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THE USE AND APPLICABILITY OF CAPACITY PLANNING METHODS

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Abstract

This study identifies the use of capacity planning methods and analyzes the characteristic modes of application among satisfied users. It is based on data collected from 84 Swedish manufacturing companies. Capacity planning using overall factors and capacity requirements planning are the most common planning methods in Swedish manufacturing industries. Capacity bills is the method with lowest average level of applicability. Satisfied users base capacity requirement determination on objective data and up-date the plans more frequently than dissatisfied users.

Capacity planning is an activity that should be conducted in parallel with priority planning. Available capacity needs to match the load. Too less capacity decreases the service levels and increases the tied-up capital, while too much capacity is associated with unnecessary costs.

In a planning situation there are various capacity planning methods to choose from (e.g. capacity planning using overall factors, capacity bills, resource profiles and CRP). A specific method is more or less appropriate in various planning environments [2], and the choice of method could be a result of an internal analysis where the appropriateness of various approaches are evaluated, or it could be more random and based on intuition. Choosing a method that is appropriate for a specific planning environment does however not necessarily lead to a satisfactory usage. The method also needs to be applied in a proper way, i.e. time standards, routing information, planning periods, planning frequency, etc. need to be determined and carried out correctly.

Very few studies that analyze the use and perceived satisfaction of capacity planning methods have been conducted. Burcher [1] showed that Capacity Requirements Planning (CRP) is a common planning method and that the absence of time standards and routing information, or the unreliability of this data, was the primary reason for the lack of successful usage. Jonsson and Mattsson [2] analyzed the appropriateness of various capacity planning methods in companies with complex customer order production, production of optional products, batch production of standardized products, and repetitive mass production. CRP was the most common method, but also the method with the highest proportion of dissatisfied users in all planning environments.

This paper focuses on the following research questions:

1. What capacity planning methods are used in Swedish manufacturing companies?
2. Why are the respective methods used?
3. How are the methods used?
4. How do the satisfied users use the methods?

The first objective is to describe the use, motives of choosing, and modes of applying various capacity planning methods in Swedish manufacturing industries. The second is to identify the characteristic modes of applying capacity planning methods among "satisfied" users. The paper is structured in accordance to the objectives.

CAPACITY PLANNING METHODS

The four capacity planning methods (see e.g. [4]) capacity planning using overall factors, capacity bills, resource profiles and CRP are included in the study.

Capacity planning using overall factors is the simplest capacity planning method, and is normally done on a manual basis. It is based on planning factors derived from the end products and used for resource and rough-cut capacity planning. The advantages of the method is that calculations and data requirements are minimal.

Capacity planning using capacity bills is also a rough-cut method, but requires more data than overall factors and is consequently more detailed. Data for the capacity bills are based on estimation from experience or are automatically generated from the BOM and routing data files. No load off-setting is carried out.

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Capacity planning using resource profiles is based on the same structure as capacity bills, but it also includes lead-time off-setting of the workload.

CRP is the most detailed and sophisticated of the four methods. It requires bills of material, routings, time standards, lead-times, planned orders and current status of open orders at each work center. The level of detail is higher compared to the former methods. It is the only method that by necessity needs support from an ERP system.

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. Companies with a turnover below 100 Million Swedish Crones, MSEK, (approximately 10 Million USD) or less than 50 employees were defined as small. Those with a turnover between 100 and 300 MSEK and with more than 50 employees were medium sized companies.

The questionnaire was pre-tested and some questions were adjusted before sent out. All respondents were members of PLAN. This should secure a common knowledge about planning methods. An eight page document with definitions and descriptions of the studied methods was attached to the survey. This should further improve the understanding and reliability of the questionnaire.

USE OF PLANNING METHODS

The capacity planning methods are more or less applicable to various planning environments, planning horizons and levels of details [2]. Therefore, it may be necessary for a company to use a mix of capacity planning methods.

Capacity planning with overall factors is the simplest method for capacity planning. A prerequisite to be able to successfully use it is that the products are homogeneous from manufacturing point of view. The method assumes that the load from manufacturing a product is in the same planning period as the delivery date. This means that the method should only be used in environments with flat bill of materials and short lead-times compared to the length of the planning period. Another consequence is that the method should be used on long-term planning horizons, and with long planning periods.

Having a homogeneous type of manufacturing is less important when using capacity bills as the capacity planning method. The capacity bills method does, however, also assume that the load from manufacturing a product is in the same planning period as the delivery date and it does not, like overall factors, consider stock-on-hand for components.

With resource profiles the lead-time off-setting of load relative delivery date is possible and this capacity planning method has, accordingly, advantages compared to the previous methods in planning environments with long lead-times. In the same way as for capacity bills, resource profiles can not, however, consider stock-on-hand for components used in the products. Both methods allow capacity planning even before the detailed design and production planning is ready and that bill of material and routing files exist. Planning with capacity bills and profiles allow for more detailed planning compared to overall factors. It measures capacity requirements on department or work center level.

The most generally applicable capacity planning method irrespective of planning environment is CRP. It can be used successfully in all types of environments but its relative strength is in environments with complex standard products or complex products that are customer build from standardized components. CRP also considers stock-on-hand of components which means that it has major advantages in environments where components are made in batches to stock. The method focuses on the individual items within the bill-of-material. It is the one that is most applicable for planning of short-term horizons.

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Table 1 shows the use and planning horizon of the capacity planning methods. Each method could be used as "main method" or be "complementary". The definition of a "main method" is that it is used for the majority of planning objects. Only 37% of the studied companies used more than one capacity planning method. The "simple" method capacity planning using overall factors and the "detailed" CRP are most common "main methods", while capacity bills and profiles are used as complementary.

Capacity planning using overall factors and CRP are also the most used planning methods. More than 80% of the studied companies used CRP and more than half used overall factors. Capacity planning with capacity bills or profiles were used by about every fourth company.

TABLE 1: Use of Planning Methods

<i>Data Element</i>	<i>Planning Methods (Percent of users)</i>			
	<i>Factors</i>	<i>Bills</i>	<i>Profiles</i>	<i>CRP</i>
Planning horizon				
Short	1	6	6	33
Medium	5	13	13	38
Long	51	11	9	10
Use of methods regardless of horizon				
Method used (Several methods can be used in parallel)	57	30	28	81
Method used as 'main method' (Used for the majority of planning objects)	32	4	3	61

A reason for the wide-spread use of CRP is probably that it is included in most Enterprise Resource Planning (ERP) systems, and that it is applicable to most planning horizons. The fact that as many as 46% of the companies use overall factors as main method is however surprising, because of its lack of precision. Most of them are using it for long-term planning, though.

Table 1 further shows that overall factors, which is the simplest planning method, is used to plan long-term capacity requirements. CRP, on the other hand, is most common for short- and medium-term decisions. Planning bills and profiles are used on all planning horizons. Overall factors is most common among companies with repetitive mass production, where 80% of the companies use the method. CRP is used by all companies with complex customer order production, and only by 32% of them with repetitive mass production.

The motives for choosing a specific planning method could be the result of an internal analysis and assessment process, where the characteristics of the method is matched against the planning environment, planning horizon and level of detail. About a third of the users had conducted such an analysis prior to choosing method (Table 2). Another third of the users had chosen method because it was included in the available ERP system. This may explain why CRP is very common, and capacity bills and profiles are not very much used.

The motives differ between company sizes. It is not very common among small companies to base the decisions on analysis and recommendations (alternatives 1, 5 or 6). Only 11% of the small companies used any of those motives, compared to 43% among the large and 42% among the medium sized companies. Large companies are the only companies that use recommendations from consultants.

TABLE 2: Motives for Choosing Planning Method

<i>Data Element</i>	<i>Percent of users</i>
1. Based on analysis and assessment	37
2. Method included in available ERP system	32
3. Don't know/Method has "always" been used	14
4. No special motive	9
5. Method used by other companies	4
6. Method recommended by consultant	1

MODES OF APPLICATION

Each planning method could be applied in various ways. Here, we discuss modes of application, that are common for all four methods (strategy for determining planning data, length of planning periods and planning frequency). Some method-specific modes are also discussed, for example planning factors used in overall factors, number of included work centers in capacity bills and profiles, use of forward or backward scheduling in CRP.

Planning Data

The strategies for determining planning data (queue, set-up, run, wait and move time) are more or less common for all methods. Data could be estimated through two main strategies; (1) subjectively based on intuition and experience, and (2) objectively based, i.e. calculation based on information from data files, conducted stopwatch time study or measuring historical capacity consumption. Intuition is typically the only possible strategy when products and production are heavily customer oriented. Objective strategies are possible in more standardized environments and when planning data are stored in the data files of ERP systems. Table 3 shows how planning data for the four capacity planning methods are determined.

TABLE 3: Determining Planning Data

<i>Data Element</i>	<i>Factors</i>	<i>Planning Methods (Percent of users)</i>			
		<i>Bills</i>	<i>Profiles</i>	<i>CRP (run/set-up)</i>	<i>CRP (queue/move)</i>
Intuitively	14	12	45	29	78
Calculation from data files/Time study/ Historical capacity consumption	86	88	55	71	22

Intuition and experience are the most common sources when determining queue and move times for CRP calculations, but calculation based on information from data files, conducting stopwatch time studies, and following up historical capacity consumption are most common strategies for determining run and set-up times for all methods. Intuition is more common among small companies compared to medium and large sized companies.

Planning Period and Frequency

The planning period is the time period for which each plan is conducted. The length could vary from day to year. Most of the studied capacity planning methods are used for resource and rough-cut capacity planning. CRP is in most cases the most appropriate for detailed capacity planning. Therefore, the time length day is not included.

TABLE 4: Planning Period and Frequency

<i>Data Element</i>	<i>Planning Methods (Percent of users)</i>			
	<i>Factors</i>	<i>Bills</i>	<i>Profiles</i>	<i>CRP</i>
Length of planning period				
Week	50	54	38	55
Month	30	27	48	27
Quarter	9	8	9	11
Other length	11	11	5	7
Planning frequency				
Less than annually	2	8	18	0
Annually	6	18	5	3
Twice the year	9	7	18	11
Monthly	48	41	27	24
Weekly or transaction based	35	26	32	62

The length of the planning period could increase when the planning horizon gets longer and the planning level becomes rougher. Capacity planning with overall factors is used mostly on long-term planning levels, while CRP is more common for short- and medium-term planning levels (cp. Table 1). Therefore, it would be relevant to use longer planning periods for overall factors compared to CRP. This is however not true (Table 4). Weeks and months are the most common period lengths for overall factors as well as for CRP. Week seems to be an unnecessary short planning period for long-term capacity planning using overall factors.

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Planning frequency illustrates the frequency of re-planning. It could be done every time priority planning is carried out, which could occur several times a day, or it could be carried out sporadically during the year. Short-term plans should be re-planned more often than long-term plans.

Table 5 indicates that plans based on CRP are reviewed more frequently than plans based on any of the other planning methods. 62 % of the plans generated from CRP are reviewed more frequently than weekly, while corresponding percentages for the other planning methods are 26 to 35 %. The differences are expected, because CRP is used on shorter planning horizons and consequently requires higher precision compared to the other methods. CRP is integrated into most ERP systems, which allow for frequent and automatic planning.

Overall Factors

The capacity requirement in the planning method with overall factors can be expressed in terms of produced number of units, machine hours, labor hours, produced volume or produced value.

TABLE 5: Used Planning Factor

<i>Data Element</i>	<i>Percent of Users</i>
Units produced	40
Machine hour	31
Labor hour	14
Volume	10
Value	4
Other variable	2

Number of produced units and machine hours are the two most commonly used planning factors (Table 5). Units produced is the factor that is easiest to understand. However, it also requires that all products have similar capacity requirements. Number of produced units is most common in large companies and in chemistry and food manufacturing industries. 64% of the companies in those industries use that factor, compared to 38% in mechanical engineering and 31% in other industries. 56% of the large companies use produced units, compared to 36% in medium sized and 14% in small companies. The same relationship exists for volume. Machine and labor hours are however most common in mechanical engineering and other industries, compared to the chemistry and food industries.

Bills and Profiles

Capacity planning with capacity bills and profiles could be used on different levels of detail. The planning is more detailed when bills or profiles contain several departments/work centers, compared to when they contain few departments/work centers. It is most common to include several (more than 10) departments/centers in the bills and profiles (Table 6), i.e. the methods are not primarily used for very broad and long-term planning. Small and medium sized companies, however, include fewer departments/centers than large companies.

TABLE 6: Complexity, Frequency and Through-put Time of Bills and Profiles

<i>Data Element</i>	<i>Planning Methods (Percent of users)</i>	
	<i>Bills</i>	<i>Profiles</i>
No. of included work centers in bills/profiles		
1-5	30	33
6-10	26	29
More than 10	44	38
Frequency of revising bills/profiles		
Less than annually	15	18
Annually	35	41
More frequently than annually	50	41
Total through-put time in production		
1-5 days	13	0
1 week	17	4
1-4 weeks	35	46
> 4 weeks	35	50

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The frequency of revising capacity bills and profiles depends on the costs for the required work and the expected improvements received from the revision. 50 to 60% of the studied companies revise their bills and profiles annually or less frequently than annually. The mechanical engineering industry revises more frequently than companies from other industries. Companies with high frequency of revision use information from data files, when calculating capacity requirements, more so than companies with lower frequency, which allows the procedure to be automatic.

When planning periods are long, compared to the lead-times, much of the time-phased information may be lost in aggregating the data. An important prerequisite for capacity bills to give satisfactory plans on more detailed planning levels is that the accumulated through-put time doesn't exceed about the double period length [4]. If the through-put time is longer, the lack of time off-setting will be too misleading. This problem does not occur for resource profiles because of its time-phased planning. Therefore, resource profiles is a more appropriate method when the through-put time is long.

Table 6 shows that planning with resource profiles are more common than capacity bills when the through-put time is long. However, as many as 43 % of the capacity bills users have through-put times that are more than twice as long as the planning periods. This may explain why capacity bills is the method with least satisfied users (see Table 8). The corresponding figure for resource profile users is 56%.

CRP

The most important mode of applying CRP is how to schedule capacity requirements. Three different strategies could be used; forward scheduling, backward scheduling and a mix between forward and backward scheduling. Forward scheduling loads an order in a work center as soon as planned capacity is available, which may result in a mismatch between the due date and completion date for the order. Backward scheduling takes the job backward from its due date, which may lead to a mismatch between the start date of the first operation and the order start date. The third strategy is a mix between forward and backward scheduling. The queue/wait/move time between operations is adjusted, so that the risk for mismatch between due dates and start dates in most cases is eliminated. Consequently, this is the theoretically most correct strategy.

TABLE 7: Planning Strategy

<i>Data Element</i>	<i>Percent of users</i>
Front scheduling	13
Back scheduling	78
Mixed front and back scheduling	9

Table 7 shows that back scheduling is the dominating planning mode. Only large companies use front scheduling. The CRP procedure is closely connected to the material requirements planning procedure, which uses a back scheduling approach.

Another possibility in CRP is to separate planned from released open orders. 34 percent of the users separate the orders, while 66 percentages do not. It is more common to separate order types in large companies and in the mechanical engineering industry.

SATISFIED USERS

The degree of satisfaction of the respective methods was measured on a five point Likert scale (Table 8). The average degree of satisfaction is higher for methods that have the most users. Capacity bills has the lowest level of satisfaction. It is the only method with an average level below "3". However, the difference is not significant on the $p < 0.05$ level. Five of the 116 perceptions corresponded to the category "bad" (evenly distributed among the four methods). 15 were of category "very well" (5 overall factors, 1 resource profiles, 9 CRP).

TABLE 8: Degree of Satisfaction

<i>Data Element</i>	<i>Planning Methods (Five point Likert scale, where "1" = bad; "3" = satisfactory; and "5" = very well)</i>			
	<i>Factors</i>	<i>Bills</i>	<i>Profiles</i>	<i>CRP</i>
Average degree of satisfaction	3.32	2.87	3.12	3.33

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Table 9 shows the characteristics of the satisfied users of respective capacity planning method. The table shows the modes for which more than a third of the users are satisfied and where there is a "significant" difference (more than 10 percent) from the mode with second most satisfied users. The percentages measure the proportion of satisfied users. ("Satisfied user" is a user with a perceived level of applicability of "4" or "5". A dissatisfied user has a perceived level of applicability of "1" or "2"). The general findings are that satisfied users base the parameter determination on objective calculations rather than subjective intuition. They also use more accurate capacity requirements data in the planning procedure (e.g. using planned standard hours when determining required capacity), and review the capacity plans more frequently than dissatisfied users.

TABLE 9: Modes of Application among "Satisfied" Users

<i>Planning method</i>	<i>Mode of application among "satisfied" users (Percent of satisfied users)</i>
<i>Overall factors</i>	Expresses capacity requirement as units or time (50 %) Determines capacity requirement by following up historical capacity consumption (64 %)
<i>Capacity bills</i>	Bases capacity bill calculations on information from data files (33 %) Uses planned standard hours in capacity bills (33 %) Reviews capacity bills at least annually (33 %)
<i>Resource profiles</i>	Includes several departments/work centers in the profiles (67 %) Uses planned efficient time in the profiles (43 %) Reviews the resource profiles at least twice a year (40 %)
<i>Capacity requirements planning</i>	Determines queuing time by following up historical time (62 %) Determines run time by following up actual working hours (50 %) Separates capacity requirements from planned and released orders (45 %)

CONCLUSIONS

The study shows that capacity planning using overall factors and CRP are the two most commonly used capacity planning methods. Overall factors are used in simple and stable planning environments and for rough long-term planning. CRP are used in more complex environments and for more detailed decisions.

Intuition is the dominating strategy for determining queuing and move times in CRP, while calculation based on information from data files, work studies and historical capacity consumption is more common for determining run and set-up times, irrespective of what capacity planning methods that is used. The latter strategy is more common among satisfied users than among dissatisfied users.

It is most common with weekly planning periods. Most CRP users conduct weekly or transaction based re-planning, while re-planning is more infrequent for the other planning methods. Frequent re-planning is more common among satisfied users than among dissatisfied.

The average perceived satisfaction of overall factors and CRP are somewhat higher than of capacity bills and profiles.

The modes of application differ between companies of various sizes. Small companies use planning methods that are included in available ERP systems, while large companies to greater extent base the decisions of choosing planning methods on analyses and recommendations. Intuition is a more common strategy for parameter determination in small rather than in large companies.

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REFERENCES

1. Burcher, P. "Effective Capacity Planning", *Management Services* 36, no. 10 (1992): 22-27.

Full reference to this article: Jonsson, P. and Mattsson, S-A. (2002), "The use and applicability of capacity planning methods", *Production and Inventory Management Journal*, Vol. 43, No. 3/4; pp. 89-95.

2. Jonsson, P, Mattsson, S-A. " The Implication of Planning Environments on the Use of Manufacturing Planning and Control Methods", *Proceedings of the Twelfth Annual Conference of the Production and Operations Management Society*, POM-2001, Orlando Fl, 2001.
3. Mattsson, S-A. *Produktionslogistik: Planeringsmiljöer och planeringsmetoder (in Swedish)*, Malmö: Permatron, 1999.
4. Vollmann, T, Berry, W, Whybark, C. *Manufacturing Planing and Control Systems*, New York: Irwin/McGraw-Hill, 1997.