together. Product families and production steps can be located in at least one of the eight modules, see Table 6. In PIs, hybridity in at least one dimension (i.e. object type) exists unless the DDP is positioned at the very end of the production process, for example, when the CO is loaded in trucks or trains for delivery or transported in pipelines. The output of this step is the actual design of the flow in terms of a set of modules selected during configuration of the supply chain.

5.4. Step 4: perform S&OP periodically

In this step, the generic S&OP process as suggested by, for example, Wallace and Stahl (2008) and Jacobs et al. (2011) is performed. This process has been explained briefly in the literature review section. In addition to this generic process, companies should also consider the specific add-ons to their S&OP decision variables according to the position of each product family in the framework’s content, as illustrated in Table 6. At this level, the company should achieve a consensus for future demand, inventory levels for end and intermediate products, backlog levels, production levels, capacity allocation policies, and cycle length. In addition, for CD product families, the policy for order acceptance should be developed (Fransoo, 1993; Soman et al., 2004). To be in line with the focus on PIs, the relevant issues gathered in Table 2, such as demand uncertainty, maintenance plans, energy issues, and inventory restrictions, should be integrated into the S&OP as well.

5.5. Step 5: follow-up and feedback

It is of great importance to evaluate the process in order to find the opportunities for further refinements and improvements. Since S&OP is a cross-functional process, it is beneficial to use cross-functional measures in order to integrate different functions with various, or even contradictory, goals. Different companies might need different sets of measures based on, for
example, the position of their product families and processes in the modules of the typology used in this paper. The point is that the framework’s content can be used as a basis for designing a specific measurement system at S&OP level for each company. Some examples of measures are capacity utilization (Hahn & Kuhn, 2012) for CO, inventory level and forecast accuracy (Davis & Novack, 2012) for CM and SD, and set-up cost (Olhager & Rudberg, 2002) for IM. Financial metrics, such as revenue, profitability (Cecere, 2005; Muzumdar & Fontanella, 2006), cash conversion cycle and gross profit margin (Viswanathan, 2011), act cross-functionally in order to integrate different functions and goals.

Based on the identified problems, it is necessary to go back to the previous steps and modify the process. A tuned up-to-date S&OP helps companies to improve their financial measures, responsiveness to market changes, time to market (Sabri & Shaikh, 2013), performance measures (Gianesi, 1998), and customer satisfaction (Muzumdar & Fontanella, 2006). Note, however, that the measures to be used in the follow up should already have been integrated into the process during the design phase to be aligned.

An example is provided in the next section to show how the framework’s process steps can be applied to a case company.

6. Illustration from a steel company

In this section, the secondary data from a steel company in Rudberg and Cederborg (2011), has been used to illustrate the framework’s content and process. Steel companies are typically considered as PIs and have a DDP in their production process. This case is interesting since it involves all three decoupling points of the framework and is thus useful for our purpose. It should, however, be noticed that in other cases only a subset of the three decoupling points might be present.

The company’s sales are divided into two parts: 40% of the sales are on SKUs, which are MTS, and 60% of the sales are on external grade thickness groups (EGTs) which are product families that are FTO (Rudberg & Cederborg, 2011). Since S&OP is mainly focused on product families, the MTS families (SKUs) are excluded and the current paper only considers the FTO families (EGTs). The production process for the FTO product families starts with conversion of coal into coke in the coking plant. The coke is then heated up continuously with the iron ore and limestone in the blast surface. The hot metal is then continuously fed to the torpedo cars each with the capacity for 300 tons of molten metal. The hot metal is thereafter conveyed to the LD converter and ladle surface for further processes, and finally

![Figure 3. Supply chain modules of the steel company.](image-url)
in the continuous casting machine the steel is converted into solid form and cut into slabs. These slabs are then transported to the rolling mills to be further processed and cut into plates with the right sizes and thickness according to the customers’ orders (The Steel Book, 2009; The Steel Book, 2012). The suggested implementation steps for the case company are as follows.

**Step 1:** Identify and segment product families: the segmentation is generally based on geographical areas which are called business areas (Rudberg & Cederborg, 2011). The business areas are further divided into geographical sales areas and sales regions (ibid.). Thus, product/market segmentation is based on geographical location and should be translated into production product families to be used in the S&OP process.

**Step 2:** Position the decoupling points per production product family: as mentioned earlier, the positions of DDP and CMDP are dependent on the production process and are usually the same for product families which are produced on the same production line. As explained above, in this steel company the DDP is positioned in the continuous casting machine and CMDP is in the torpedo cars. The position of CODP in this case company is the same for all product families (regardless of the market they are sold in) and is positioned at the inventory before the rolling mill.

**Step 3:** Assign the product families and process steps to modules: the identified modules, according to the typology of Figure 1, are shown in Figure 3 where the modules are outlined as a sequence from a flow perspective. For each module, the property of each dimension is indicated on the side of the corresponding box in the figure. Red text indicates that the property has changed since the previous module in the flow. For example, the second module from the left is CO-IM-SD (module 3) and since IM is indicated with red, it is different from the previous module CO-CM-SD (module 1).

All types of hybridities and several cross hybridities are present in this example and should be reflected in the S&OP since they imply the need for different decision support. The following modules are used and illustrated in Figure 3: CO-CM-SD (module 1), CO-IM-SD (module 3), DO-IM-SD (module 7), and DO-IM-CD (module 8). As can be noticed, this is a typical FTO case since the production process trigger is based on speculation for the first three modules and the steps of the final module are performed according to customers’ orders.

**Step 4:** Perform S&OP periodically: referring to the case company and considering the four identified modules in step 3, in addition to the generic S&OP process the following factors should be taken into account. The steel company uses heat in different production processes in order to, for example, melt the metal, so energy consumption and cost are important properties/decision variables in the S&OP related to CO part (see Table 6) in order to achieve maximized profit (Rudberg & Cederborg, 2011). At S&OP, the CM and IM are not distinguished in the company, and the main focus is on finite capacity planning at the bottlenecks based on profitability (ibid.). Regarding SD and CD, a stock exists at CODP where slabs are kept, and the limit for this intermediate inventory is an important factor to achieve higher service levels without compromising profitability and can be decided at S&OP. The company has limited capacity, so safety capacity is not included in the CD decisions. The company limits the backlog level through the use of a 12-week time fence, meaning that it accepts the orders only if they can be produced in a 12-week horizon. Otherwise, the orders get rejected (ibid.). The length of this time fence can be decided at S&OP level, based on the strategic goals of the company.
For more details about this steel company’s generic S&OP process, the readers are referred to Rudberg and Cederborg (2011). The cross hybridities are not discussed in Rudberg and Cederborg (2011), so they are excluded from the discussion here.

**Step 5:** Follow-up and feedback: in this example, the case company can measure, for example, energy costs for the CO, cycle time for the intermittent mode, backlog level for CD, and finished goods inventory level for the SD and continuous mode. It should be noticed that the performance measures are not included in the secondary data provided by Rudberg and Cederborg (2011), and are suggestions from the current papers’ authors.

The suggested framework helps the steel company to identify its supply chain modules through the design phase in the framework’s process, and to reflect on these modules in their S&OP through the framework’s content. In this way, the case company can improve its S&OP by further consideration of its specific characteristics, which affects the decision variables in S&OP and improves its competitive advantages. Since the framework is based on a typology with standard modules, it is also possible for the company to benchmark and gain experience from analogies with other industries, for example, even DIs, that would not have been possible if the foundation was only based on PIs.

### 7. Concluding discussion and further research

The aim of this paper is to suggest a framework for S&OP applicable to both PIs and DIs where PIs are hybrids of continuous production and discrete production and DIs only deploy discrete production. To achieve this goal, a modularized approach for S&OP has been suggested that uses decoupling points through integrating the concepts of object type, control mode, and flow driver. This paper contributes by gathering these three concepts in a framework with eight modules and outlining the differentiating characteristics of each module that can influence the design/implementation of S&OP by looking at how they affect the decision variables. Thus, the suggested framework’s content provides more details with regard to the supply chain in comparison to the generic S&OP which is used as a base model for the implementation of S&OP in industries. The results have been presented as the framework’s content in Table 6 and the framework’s process in Figure 2. The need for a more elaborate design to precede the operational use of the S&OP process for different production contexts is stressed in the framework’s process. In this context, PIs have been emphasized through the inclusion of the CO type in the framework. It should also be noted that in comparison to other works in this field, for example, the paper by Ivert et al. (2015) which is focused on food industries, our approach includes different types of PIs. In this approach, a key difference between various types of PIs is the location of DDP, meaning that DDP can be positioned early or late in the production process of PIs. The framework’s content deals with how the S&OP should be performed in the companies and what decision criteria should be taken into account, based on the properties of each module, as well as how they influence the decision variables in S&OP. Thus, the suggested framework helps the companies to reflect on and manage the specific characteristics and requirements of their supply chains in their S&OP based on a modularized approach. The standard modules of the suggested S&OP framework provide the possibility of benchmarking and gaining experience from other industries. An example of a steel company is used to illustrate how the framework can be used in practice.
The hybridity within the three dimensions and the cross hybridity, that is the hybridity between the dimensions, have been emphasized in the framework as well. Even though the effect of hybridity within each dimension on S&OP has been discussed in the literature, the influence of cross hybridity has not been covered so far, and thus is the contribution of the current paper. In general, the results show that the focus in PIs is more on supply planning/management, which is in line with the significance of resource management in these industries.

The framework is based on theory and the secondary empirical data from the literature. Further research will involve application of the framework in a wide set of case companies, which might result in further refinement and improvement of it. Another interesting subject would be to combine the framework presented in this paper with the five-step S&OP process with more detail and to integrate supply chain partners in the framework to provide a broader supply chain context. Even though we have tried to present the results in alignment with the S&OP steps, there is limited information in the literature on related demand planning and balancing issues that would provide additional opportunities for future research. As mentioned earlier, the framework can further be used as a basis for designing a performance measurement system at the S&OP level based on the specific needs of companies and in alignment with their supply chain modularization.

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