The Implication of Planning Environments on the Success of Manufacturing Planning and Control Methods

Track Title: Models and Methods for Operations Systems

Abstract

The applicability of manufacturing planning and control methods differs between environments. The paper explains the effect of the planning environment on the perceived satisfaction of methods for materials and capacity planning on the detailed material planning and shop-floor planning levels. The study is based on a survey of 83 Swedish manufacturing companies. Results show the use of planning methods and their levels of satisfaction and dissatisfaction in complex customer order production, production of optional products, batch production of standardized products and repetitive mass production, respectively.

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1. Introduction

The appropriateness of various manufacturing planning and control methods depends on the demand, products and manufacturing characteristics. A method that works perfectly well in one situation can be a completely wrong approach in another situation.

Only a very limited number of research that links planning methods to specific environments has been found. Berry and Hill (1992) and Schroeder et al. (1995), for example, described cases where a mismatch between the market requirements, manufacturing process design and choice of planning method affected the performances of manufacturing firms. Olhager and Rudberg (2000) discussed the importance of process choice for choosing planning methods on various planning levels. Newman and Sridharan (1995) identified, through a survey, that companies could be high performing no matter what material planning method they used. The method first had to match the environmental characteristics. Krajewski et al. (1987) and Gianque and Sawaya (1992) used simulation models and conceptual discussion to identify differences in planning environments for material requirements planning and kanban. The conducted research is conceptual and focuses very much on materials planning methods. Only one identified reference (Olhager and Rudberg, 2000) discussed capacity planning or shop floor control.

Consequently, there is a lack of empirical studies that explain the characteristic environments for planning methods. This paper seeks to fill some of the gaps in the literature and provide practical knowledge on manufacturing planning and control. The objectives of the paper are to explain the impact of the planning environment on the use of planning methods, and the perceived satisfaction and dissatisfaction of planning methods used in various environments.

2. Planning Methods

Planning methods are used on various planning horizons and levels of details. The focus of the present study is on the detailed material planning, shop floor control, and capacity planning levels. At each level there are a number of planning methods (see for example Vollmann et al., 1997). The methods included in this study are described in Figure 1.

Take in Figure 1 about here!

3. Planning Environments

Planning methods are designed and appropriate for various environments. Berry and Hill (1992) stated that successful companies need to link market requirements to processes, and processes to manufacturing planning and control. They showed examples where a changed manufacturing process leads to a change in planning methods. Olhager and Rudberg (2000) further stated that market (material flow) characteristics are important at the higher planning levels (Sales and operations planning), while manufacturing process characteristics are most important at lower levels (detailed material planning and shop floor control levels). Product characteristics, on the other hand, should be important at all levels. Newman and Sridharan (1995), Krajewski et al

(1987), Gianque and Sawaya (1992) have conducted focused studies on the choice of methods at the detailed material planning level. They especially compare material requirements planning, re-order point system and kanban.

The following sections conceptually identify generic planning environments and describe the applicability of planning methods in various environments.

3.1 Environmental Variables

The planning environment is characterized by the product, the material flow (demand) and the manufacturing process (Mattsson, 1999). It always differs from those in other companies. It should, however, be possible to identify a few more or less universal types of planning environments, in which most companies can be classified. Based on seven of the most important product, demand and manufacturing process related variables (see Table 1), the following generic types of planning environments has been identified in manufacturing companies (it should be noted that a company may contain more than one type):

- Complex customer order production (type 1)
- Production of optional products (type 2)
- Batch production of standardized products (type 3)
- Repetitive mass production (type 4)

Take in Table 1 about here!

3.2 Planning Environments and Planning Methods

Based on an analysis of the characteristics of various planning methods, an assessment has been made of how well the various planning methods can be expected to perform in the four types of planning environments. The conclusions from this assessment are summarized in table 2. The matrix can be seen as a hypothesis of to what extent the various planning methods can be effectively used and the users satisfied in each of the planning environments.

Two plusses means a strong match between planning method and planning environment, i.e. the planning method can be expected to perform with high effectiveness when used in this environment and accordingly result in a high perceived satisfaction. One plus means a weak match, i.e. the planning method can be expected to work reasonably well and satisfactory. A minus means a mismatch between planning method and planning environment, i.e. the planning method should not be used in this environment. If still applied, satisfied users can not be expected. Combinations with no marking are considered as neutral from an effectiveness and user satisfaction point of view.

Take in Table 2 about here!

4. Methodology

A mailed survey was sent to 380 members of the Swedish Production and Inventory Management Society (PLAN), each representing different manufacturing companies. The members of PLAN are, more or less, distributed among manufacturing industries in accordance

with the average for Swedish manufacturing industries (i.e. with about half of the companies in the mechanical engineering industry). 84 of the 380 companies, to which the survey was sent, responded. This is equivalent with a response rate of 22 %. Almost half of the respondents belonged to the mechanical engineering industry and more than half were large companies. The distributions of respondents among industries and company sizes are about the same as the population, Swedish manufacturing industries.

A classification system was developed and used to identifying types of planning environments in the 84 studied companies. When using the system, only a few companies belonged to more than one environment. These companies were not included in the analysis. 54 of the 84 studied companies could be linked to specific types of environments. All together, 11 companies belonged to the type 1 environment (Complex customer order production), 22 to type 2 (production of optional products), 14 to type 3 (Batch production of standardized products) and 7 to type 4 (Repetitive mass production).

The perceived satisfaction of planning methods was based on the question "To what extent do you consider that the method fulfills its objectives?". The answers were measured on a five point Likert scale, where "1" was equivalent with "bad", "3" with satisfactory, and "5" with "very well". Respondents marking either of the alternatives "1" or "2" were defined as "unsatisfied" users, while those marking "4" or "5" were "satisfied" users.

The general knowledge about materials planning methods among the respondents are most likely better than those for capacity planning and shop floor control methods. The questions about capacity planning and shop floor control followed the same structure as those for materials planning, which should improve the overall reliability. An eight pages documentation with definitions and descriptions of the studied methods for material planning, capacity planning and shop floor control was attached to the survey. This should further improve the understanding and reliability of the questionnaire.

5. Planning Environments and Perceived Satisfaction

The use of respective planning method in Swedish industry is described. The use and perceived satisfaction and dissatisfaction of the methods in the four generic types of planning environments are also analyzed. The empirical data is compared to the conceptually derived matching of environments and methods in section 3.2.

5.1 Material Planning Environments

The use and perceived satisfaction of the studied material planning methods are distributed among planning environments in accordance with table 3. Re-order point system, material requirements planning, and project order control are the three most commonly used planning methods. Material requirements planning, however, is the quite most important "main method". For all four types of planning environments, there are planning methods where the majority of the users are satisfied. Batch production of standardized products is the environment with highest proportion of satisfied, and lowest of dissatisfied, users.

Take in Table 3 about here!

The re-order point system should be important as complementary method in most environments. It is one of the most used methods in all environments, except for in repetitive mass production. Batch production of standardized products is the only environment where more than 50 % of the users are satisfied with the method and none is dissatisfied. In all the other environments, only about a third of the users are satisfied and between 11 and 33 % are dissatisfied.

Cover-time planning, where orders are initiated when the cover-time of the available inventory is less than the sum of the lead time and a safety time, is an alternative to the re-order point system. It has overall higher proportions of satisfied users than the re-order point system. None is dissatisfied with the method.

Material requirements planning and kanban control are the two methods where more than 50 % of the users are satisfied and only small proportions are dissatisfied, no matter planning environment (The only exception is kanban control, which is not used of all in the complex customer order environment).

Most kanban users in the Types 2, 3 and 4 environments are satisfied with the method. Production of optional products (Type 2) and repetitive mass production (Type 4) are typical "Kanban control environments", and these also include most of the satisfied and not dissatisfied kanban users.

The high overall level of satisfaction of material requirements planning may be somewhat surprising, because the method has got pretty much criticism over the years, and because it requires more accurate planning data than the other methods. 61 % of all material requirements planning users are satisfied with the method, and 12 % of them are dissatisfied. It has most satisfied users (75 %) in the environment with batch production of standardized products, which is a typical "MRP environment". The large difference between the proportions of satisfied and dissatisfied users also verifies that the method fits to this environment.

Material requirements planning also has the highest proportion of satisfied users and has no dissatisfied users in the complex customer order production environment. Therefore, it seams like the possibility of the material requirements planning to deal with high bill-of-material complexity is more important, than allowing ordering of customer specific items. Project order control, that was expected to be a more appropriate method in complex customer order environments, has more users, but only 38 % of them are satisfied with the method and 12 % are dissatisfied. Project order control is also used in the other planning environments, where its levels of satisfaction are higher. In those environments the method is not the "main method", but is used as a complementary.

5.2 Capacity Planning Environments

Capacity planning with overall factors and capacity requirements planning are the two most commonly used capacity planning methods (Table 4). They are even more dominating as "main methods". Capacity planning with capacity bills and resource profiles are only used by 15 and 20 % of the 54 companies, respectively.

The overall level of user satisfaction among capacity planning methods is quite lower than for materials planning methods. 22 % of the users are satisfied and 33 % dissatisfied with the capacity planning methods. Corresponding figures for materials planning methods are 31 % and 13 %, respectively.

Production of optional products is the environment with least satisfied and most dissatisfied users. Accordingly, it seems like small batch sizes, short through-put times and frequent customer orders of customized product variants drastically complicate the capacity planning.

Take in table 4 about here!

Among the studied capacity planning methods, only capacity planning with overall factors has close to 50 % satisfied users (Table 4). It is the simplest method to use, which may explain why it has most satisfied users. All of its users in the repetitive mass production environment are satisfied. This is the typical "overall factors environment". The empirical verification is weak, though, because of the small number of respondents. Overall factors also has a large proportion of satisfied users (67 %) among complex customer order producing companies (Type 1). This, however, is an environment with too complex short- and medium-term planning to fit overall factors, but the method could be used for long-term capacity planning.

Capacity requirements planning is an appropriate method in all environments, and is also the most frequently used capacity planning method in all environments. It has most satisfied users (40 %) in the Type 3 environment, which is the typical "CRP environment". This is the only environment where it has more satisfied than dissatisfied users. Consequently, the method is frequently used, perhaps due to its existence in most Enterprise Resource Planning (ERP) software, but it requires more accurate planning data than other methods.

Capacity bills have only sporadic users, and few of them are satisfied. Resource profiles is the second most used method in the Type 1 environment, which is its typical planning environment. Two of five users are satisfied with the method and none is dissatisfied, which indicates that the method should fit the environment.

5.3 Shop Floor Control Environments

Infinite capacity scheduling is the most commonly used loading method, and dispatch lists the most common method to support sequencing of orders in production groups. The number of users of shop floor control methods is lower than those for materials planning and capacity planning methods. Overall, loading and sequencing methods have most satisfied users among batch producers of standardized products, and most dissatisfied among optional product and repetitive mass producers. Obviously, the methods (especially sequencing) do not properly manage to control shop floor activities in dynamic planning environments with short through-put times. Further, the four types of planning environments are not very discriminating regarding shop floor control methods. Therefore, it is hard to draw too far conclusions from the data in table 5.

Take in table 5 about here!

The proportions of satisfied users of the three loading methods are 33 %, 30 % and 56 %, respectively. Corresponding figures for the three sequencing methods are 33 %, 50 % and 38 %. Input/output control is the least used, but most satisfactory loading method. Sequencing with dispatch lists is the most used sequencing method, and also the one with most satisfied users.

Infinite capacity scheduling requires small demand and capacity variations to be used successfully and should therefore be most applicable to the Type 4 environment. It is, however, the most used method in environments 1, 2 and 3. This is quite contradictory compared to the expectations. Possible reasons may be that the method is very simple to apply and that companies do not have available software for finite capacity scheduling or input/output control. Due to the small number of respondents from the Type 4, it is difficult to analyze the use of shop floor control methods in that environment. Finite capacity scheduling manages to control variations in demand and capacity in a better way than infinite scheduling, and, therefore, it should fit the Type 3 environment even better. Batch producers of standardized products (Type 3) are those with quite most satisfied and least dissatisfied users of infinite, as well as, finite capacity scheduling. This verifies the fit for finite scheduling in the environment, but it also indicates that infinite scheduling could be an appropriate method. Input/output control should fit environments with product oriented layouts, but the small number of users makes it hard to analyze the usability of the method.

Dispatch lists are applicable to and used in all environments. The Types 3 and 4 environments contain highest proportions of satisfied and lowest of dissatisfied users.

6. Conclusions and Discussion

The appropriateness of manufacturing planning and control methods depends on the characteristics of the present product, demand and manufacturing process. Any of four generic types of planning environments (complex customer order production, production of optional products, batch production of standardized products, and repetitive mass production) should be possible to identify in manufacturing companies. Each type has various product, demand and manufacturing process characteristics, and constitutes different prerequisites for material and capacity planning. Consequently, each planning method is more or less applicable to various planning environments.

Most of the proposed matches between planning environments and material planning methods were verified. For capacity planning methods several matches could be verified, but for shop floor control methods the empirical data could not verify any strong match between environment and planning methods. The four generic environments are consequently most relevant for differentiating material and capacity planning methods. More manufacturing process related variables should be used for differentiation of shop floor control methods.

Material requirements planning is the most applicable planning method at the detailed materials planning level. It is used as the main planning method in most companies. At least half of its users, no matter planning environment, are satisfied with the method. Most kanban users are

satisfied with the method, no matter planning environment. Cover-time planning, that is an alternative to re-order point system, has overall higher proportions of satisfied and lower of dissatisfied users compared to those using re-order points. The overall level of satisfaction of capacity planning and shop floor control methods are lower than for material planning methods.

The proportion of satisfied users differs between planning environments. Complex customer order producers have lowest overall proportions of satisfied users of materials planning and shop floor control methods, which indicates that it may be hardest to conduct priority planning in turbulent and dynamic environments. Batch production of standardized products has highest proportion of satisfied users of materials planning and shop floor control methods. The make-to-stock and deliver from stock strategies result in stable planning environments, which consequently are very important for the applicability of planning methods. Production of optional products is the environment with least satisfied and most dissatisfied users of capacity planning methods.

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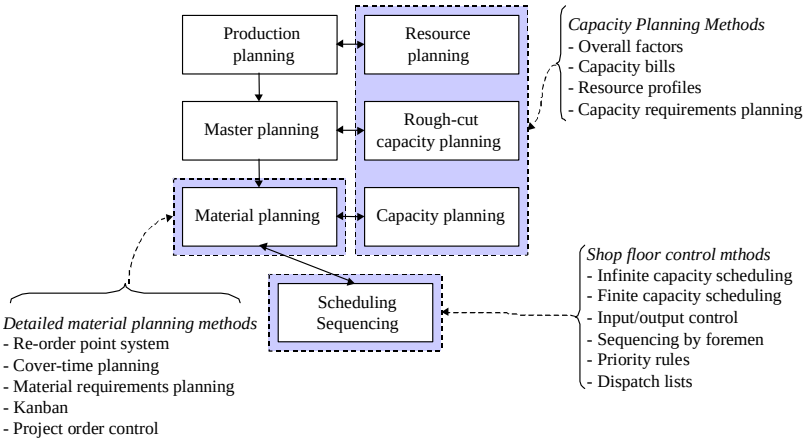

Figure 1. Planning methods included in the study

Table 1. Classification of planning environments

	Type 1	**Type 2**	**Type 3**	**Type 4**
Product characteristics:				
Product (BOM) complexity	high	medium	medium	low
Degree of value added at order entry	ETO	ATO/MTO	MTS	MTS/ATO
Demand characteristics:				
Customer order characteristics	few/small	many/medium	many/large	call-offs
Manufacturing process characteristics:				
Production process	one-off		batch	mass
Shop floor layout	functional	product/line	product/functional	line
Batch sizes	small	small	medium/large	
Through-put times	long	short	medium	short

Table 2. Matching planning environments and methods

Planning Method	**Planning Environment**			
	Type 1	Type 2	Type 3	Type 4
Detailed material planning				
Re-order point system		+	++	+
Cover-time planning		+	++	+
Material requirements planning	+	++	++	+
Kanban	-	+	+	++
Project order control	++	+		-
Capacity planning				
Overall factors	-		-	++
Capacity bills		+	+	+
Resource profiles	++	+	+	+
Capacity requirements planning	+	+	++	+
Scheduling				
Infinite capacity scheduling				++
Finite capacity scheduling	+		++	
Input/output control		++	+	++
Sequencing				
Sequencing by foremen	+			-
Priority rules		+		+
Dispatch lists	++	++	++	+

Note: ++ Strong match, + Weak match, - Mismatch

Table 3. Material planning methods with satisfied users

		Planning environment											
		Type 1			Type 2			Type 3			Type 4		
Planning methods	Total	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat
Re-order point system	40 (74)	8	37	12	18	33	6	11	64	0	3	33	33
Cover-time planning	11 (20)	0			4	50	0	5	80	0	2	0	0
Material requirements planning	41 (76)	6	67	0	16	50	19	12	75	8	7	57	14
Kanban control	19 (35)	0			9	78	0	6	67	17	4	75	0
Project order control	23 (43)	8	38	12	8	63	0	6	50	0	1	100	0

Note: "Total" measures the number of users, and the proportion of users among all 54 companies (within brackets), "Users" measures the number of users of respective method. "Satisf" measures the percentage of satisfied users. "Dissat" measures the percentage of dissatisfied users.

Table 4. Capacity planning methods with satisfied users

		Planning environment											
		Type 1			Type 2			Type 3			Type 4		
Planning methods	Total	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat
Overall factors	20 (37)	3	67	0	10	30	30	5	40	0	2	100	0
Capacity bills	8 (15)	0			4	25	75	3	33	0	1	0	0
Resource profiles	11 (20)	5	40	0	4	25	25	1	0	0	1	0	0
Capacity requirements planning	39 (72)	10	10	20	17	29	35	10	40	10	2	0	50

Note: "Total" measures the number of users, and the proportion of users among all 54 companies (within brackets), "Users" measures the number of users of respective method. "Satisf" measures the percentage of satisfied users. "Dissat" measures the percentage of dissatisfied users.

Table 5. Shop floor methods with satisfied users

		Planning environment											
		Type 1			Type 2			Type 3			Type 4		
Planning methods	Total	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat
Loading													
Infinite capacity scheduling	30 (56)	8	37	0	14	14	21	7	71	0	1	0	0
Finite capacity scheduling	20 (37)	5	20	20	6	33	33	6	50	0	3	33	67
Input/output control	9 (17)	2	50	0	4	50	0	1	0	100	2	50	50
Sequencing													
Sequencing by foremen	21 (39)	4	25	0	7	29	0	7	43	0	3	33	33
Priority rules	10 (19)	2	0	50	5	40	20	2	50	0	1	0	100
Dispatch lists	37 (69)	10	30	30	14	21	29	10	60	0	3	67	0

Note: "Total" measures the number of users, and the proportion of users among all 54 companies (within brackets), "Users" measures the number of users of respective method. "Satisf" measures the percentage of satisfied users. "Dissat" measures the percentage of dissatisfied users.