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Strategic Fit of Planning Environments: Towards an Integrated Framework

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Abstract. Numerous studies have highlighted the importance of achieving a strategic fit between the actual planning environment and the production planning and control systems that are employed. Failing to achieve this strategic fit often leads to suboptimal solutions which in turn negatively affects production planning and control performance. Through using a literature study methodology, a comprehensive planning environment mapping framework is developed and tested through investigating five manufacturing companies. The framework also investigates the causality between planning environment variables. The results from the mapping can be used as a starting point for designing appropriate production planning and control solutions, comparing companies, and identifying possible improvement areas.

Keywords: Planning environments, Strategic fit, Production planning and control

1 Introduction

Fierce competition in today's business environment puts companies under a tremendous pressure to innovate their operations strategies and practices in order to meet the changing requirements of the market [1]. These days, companies have to compete based on numerous performance objectives such as *price, quality*, and *responsiveness* [1, 2], as well as *flexibility* and *dependability* [3]. Because of this requirement to excel in a variety of dimensions and the steadily increasingly complexness of the environments in which companies operate, the need to assure a strategic fit between the production planning and control (PPC) system and the planning environment is more important than ever [4]. The lack of fit between characteristics of the planning environment and the PPC system will negatively influence the performance of the manufacturing firm [5, 6].

In order to achieve fit, it is important that the company identifies the key characteristics, both internal and external, which influences their planning environment. Jonsson and Mattsson [6] argue that knowing the actual planning environment is fundamental in order to use the appropriate planning methods for the specific environment. This is supported by Schönsleben [7], who also mentions that planning environment variables may be used for comparing results within the company or the supply chain to reveal issues that hinder an efficient supply chain. He also states that in order to compare performance indicators among different companies effectively, these variables should be taken into account.

Motivated by the importance of achieving strategic fit, this paper aims at developing a comprehensive framework for mapping a company's planning environment. This mapping can be used as a starting point for selecting appropriate PPC methods, comparing companies, and identifying possible improvement areas.

Through utilizing a literature study methodology, different existing frameworks for mapping planning environments have been identified and analyzed. Through analyzing their similarities and differences, it has been possible to assess the variables that are critical in a mapping process. These have been used as a basis to develop the integrated framework. In addition, to test the developed framework, case samples from five manufacturing companies have been collected.

This paper is an extended version of 'Frameworks for Strategic Fit of Planning Environments: A Case Based Exploratory Study' presented at the 6th International Conference on Information Systems, Logistics and Supply Chain (ILS 2016) (see [8]). The paper is structured as follows: Chapter 2 outlines the importance of PPC for manufacturing companies, while Chapter 3 investigates existing frameworks for mapping companies' planning environments. The development process of the framework and its variables are presented in Chapter 4. The results from testing the developed framework on a set of case companies are presented in Chapter 5, while Chapter 6 discusses the causality of variables and the possible usage areas of the framework. The paper is concluded and future work is outlined in Chapter 7.

2 The Importance of Production Planning and Control

PPC can be described as the activities required to match supply and demand [9], and is concerned with scheduling, coordinating, and organizing operations activities [10]. Vollmann, Berry, Whybark and Jacobs [9] define PPC as the tasks required to: '… manage efficiently the flow of material, the utilization of people and equipment, and to respond to customer requirements by utilizing the capacity of our suppliers, that of our internal facilities, and (in some cases) that of our customers to meet customer demand'. The importance of PPC for a manufacturing company to stay competitive and profitable is undeniable [9, 11], and poor PPC performance has often been found as a major reason for company bankruptcy [9]. An effective PPC system can contribute to competitive performance by lowering costs and providing greater responsiveness to the market [9]. Further, Vollmann, Berry, Whybark and Jacobs [9] highlight that both the production process in a company and their market requirements have implications for the PPC design, as illustrated by Bertrand, Wortmann and Wijngaard [12] in their case studies of four diverse companies.

The customer order decoupling point (CODP) is the point in the manufacturing value chain for a product where the product is linked to the specific customer order. Thus, it is the point that separates production based on forecasts and plans, from production based on an actual customer order [13]. The positioning of the CODP has great implications for a company's manufacturing strategy, as different approaches to and methods for planning and control is needed upstream and downstream of this point. The position of the CODP is also used to classify the production environment. Vollmann, Berry, Whybark and Jacobs [9], Olhager [13], and Schönsleben [7] all use a classification that consists of four different manufacturing situations: Make-to-stock (MTS), Assemble-to-order (ATO), Make-to-order (MTO), and Engineer-to-order (ETO). Olhager [13] investigates the most important factors affecting the positioning of the CODP and divides them into the three categories: *market, product,* and *production characteristics.* Forward or backward shifting of the CODP to better correspond to these factors may give increased competitive advantage.

Knowing the importance of PPC on the manufacturing firm's performance and the importance of achieving a strategic fit of these methods inspired us to map and evaluate existing frameworks for mapping the planning environment and identify which variables that are of importance.

3 Existing Frameworks for Mapping the Planning Environment

Although frequently discussed, there is a lack of a clear definition of a 'planning environment'. Based on the literature findings, the following definition is proposed and used for this study: *'The production planning environment is the sum of internal and external variables that influence the production planning and control process'.* A planning environment is company-specific and normally differs from company to company [3].

Through the literature study, multiple frameworks for mapping the planning environment were identified. However, none are comprehensive enough to capture the many facets of PPC and their influencing variables. This study has mainly investigated frameworks by: Jonsson and Mattsson [6], Schönsleben [7], Lödding [11], and Olhager and Rudberg [14].

Jonsson and Mattsson [6] conducted a conceptual study and a survey of 84 Swedish manufacturers to examine the fit between the planning environment and production PPC methods. Jonsson and Mattsson [6] argue that the fit of PPC methods is dependent on characteristic features related to product, demand, and manufacturing processes. Of the examined frameworks, this framework consists of the most variables, 21 in total. This framework has been chosen as the basis for the development of the integrated framework. It has further been complemented with the three other frameworks to cover an even broader scope of variables. This approach is supported by Jonsson and Mattsson [6], which points out that a larger number of variables for mapping the planning environment, especially related to the manufacturing process and shop floor control, are of great value.

Schönsleben [7] argues that the choice of a suitable concept of PPC is dependent on characteristic features describing the *customer, product or product family, the logistics and production resources,* and *the production or procurement order*. Especially the category 'production or procurement order' includes variables not present in Jonsson and Mattsson [6]. Hence, including these variables expands the scope of mapping variables.

Lödding [11] presents a framework for mapping variables affecting the choice of manufacturing control methods. It does not include a categorization of the variables, and compared to both Jonsson and Mattsson [6] and Schönsleben [7], the number of variables is relatively low. Lödding's framework is focusing the production control part of PPC as opposed to the two previously mentioned frameworks, consisting of variables closer related to shop floor control. It thus complements Jonsson and Mattsson's [6] framework, which, as stated previously, has a need for more shop floor control related variables.

Olhager and Rudberg [14] develop a simple framework where they present the different PPC levels and define what they consider the most important variables for each level. This framework only consists of five variables, and although the majority of these five are already covered by the previously presented frameworks, it complements the development process and points out important variables.

A comparison of the frameworks examined in this paper shows that they are partly overlapping, but all of them have some unique mapping variables. Furthermore, the different frameworks use different categories for dividing the mapping variables. A brief summary of the investigated frameworks is presented in Table 1. Through using these findings, an integrated and more comprehensive framework can be developed. The development of the integrated framework is described in Chapter 4.

Table 1. Investigated frameworks.

	Jonsson and Mattsson [6]	**Schönsleben [7]**	**Lödding [11]**	**Olhager and Rudberg [14]**
Categories	Product, demand, manufacturing process	Product, production resources, production/ procurement order	N/A	Product, market, process
No. of variables	21	16	8	5

4 Towards an Integrated Framework

Based on the previously published mapping frameworks mentioned in the previous section, variables were extracted and fitted into the integrated framework. In addition, to ease the use of the framework and make it more applicable for cross case studies, values were defined for each variable. These values represent the different states that each variable can have. Some of these were found in literature, while others were constructed for this framework. The framework consists of 30 variables, grouped into three categories. These are *product, market,* and *manufacturing process related*. This is a frequently used classification scheme, used by among others Olhager [13], Hill [15], and van Donk and van Doorne [16]. This chapter presents and describes the 30 different variables, and, where it is considered necessary, the different values of each variable are explained.

4.1 Product Related Variables

The *CODP placement* illustrates at which point in the value chain a product is linked to a specific customer order [13]. In the framework, four distinctive production environments are pointed out: ETO, MTO, ATO, and MTS. In this framework, these four production environments have been used to sort the values of the rest of the variables, such that typical ETO-characteristics can be found on the left, while typical MTS-characteristics can be found on the right, as these two represent the two 'extremes' of production environments. This is similar to Hill's [15] 'product-profiling concept'. The possible uses of this structure are discussed further in Chapter 6.

Level of customization refers to the extent in which the customer can specify the properties of the finished product [6]. Is it a standard product, are some specifications allowed, or is it a fully customer-specific product?

Product variety represents the number of different product variants the firm is able to deliver [6]. Companies that aim at delivering a large range of products tend to find it beneficial to put their CODP upstream in the value chain, while companies with a narrow product range find it easier to go for a MTS strategy.

Bill-of-material (BOM) complexity represents how many levels we can find in a BOM for a typical product that the company is producing [6].

Product data accuracy is referring to the data accuracy in the BOM and the routing file [6]. The importance of this variable is illustrated by the fact that inaccuracies in the BOM may lead to differences between planned and actual material usage, while incorrect data in the routing file might lead to a sub-optimized shop floor layout.

Level of process planning is the extent of which detailed process planning, such as systematic determination of manufacturing operations and their sequences, is carried out prior to initiating the manufacturing of the product [6]. In the framework, this variable ranges from 'none', which illustrates a situation where they plan the production on-the-go, to a fully designed process where every operation is planned in detail before initiating production.

4.2 Market Related Variables

P/D ratio represents the ratio between accumulated production lead time (P) and the delivery lead time (D) required by the customer [6]. As emphasized by Olhager [13], this is one of the most important parameters to consider when deciding the CODP placement. Is the production lead time short enough to meet the customer requirement, or is a stock of finished goods required?

Demand type refers to the origin of the production orders. This could either be from forecasts, calculated requirements based on the company's safety stock policy, or actual customer orders [6, 7].

Source *of demand* indicates the origin of the sales order. Either it comes from a stock replenishment order (vendor managed inventory (VMI)) or an actual customer order [6].

Volume/frequency refers to the annual manufacturing volume and the frequency of which products are manufactured. The variable ranges from a few high-value customer orders per year, to a large number of customer orders per year. Another alternative is that customers place call-off orders based on the company's production and delivery schedules [6].

Frequency of customer demand is defined as the regularity of demand for a specific product. *Unique* refers to once within a specific observation period, typically a year. *Block-wise or sporadic* means multiple times within the period, but with no recognizable regularity. *Regular* indicates a regular demand, which can be calculated for each period using forecasting techniques. *Continuous* refers to a demand that is about the same in each observation period [7].

Time distributed demand refers to how detailed the calculated demand is. It can either be time distributed or simply given as an annual figure [6].

Demand characteristics says whether the demand is independent or dependent [6]. Independent demand is demand for a finished product, while dependent demand is defined as demand for components or sub-assemblies [17].

Type of procurement ordering indicates how supplies are procured. *Order by order procurement* refers to a situation where the company simply is ordering their calculated needs from a supplier, while *order releases from a delivery agreement* refers to an integrated solution where the company has established a delivery agreement with their suppliers regarding regular deliveries [6].

Inventory accuracy is defined as the accuracy of the stock on hand data [6]. Inaccuracies in stock data could be a result of poor discipline regarding keeping the stock data updated or poorly designed systems.

4.3 Manufacturing Process Related Variables

Manufacturing mix indicate, from a manufacturing process perspective, whether the products are considered homogenous or mixed [6]. Homogenous products require more or less the same production process, while mixed products have significant differences in processing needs.

Shop floor layout refers to how the shop floor is organized [6, 7, 11]. To differentiate, the typology by Slack, Chambers and Johnston [10] is used, which defines four types: *Fixed-position, functional, cell,* and *product layout.*

Type of production refers to the average size of the production run and how frequently these runs are repeated [7, 11]. Lödding [11] differentiates between four types: *single unit production, small series, serial production,* and *mass production*. Table 2 states the differences between these four.

Table 2. Four types of production [11].

One-time production	Small series	Serial production	Mass production
Small production runs	Size of production run < 50	Size of production run > 50	Very large production runs
No repetition	Number of repetitions < 12	Number of repetitions < 24	Continuous production

Throughput time refers to the typical throughput time in the production, i.e. the time spent for a product to go through the entire production [6]. This may range from hours up to years for some products.

Number of major operations represents the number of major operations in a typical production routing [6].

Batch size refers to the typical size of a production order [6]. For ETO, MTO, and ATO companies, the batch size is usually equivalent with the customer order quantity. For MTS companies, the batch size is usually measured relatively to the number of weeks of demand it covers.

Frequency of production order repetition is, within a time period, how often a production order for the same product is released [7].

Fluctuations of capacity requirements refer to how much the production capacity requirements vary. The capacity fluctuations are mainly due to fluctuations in customer demand, but are usually not as strong as the demand oscillations, since the use of safety stocks may mitigate this effect [11].

Planning points is the number of manufacturing resources that, from a production and capacity planning point of view, can be seen as one entity [14].

Set-up times refer to the typical time that is needed to prepare the manufacturing resources to perform the specific task [6, 14].

Sequencing dependency indicates whether the manufacturing set-up times are dependent on the manufacturing sequence [6]. Sequencing dependency might stem from the fact that some products can be produced with the same tooling, while others require different tooling.

Part flow refers to the transport of parts between workstations [11]. Four distinct types of part flow are outlined in the framework. *Bulk* refers to a situation where the entire batch is processed together. For *lot-wise flow*, smaller parts of the batch, i.e. lots, are transported and processed together. *Overlapped flow* refers to the case where an already processed portion of a lot is transported to the next workstation in order to keep up the utilization. The last type is *one-piece-flow* which means that the part is transported to the next workstation as soon as it has been processed [11].

Material flow complexity depicts the complexity of the material flow at the shop floor. The complexity increases with the number of different possible routings in the production, in addition to the optimization level of the production layout [11].

Capacity flexibility refers to which degree the company is able to adjust the production capacity and how quickly they can do it [11].

Load flexibility, on the other hand, refers to the possibility of adapting the load to the available capacity. This can, for instance, be done by shifting the start or end-date of an order, placing orders externally, or declining orders when capacities are fully booked [11].

5 Case Samples

As part of testing the framework, as well as initiating a cross-company research project, five manufacturing companies have been investigated. This includes a shipyard, a manufacturer of ship propulsion systems, a furniture manufacturer, a pipe manufacturer, and a manufacturer of underwater sensor systems. Because of the large differences regarding the product complexity, market requirements, and production processes, it is expected that there also will be significant differences in the planning environments. This hypothesis was tested through using the developed framework.

Kleven is a shipyard that produces both new vessels as well as offers service, repair, and rebuilding of all types of vessels. Their products have a very complex structure; the production lead times are long, and there is a lot of coordination required in the production.

Brunvoll produces thruster systems for ships. The products are mostly standard, but there are some adaptations to the thrusters depending on the customer requirements. These products have a highly complex structure, and they produce around 350 units a year.

Ekornes is a furniture producer that produces according to customer orders. They offer mass customization by providing the customer with choices regarding e.g. the color of their furniture. A large part of their production is manual labor.

Pipelife produces plastic pipe systems used for, among others, water, ventilation, and electrical purposes, which are standard products. Because of very strict required delivery times, they have to produce to stock. They have challenges with forecasting future demand, which leads to stock build-ups. In addition, the setup times in production are extensive, which means that they have to carefully balance batch size with responsiveness.

Kongsberg Maritime Subsea develops and produces underwater acoustic sensor systems used in underwater mapping, underwater navigation, and fishing. They produce standard products with some room for customer specifications. Because of the P/D ratio, where the required delivery lead time is considerably lower than the production lead time, products are made to stock. Of the major challenges in the current planning and control are long throughput times and high WIP levels. These issues are a consequence of the high product complexity and the high material flow complexity in the job shop environment.

The framework was filled out for each company through interviewing representatives with detailed knowledge of the company. Each variable was classified according to the proposed classification scheme in the framework. The results are presented in Table 3.

Table 3. Integrated framework for mapping the planning environment.

A: Kleven**, B:** Brunvoll**, C:** Ekornes**, D:** Pipelife**, E:** Kongsberg Maritime Subsea

<table>
<tr><th></th><th>Variable</th><th colspan="12">Values</th><th>Ref.</th></tr>
<tr><td rowspan="6">Product related</td><td>CODP placement</td><td colspan="3">ETO
A, B</td><td colspan="3">MTO
B, C</td><td colspan="3">ATO</td><td colspan="3">MTS
D, E</td><td>[6, 7]</td></tr>
<tr><td>Level of customization</td><td colspan="4">Fully customer specific
A</td><td colspan="4">Some specifications are allowed
B, C, E</td><td colspan="4">None
D</td><td>[6]</td></tr>
<tr><td>Product variety</td><td colspan="4">High
A, B, C, E</td><td colspan="4">Medium</td><td colspan="4">Low
D</td><td>[6, 11, 14]</td></tr>
<tr><td>BOM complexity</td><td colspan="3">More than 5 levels
A, E</td><td colspan="3">3-5 levels
B</td><td colspan="3">1-2 levels and several items
C</td><td colspan="3">1-2 levels and few items
D</td><td>[6, 7, 14]</td></tr>
<tr><td>Product data accuracy</td><td colspan="4">Low
A, B</td><td colspan="4">Medium
A, B, C</td><td colspan="4">High
C, D, E</td><td>[6]</td></tr>
<tr><td>Level of process planning</td><td colspan="4">None</td><td colspan="4">Partial process planning
A, C, E</td><td colspan="4">Fully designed process
B, D</td><td>[6]</td></tr>
<tr><td rowspan="9">Market related</td><td>P/D ratio</td><td colspan="4"><1
A, B, C</td><td colspan="4">1</td><td colspan="4">>1
D, E</td><td>[6]</td></tr>
<tr><td>Demand type</td><td colspan="4">Customer order allocation
A, B, C</td><td colspan="4">Calculated requirements</td><td colspan="4">Forecast
D, E</td><td>[6, 7]</td></tr>
<tr><td>Source of demand</td><td colspan="6">Customer order
A, B, C, D, E</td><td colspan="6">Stock replenishment order
D, E</td><td>[6]</td></tr>
<tr><td>Volume / frequency</td><td colspan="3">Few large customer orders per year
A, B</td><td colspan="3">Several customer orders with large quantities per year</td><td colspan="3">Large number of customer orders with medium quantities per year
C, D, E</td><td colspan="3">Frequent call-offs based on delivery schedules</td><td>[6, 14]</td></tr>
<tr><td>Frequency of customer demand</td><td colspan="3">Unique
A, B</td><td colspan="3">Block-wise or sporadic
B, C, E</td><td colspan="3">Regular
C, D, E</td><td colspan="3">Steady (continuous)</td><td>[7]</td></tr>
<tr><td>Time distributed demand</td><td colspan="6">Annual figure
A, B, E</td><td colspan="6">Time distributed
C, D</td><td>[6]</td></tr>
<tr><td>Demand characteristics (*)</td><td colspan="6">Dependent
B</td><td colspan="6">Independent
A, C, D, E</td><td>[6]</td></tr>
<tr><td>Type of procurement ordering (*)</td><td colspan="6">Order by order procurement
A, B, C, D, E</td><td colspan="6">Order releases from a delivery agreement
C, D</td><td>[6]</td></tr>
<tr><td>Inventory accuracy (*)</td><td colspan="4">Low</td><td colspan="4">Medium
A, B, C</td><td colspan="4">High
D, E</td><td>[6]</td></tr>
</table>

Table 3. Integrated framework for mapping the planning environment (continued).

A: Kleven**, B:** Brunvoll**, C:** Ekornes**, D:** Pipelife, **E:** Kongsberg Maritime Subsea

	Variable	**Values**					**Ref.**
Manufacturing process related	Manufacturing mix	Mixed products **A, E**	Homogenous products **B, C, D**				[6]
	Shop floor layout	Fixed-position **A, B**	Functional **C, E**	Cell **B**	Product **D**		[6, 7, 10, 11]
	Type of production	Single unit production **A, B, E**	Small series **B, E**	Serial production **C**	Mass production **D**		[7, 11]
	Throughput time	Years **A**	Months **A, B, E**	Weeks **B, C**	Days **C, D**	Hours **D**	[6]
	Number of major operations	High **A, B, E**	Medium **C**	Low **D**			[6]
	Batch size	Equal to customer order quantities **A, B, C**	Small, equal to one week of demand **E**	Medium, equal to a few weeks of demand **D**	Large, equal to a month's demand or more **D**		[6]
	Frequency of production order repetition	Non-repetitive production **A**	Production with infrequent repetition **B**	Production with frequent repetition **C, D, E**			[7]
	Fluctuations of capacity req.	High	Medium **A, B, C, E**	Low **D**			[11]
	Planning points	High **A**	Medium **B, C, E**	Low **D**			[14]
	Set-up times	Low **C, E**	Medium **A, B**	High **D**			[6, 14]
	Sequencing dependency	None	Low **C, E**	Medium **A, B**	High **D**		[6]
	Part flow	One-Piece-Flow **A, B**	Overlapped **E**	Lot-Wise **B, C, D**	Bulk (Batch)		[11]
	Material flow complexity	High **A, E**	Medium **B, C**	Low **D**			[11]
	Capacity flexibility	High	Medium **C**	Low **A, B, D, E**			[11]
	Load flexibility	High **A**	Medium **B, C, E**	Low **D**			[11]
(*): Not dependent on production environment							

6 Discussion

This paper presents an integrated framework for mapping a company's planning environment. This section discusses the causality between the variables, the difference between internal and external variables, as well as the different uses of this framework.

6.1 Causality of Variables

The framework presented 30 mapping variables, but there is undoubtedly some causality between a number of the variables. Based on a conceptual analysis of the different variables, an assessment has been made regarding the causality between the variables. This is based mainly on logical assumptions and can be seen as an initial hypothesis regarding how the variables interact. The causality between the variables is presented in Table 4. Two plusses indicate a strong causality, i.e. it is expected that the value of this variable strongly influences the value of the other. One plus implies a weaker, but still existing causality. For the rest, no direct causality is presumed, although it might be an indirect causality through other variables. The possible uses of this table are discussed in Section 6.3.

6.2 Internal and External Variables

Internal variables can be defined as variables that the company can adjust through altering their management system. External variables are given by the environment, and the company needs to adapt to these. Although some of the variables presented in the framework are influenced by external variables, few are purely external. The only variable that can be considered purely external is *frequency of customer demand.* Some might argue that this one can also be influenced, for instance through marketing initiatives, but in the end, it still remains out of the company's control.

6.3 Usage Areas

Common Reference Framework. The literature study uncovered several frameworks, but there are seemingly no preferred frameworks for investigating companies' planning environments. Agreeing on a common reference framework will increase rigor of future research within the field. It can, for instance, be a starting point to identify appropriate PPC methods for a particular environment.

Initial Screening. This framework can be used to do an initial screening of a manufacturing company and to get an overview of their planning environment. It presents straightforward variables that can be used as a comprehensive checklist in the mapping process. A mapping like this can thus also be used as a starting point for externals, such as consultants working with the company.

Table 4. Causality between the mapping variables.

	Variables																													
Influenced by	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1						+		++									++	++			++			+						
2	++		++	+	++		++	+	+	+	++	+				++	++	++			+	+	+	+			+	+		
3	++				+					+	++	+				+	+	+			+	+	+							
4	++				+															+				+						
5	+														++															
6																			+											
7	++					+		+													+									++
8						+															+									+
9	+							+		+																				
10	+																+	++			++		++							
11	++									+		++					+	++				++								
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26		+	+																						++					
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28																														
29	++	+																												
30		+																												

Note: ++ Strong causality; + Weak causality; **Variables:** 1: CODP placement; 2: Level of customization; 3: Product variety; 4: BOM complexity; 5: Product data accuracy; 6: Level of process planning; 7: P/D ratio; 8: Demand type; 9: Source of demand; 10: Volume/frequency; 11: Frequency of customer demand; 12: Time distributed demand; 13: Demand characteristics; 14: Type of procurement ordering; 15: Inventory accuracy; 16: Manufacturing mix; 17: Shop floor layout; 18: Type of production; 19: Throughput time; 20: Number of major operations; 21: Batch size; 22: Frequency of production order repetition; 23: Fluctuations of capacity requirement; 24: Planning points; 25: Setup times; 26: Sequencing dependency; 27: Part flow; 28: Material flow complexity; 29: Capacity flexibility; 30: Load flexibility

Case Study Tool. Developed as a matrix, the framework allows for an easy arrangement of the collected data, detailed analysis, and cross case analysis [18]. While the standard values for each variable simplifies the cross case studies, it might be argued that the framework therefore is better for cross case analysis than for single case studies. However, the framework can easily be adapted to an in-depth single case study through making the values more exact, for instance by giving the exact number of product variants. Regarding the variables with high, medium, and low scales, the researcher should decide whether to rank these relatively among the cases or not. The benefit of ranking them relatively is that the researcher can highlight the differences between the cases to a larger degree, and the results are independent of the researcher's 'realm of experience'

[19, p. 392]. The disadvantage of choosing this approach is that it makes the analysis inaccurate outside of the case sample, and the resulting company profiling cannot be used to evaluate the conformance between the variables.

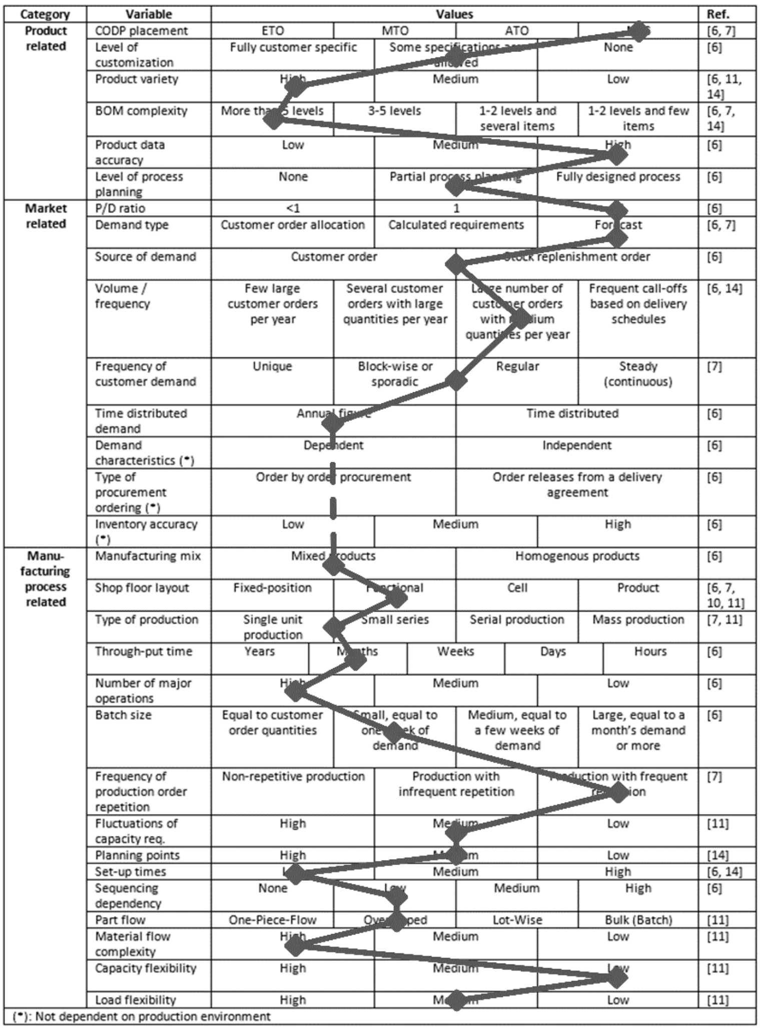
Benchmarking. By using the framework to map different companies, it will be easy to compare them and identify similarities and differences. This way, it could also be used as a benchmarking tool to compare against, for instance, a company that is considered 'best-in-class'. Through comparing the state of the variables, it is possible to uncover improvement areas.

Causality Effect. The causality matrix presented in Table 4 may be used as a decision support tool for change processes. For instance, if a company experiences that a variable suddenly changes state, either because of changes in their own structure or because of external influence, the matrix gives input on which other variables might be influenced and possibly also need to be adjusted to better conform to the new premises. As visible in the matrix, some variables are heavily influenced by other variables, while some are more or less independent.

Company Profiling. Because of interrelations between the variables, the framework is structured in a way that companies clearly should see a pattern, a so-called company profiling, when populating the framework. This is similar to Hill's [15] product profiling concept. As mentioned in Chapter 4, there are typical 'ETO characteristics' and 'MTS characteristics'. To some degree, the case study confirmed this. Companies that produce complex, customized products see that a majority of their variables correspond to the values on the left side in Table 3. On the other hand, companies that mass-produce standardized products find that their variables mostly correspond to values on the right side in Table 3. However, some of the variables are not considered to be dependent on the type of production environment. These are *demand characteristics, type of procurement ordering,* and *inventory accuracy*. These variables should therefore be ignored when using the framework as a profiling tool.

Briefly explained, the framework can be used to analyze the match between product and market characteristics and the manufacturing process choices. The resulting profiling will identify any mismatches and therefore highlight the areas that should be looked into for better conformance between the different groups of characteristics [15]. The framework can thus be used as a decision support tool. There are typically four ways to address a mismatch in the profiling [15]: The first alternative is to 'live with it' and continue as before. The second alternative is to alter the marketing strategy to ensure a better fit with the existing manufacturing process. The third alternative is to adjust and change the manufacturing process so that it, to a larger degree, matches the competitive priorities of the company. The fourth alternative is to go for a combination of the second and third alternative.

The majority of the investigated companies to a large degree follow the proposed profiling. As visible in the mapping, Kleven is a classic ETO company, while Pipelife, on the other hand, is a typical MTS company. The one who differs the most from the ‘ideal’ profiling was case company E, Kongsberg Maritime Subsea. This is a result of the fact that they produce highly complex products, typically associated with ETO and MTO companies, but the customers require such short delivery times that they find it necessary to produce to stock. This mismatch is easily spotted in their profiling (Fig. 1). The results can then be used to identify aspects that they should aim to alter. It should be noted, however, that the results should not be used ‘blindly’. Taking examples from Fig. 1, even if a low setup time typically is associated with companies producing to orders, the deviation in profiling does not mean that the company should increase the setup time to better conform to MTS characteristics. It is rather an indication that, based on their setup time, the company might be responsive enough to produce based on customer orders.



Category	Variable	Values	Ref.
Product related	CODP placement	ETO; MTO; ATO; MTS	[6, 7]
	Level of customization	Fully customer specific; Some specifications are allowed; None	[6]
	Product variety	High; Medium; Low	[6, 11, 14]
	BOM complexity	More than 5 levels; 3-5 levels; 1-2 levels and several items; 1-2 levels and few items	[6, 7, 14]
	Product data accuracy	Low; Medium; High	[6]
	Level of process planning	None; Partial process planning; Fully designed process	[6]
Market related	P/D ratio	<1; 1; >1	[6]
	Demand type	Customer order allocation; Calculated requirements; Forecast	[6, 7]
	Source of demand	Customer order; Stock replenishment order	[6]
	Volume / frequency	Few large customer orders per year; Several customer orders with large quantities per year; Large number of customer orders with medium quantities per year; Frequent call-offs based on delivery schedules	[6, 14]
	Frequency of customer demand	Unique; Block-wise or sporadic; Regular; Steady (continuous)	[7]
	Time distributed demand	Annual figure; Time distributed	[6]
	Demand characteristics (*)	Dependent; Independent	[6]
	Type of procurement ordering (*)	Order by order procurement; Order releases from a delivery agreement	[6]
	Inventory accuracy (*)	Low; Medium; High	[6]
Manu-facturing process related	Manufacturing mix	Mixed products; Homogenous products	[6]
	Shop floor layout	Fixed-position; Functional; Cell; Product	[6, 7, 10, 11]
	Type of production	Single unit production; Small series; Serial production; Mass production	[7, 11]
	Through-put time	Years; Months; Weeks; Days; Hours	[6]
	Number of major operations	High; Medium; Low	[6]
	Batch size	Equal to customer order quantities; Small, equal to one week of demand; Medium, equal to a few weeks of demand; Large, equal to a month’s demand or more	[6]
	Frequency of production order repetition	Non-repetitive production; Production with infrequent repetition; Production with frequent repetition	[7]
	Fluctuations of capacity req.	High; Medium; Low	[11]
	Planning points	High; Medium; Low	[14]
	Set-up times	Low; Medium; High	[6, 14]
	Sequencing dependency	None; Low; Medium; High	[6]
	Part flow	One-Piece-Flow; Overlapped; Lot-Wise; Bulk (Batch)	[11]
	Material flow complexity	High; Medium; Low	[11]
	Capacity flexibility	High; Medium; Low	[11]
	Load flexibility	High; Medium; Low	[11]

(*): Not dependent on production environment

Fig. 1. Profiling of Kongsberg Maritime Subsea.

7 Conclusion and Future Work

Through the literature findings, it became evident that there is a lack of an agreed upon framework for mapping planning environments, and there are disagreements regarding which variables should be investigated in order to get a comprehensive understanding of a firm's planning environment. This paper presents an integrated framework that can be used both as a mapping and decision support tool. It also investigates the causality between the variables, which no studies have done previously. Initial testing of the framework on five manufacturing companies shows that the framework is clearly able to highlight differences between these, while also highlighting variables that should be looked into to achieve better conformance between the variables.

Future research should examine whether it is beneficial to make the variables and their respective values more precise, especially keeping single case studies in mind, as this will give a more detailed mapping of planning environment. It may also reduce the bias when mapping the variables currently using scales of high, medium, and low. It should also be investigated how to use a mapping of a company's planning environment to determine appropriate PPC methods. Further, an assessment should be made whether the size of the framework can be reduced, for instance by discovering redundancy between variables. Lastly, the causality between the variables should be further investigated through large-scale empirical studies to see whether it supports the results from the conceptual analysis.

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