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The implications of fit between planning environments and manufacturing planning and control methods

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Abstract *The applicability of manufacturing planning and control methods differs between environments. This paper explains the fit between the planning environment and material and capacity planning on the detailed material planning and shop-floor planning levels. The study is based on a conceptual discussion and a survey of 84 Swedish manufacturing companies. Results show the use of planning methods and their levels of user satisfaction in complex customer order production, configure to order production, batch production of standardized products and repetitive mass production, respectively.*

1 Introduction

The suitability 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. For example, the objectives of both re-order point and material requirements planning (MRP) methods are to plan when and how much to order of individual items. The re-order point method requires even demand and is possible to use without computerized support, while MRP needs a computerized system and is more applicable to products with complex product structures, dependent demand, long lead-times and erratic demand, than the re-order point method. Similar differences in applicability can be identified for other material planning, capacity planning (e.g. capacity bills vs capacity requirements planning) and shop floor control methods (e.g. input/output control vs finite/infinite capacity scheduling) (e.g. Fogerty *et al.* 1991; Vollmann *et al.*, 1997).

Only a very limited amount of research linking planning methods to specific environments has been found. One group of research compares single material planning methods, for example MRP and kanban, and analyses their usability in various situations. Newman and Sridharan (1995) identified through a

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survey, that companies could be high performers no matter whether they are using MRP, kanban or re-order point methods. The method merely 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 MRP and kanban. Similar approaches exist for shop floor control methods. Bergamaschi *et al.* (1997) presented eight dimensions that describe the fundamental characteristics and properties of an order release procedure. The framework is used in order to classify research in the area but could also be an input for classifying planning methods. Reed (1994) compared the usability of dispatch lists and kanbans in job shops.

Berry and Hill (1992) and Schroeder *et al.* (1995) emphasized the importance of understanding the characteristics of the planning environment. They 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 (2002) discussed the importance of process choice when choosing planning methods on various levels. These studies describe the planning environment in a more structured, but still quite broad way. They do not identify specific variables to differentiate unique planning environments and do not match unique planning environments and specific planning methods. However, there are some studies that have developed more detailed frameworks for differentiating various planning environments. One quite comprehensive approach is that of Howard *et al.* (2002), who developed a rule-base for the specification of manufacturing planning and control activities. The model uses more than 100 input characteristics to describe the specifics of a manufacturing company. The objective of the model is to make recommendations about the suitability of 14 main categories of manufacturing planning and control activities to individual manufacturing companies. The model is only valid for batch manufacturing and the presented research does not explain in detail the suitability of specific planning and control methods in various manufacturing environments. Also, Ang *et al.* (1997) used a structured model to specify the characteristics of a manufacturing system. However, they did not link the manufacturing specifics to manufacturing planning and control activities. Another approach is that of Amaro *et al.* (1999), who developed a classification scheme for non make-to-stock manufacturing companies that could be used to differentiate the planning environments of companies.

Operations management and manufacturing planning and control textbooks also discuss characteristic planning environments for material planning methods (Fogerty *et al.*, 1991; Vollmann *et al.*, 1997; Olhager, 2000; Jonsson and Mattsson, 2003), although not based on empirical data. Most of the previous research also focuses strongly on materials planning methods.

Consequently, there are some studies that compare the effects of using various planning methods, and some studies developing frameworks to differentiate manufacturing planning environments. However, there is a lack of empirical studies that match characteristic planning environments and types of planning methods. This paper seeks to fill some of the gaps in the literature by providing practical knowledge on how to differentiate various manufacturing planning environments and conducting conceptual and empirical matches between planning methods and planning environments. We propose that unsuccessful utilization of manufacturing planning and control systems, as well as not fully achieved production goals, is often the result of not using appropriate planning methods for the actual planning environment, or using the methods in the wrong way (e.g. infrequent reviewing of parameters, non-optimum lot-sizing techniques, etc.). Therefore, it is important to understand the appropriateness of using the planning methods in various planning environments. The objective of the paper is to explain the fit between the planning environment and planning methods, as well as the perceived satisfaction or dissatisfaction with the chosen methods.

In this paper we first conceptually identify product, demand, and manufacturing process-related variables. The variables are used to describe four main types of planning environments. Then, the appropriateness of material planning, capacity planning and shop floor control methods in the various environments, is conceptually explained. Finally, the use and level of perceived satisfaction and dissatisfaction with the various methods in the four types of planning environments are empirically analyzed through survey data. The design and structure of the analysis is presented in Figure 1.

2 A framework for planning methods and planning environments

2.1 Planning methods

The planning methods are used on various planning horizons and levels of detail. In long-term planning, the planning object is often the end product or product group, while on the detailed material planning level and manufacturing operations on shop floor level, the planning object is the individual dependent items. The focus of the present study is on detailed material planning, shop floor control, and capacity planning levels. At each

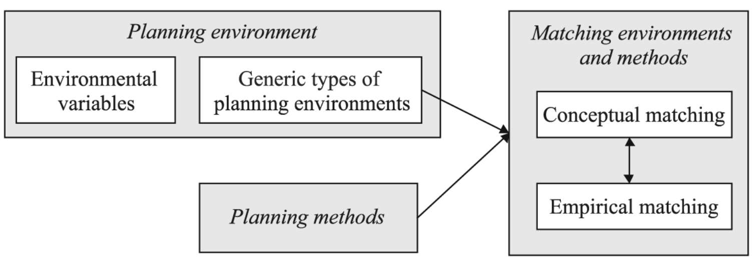

Figure 1.
Design of the analysis

level there are a number of planning methods. For each type of planning method there are several variants. No variants are studied here, only aggregated types of methods. The choice of planning methods included in this study is representative of those most readily available in commercial software packages and included in common textbooks (Fogarty *et al.*, 1991; Vollmann *et al.*, 1997) and hence most likely to be used. Therefore, some options may be missing, for example specific order release rules and the theory of constraint methods. The methods included are presented in Figure 2.

2.2 Environmental variables

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 compared material requirements planning, re-order point system and kanban. Newman and Sridharan (1995), for example, characterized the manufacturing environment in terms of product volume/variety, competitive priorities, and process technology and infrastructure availability within a firm. Berry and Hill (1992) stated that, for companies to be successful, it is necessary 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 (2002) further concluded that market (demand) 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, are important at all levels. The rule-base for specifying manufacturing planning and control activities presented by Howard *et al.* (2002) is based on similar market and company

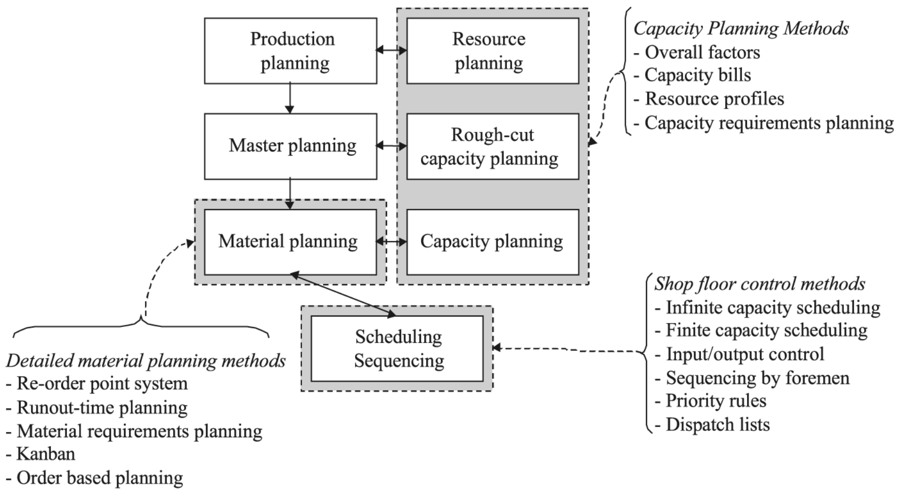

Figure 2.
Planning methods included in the study

characteristics. Mattsson (1999) developed a framework of product, demand and manufacturing process variables to characterize detailed material planning environments. The planning environments in this paper are mainly based on this framework.

Consequently, the planning environment can be characterized by a number of variables related to the product, the demand and the manufacturing process respectively. The following product related variables are considered critical from a planning and control perspective:

- *BOM complexity*. The number of levels in the bill of material and the typical number of items on each level.
- *Product variety*. The existence of optional product variants.
- *Degree of value added at order entry*. The extent to which the manufacturing of the products is finished prior to receipt of customer order.
- *Proportion of customer specific items*. The extent to which customer specific items are added to the delivered product, e.g. the addition of accessories.
- *Product data accuracy*. The data accuracy in the bill of material and routing file.
- *Level of process planning*. The extent to which detailed process planning is carried out before manufacture of the products.

The demand-related variables characterize demand and material flow from a planning perspective. The following variables are considered critical:

- *P/D ratio*. The ratio between the accumulated product lead time and the delivery lead time to the customer.
- *Volume/frequency*. The annual manufactured volume and the number of times per year that products are manufactured.
- *Type of procurement ordering*. Order by order procurement or blanket order releases from a delivery agreement.
- *Demand characteristics*. Independent or dependent demand.
- *Demand type*. Demand from forecast, calculated requirements or from customer order allocations.
- *Time distributed demand*. Demand being time distributed or just an annual figure.
- *Source of demand*. Stock replenishment order or customer order.
- *Inventory accuracy*. Accuracy of stock on hand data.

A third group of environmental variables characterizes the manufacturing process from a planning perspective. The following variables are included in this group:

- *Manufacturing mix.* Homogeneous or mixed products from a manufacturing process perspective.
- *Shop floor layout.* Functional, cellular or line layout.
- *Batch size.* The typical manufacturing order quantity.
- *Through-put time.* Typical manufacturing through-put times.
- *Number of operations.* Number of operations in typical routings.
- *Sequencing dependency.* The extent to which set-up times are dependent on manufacturing sequence in work centers.

Table I summarizes the detailed sub-variables of the three environmental characteristics.

2.3 Main types of planning environments

The manufacturing planning environment is company specific and normally differs from company to company. To be able to compare companies with different planning environments, four main groups of companies were defined. The objective of the grouping was to get strong intra-groups similarities but discrimination between the groups, with respect to their manufacturing planning and control environments. Therefore, all individual companies do not necessarily fit into any of the main groups. The following groups were formed:

(1) Complex customer products (type 1).

(2) Configure to order products (type 2).

(3) Batch production of standardized products (type 3).

(4) Repetitive mass production (type 4).

These four types are similar to Hill's (1995) process choice types, i.e. project, jobbing, batch, line and continuous. However, the types presented here are defined purely from a manufacturing planning and control perspective, while

	Environmental variables	
Product related	Demand (material-flow) related	Manufacturing process related
BOM complexity (depth)	P/D ratio	Manufacturing mix
BOM complexity (width)	Volume/frequency	Shop floor layout
Product variety	Set-up times	Batch size
Degree of value added at order entry	Type of procurement ordering	Through-put time
Proportion of customer specific items	Demand characteristics	Number of operations
Product data accuracy	Demand type	Sequencing dependency
Level of process planning	Time distributed demand	
	Source of demand	
	Inventory accuracy	

Table I. Environmental variables

Hill's types are more general operations management types. The classification is based on the product, demand and manufacturing process characteristics previously discussed in the paper. The product complexity, degree of value added at order entry, volume and frequency of customer orders, production process, shop floor layout, batch sizes and manufacturing through-put time were used for differentiating the planning environments of various companies (see Appendix).

Complex customer order production, type 1, implies a low volume, low standardization and high product variety type of production. It has similarities with Hill's project and jobbing types. The most characteristic feature of this type of planning environment is that the products are more or less designed and engineered to customer order, i.e. it is an engineer-to-order type of operation. Manufacturing batch sizes are typically small and equivalent to the customer order quantity. Products are complex with deep and wide bills of material. The manufacturing throughput times and the delivery lead-times are long. The production process is designed for one-off production, and a functional layout is often applied.

In the type 2 environment, configure-to-order products, the products have less complexity and are assembled in small batches. This type has most in common with Hill's jobbing and line processes. It can be characterized as an assembly- or made-to-order type of operation, where many optional products can be configured and manufactured by combining standardized and stocked components and semi-finished items. The number of customer orders is rather large and the delivery lead-times much less than for the complex customer order type of planning environment. The throughput times for the assembly or finishing operations are short and the batch sizes are typically small. Line and cellular layouts are more common than functional layouts.

The planning environment termed batch production of standardized products can mainly be characterized as manufacturing to stock of standardized products in medium to large sized quantity orders. This type of environment is closest to Hill's line process but could also exist in companies with jobbing processes. The number of customer orders is large, each corresponding to a small quantity, compared to the manufacturing batch sizes. Typical throughput times and batch sizes are neither long and large, nor short and small when compared with the conditions in planning environments 1 and 4.

Repetitive mass production represents a planning environment where products are made in large volumes on a repetitive and more or less continuous basis. This environment is closest to Hill's continuous and line processes. It cannot exist in companies with jobbing processes. It concerns standardized products or optional products made or assembled from standardized components characterized by having flat and simple bills of materials. The products are made-to-stock or made-to-schedule. In this environment the customer orders are small and frequent, in many cases call-offs from a delivery schedule. Typical throughput times are very short, and the manufacturing is carried out in some form of line layout.

2.4 Conceptual matching of planning environments and planning methods

Based on a conceptual 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. Because of the scarcity of literature and reference support for this assessment, it is mainly based on logical assumption. The conclusions from this assessment are summarized in Table II. The matrix can be seen as a hypothesis of to what extent the various planning methods can be effectively used and to what extent the users in each of the planning environments are satisfied.

Two plusses indicates a good match between the planning method and the planning environment, i.e. the planning method can be expected to perform with a high degree of effectiveness when used in that particular environment and accordingly result in a high perception of satisfaction. One plus means a poor match, i.e. the planning method can be expected to work reasonably well and satisfactory. A minus means a mismatch between the planning method

Table II. Conceptual matching of planning environments and methods

	Planning environment			
Planning method	Type 1	Type 2	Type 3	Type 4
Detailed materials planning				
Re-order point system		+	++	+
Runout-time planning		+	++	+
Material requirements planning	+	++	++	+
Kanban	-	+	+	++
Order-based planning	++	+		-
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, + Poor match, - Mismatch and planning environment, i.e. the planning method should not be used in that particular environment. If still applied, user satisfaction is not to be expected. Combinations with no marking are considered as neutral from the point of view of effectiveness and user satisfaction.

Detailed materials planning. Considering that re-order point systems are component rather than product oriented and basically designed for items with independent demand, they cannot be expected to perform very effectively in any of the four environments, particularly in type 1 environments with complex product structures and long manufacturing lead-times. Re-order point systems can, however, be used reasonably effectively the more standardized the product components are, the longer life cycles they have and the more stable the demand (Jacobs and Whybark, 1992; Newman and Sridharan, 1995). These conditions apply particularly to type 3 environments. The same arguments apply to runout-time planning (Jonsson and Mattsson, 2002a), which is basically a re-order point type of system using time instead of quantity as the controlling variable.

Material requirements planning can be seen as a generally applicable material planning method. It works reasonably well in all manufacturing companies irrespective of the specific planning environment (Newman and Sridharan, 1992), not least because of its strength in planning items with dependent demand. Material requirements planning is, however, most effective in environments with complex standardized products or product options, long manufacturing lead-times and items with time variations and uneven demand (Plenert, 1999). Partly because the information provided by material requirements planning better captures the actual assembly requirements, many firms have converted from re-order point systems to material requirements planning systems (Bregman, 1994). Jacobs and Whybark (1992) further showed that it requires a very proper relationship between the forecast and the actual demand before a re-order point system beats a material requirements planning system on inventory efficiency. The conditions discussed above are especially present in planning environments of types 2 and 3. Accordingly, a good match between material requirements planning and these environments can be expected.

Contrary to material requirements planning, the relative strength of kanban is greatest in environments with a regular and steady demand and where the products have a simple and flat bill of material (Gianque and Sawaya, 1992). Short lead-times and small order quantities also favor kanban (Newman and Sridharan, 1992). Accordingly, environment 4 is the most suitable environment for kanban. However, in many cases a good performance can also be found in the environments of types 2 and 3, especially if the order quantities are reasonably small. Even if exceptions can be found for some items, kanban is generally not a suitable method in planning environments of type 1. The complex products, often designed to order, the long lead-times, and the unpredictable and lumpy demand that characterize this environment are so far removed from what kanban can cope with effectively, that this combination has to be considered as a mismatch. However, integrated MRP/kanban approaches can successfully cope with planning problems in high variety/low volume manufacturing environments (Stockton and Lindley, 1995).

The most characteristic feature of order-based planning is its ability to manage complex and customer order specific products, whether designed to order or made/assembled to order. Its relative strength is also in environments characterized by long lead-times, lumpy demand and items with dependent demand (Jonsson and Mattsson, 2002a). These conditions are present to a large extent in type 1 environments and to some degree in type 2 environments also. A match between order-based planning and these two environments can therefore be expected. Environment 4, with its even and repetitive demand of standardized items and simple products, is more or less the opposite to environment 1. It is accordingly highly unlikely that order-based planning can be implemented with any degree of success or that satisfied users will be found in this environment. This combination of planning method and environment can be considered as a mismatch.

Capacity planning. Capacity planning, using overall factors, represents the simplest method of capacity planning. Of the four capacity planning methods studied, it requires the least detailed data and the least computational efforts. It is also the approach that is most affected by changes that occur in product volume or the level of effort required to build a product (Blackstone, 1989). Consequently, a prerequisite for its successful application is that the products are homogeneous from a 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 a flat bill of material and short lead-times, compared to the length of the planning period (Vollmann *et al.*, 1997; Jonsson and Mattsson, 2002b). This environment is present in particular in type 4. The complex products and typically long lead-times that characterize environments 1 and 3 render overall factors inappropriate for use in these environments and, accordingly, a mismatch is to be expected in the matrix for these combinations.

Having a homogeneous type of manufacturing is less important when using capacity bills (also known as bill of labor or bill of resources approach) as the capacity planning method. It employs detailed data on the time standards for each product. Therefore, poor time standards could become obstacles when using this method (Fogarty *et al.*, 1991). Burcher (1992) identified that the lack of optimum use of resource and capacity planning was the absence of time standards and routing information or the unreliability of this data. This effect, however, becomes even greater for capacity planning employing resource profiles and capacity requirements planning. The capacity bills method also assumes that the load from manufacturing a product is in the same planning period as the delivery date and, like overall factors, does not take stock-on-hand for components into account (Vollmann *et al.*, 1997). The match between capacity bills and planning environments 2, 3 and 4 is therefore considered poor.

Resource profiles allow the lead-time off-setting of a load relative delivery date and, accordingly, this capacity planning method has advantages compared to the previously mentioned methods for planning environments with long lead-times. In common with capacity bills, resource profiles rely on time standards and do not consider the stock-on-hand of components used in the products (Blackstone, 1989). This means that only a poor match can be expected for environments 2 and 3. In environment 4, the lead-time off-setting capacity is less important, and the simpler method capacity bills can be preferable from a user point of view. The relative strength of resource profiles is in type 1 environments. This is particularly relevant for engineer-to-order type of products because the method allows for capacity planning prior to the conclusion of the detailed design and production planning phase, thus bills of material and routing files are already available (Jonsson and Mattsson, 2002b).

The most generally applicable capacity planning method, irrespective of planning environment, is capacity requirements planning. It can be used successfully in all four types of environment but its relative strength is in environments with complex standard products or complex products that are custom built from standardized components. Capacity requirements planning also considers stock-on-hand of components, which means that it has major advantages in environments where components are manufactured in batches to stock (Fogarty *et al.*, 1991; Vollmann *et al.*, 1997; Jonsson and Mattsson, 2002b). These characteristics can typically be found in planning environments 2 and 3.

Shop floor control. The shop floor control methods consist of scheduling (order release) and sequencing (dispatching) methods. There are several rules and approaches for solving scheduling and sequencing problems (Bobrowski and Mabert, 1988; Karmarkar, 1989a, b; Melnyk and Ragatz, 1989; Rohleder and Scudder, 1993; Bergamaschi *et al.*, 1997). Here, specific rules or variants of methods are not evaluated, but instead general types of commonly used methods are compared. Three types of scheduling methods (infinite capacity scheduling, finite capacity scheduling and input/output control) and three types of sequencing methods (sequencing by foremen, priority rules and dispatch lists) are studied.

Of the various types of scheduling methods, infinite capacity scheduling is the simplest. It basically means that orders are released to the shop floor, irrespective of whether or not the current load is above available capacity. This method of releasing orders to the shop floor is easiest to apply when the load can be expected to be reasonably even, such as in environments with small order quantities and a smooth product demand, i.e. in planning environments of type 4. The larger the order quantities for semi-finished items, the more uneven is the load experienced in manufacturing, despite the fact that the load is relatively even on the master production schedule level.

In environments with uneven product demand and large order quantities, support from a scheduling system capable of loading orders to finite capacity becomes more important. This makes it possible to more effectively avoid overload and underload situations on the shop floor. Finite loading does not solve the under-capacity problem. It will, however, determine which jobs will be dealt with, based on priorities (Melnyk *et al.*, 1985). Unstable and unpredictable demand favors the use of finite capacity scheduling as it allows for more frequent rescheduling and more sophisticated considerations to the entire scheduling situation. These conditions can be found in particular in planning environment types 1 and 3.

With input/output control the release of orders to the shop floor is managed on the basis of available capacity in the gateway work center (Vollmann *et al.*, 1997). Long lead-times, many operations in the routings and a functional layout make it difficult to avoid overload or underload situations occurring in work centers for the downstream operations. The method is effective in situations where it is important to monitor backlog and to control queues, work in process, and manufacturing lead times (Fogerty *et al.*, 1991). As a consequence, input/output control can be expected to perform less satisfactorily in planning environment type 1, and to some extent in type 3, compared to types 2 and 4. Several simulation studies have found that shop floor workload reducing methods show poor due date performance (Melnyk and Ragatz, 1989; Land and Gaalman, 1998). However, these methods should still provide relative benefits compared to infinite capacity scheduling methods in the environments discussed.

In a repetitive type of planning environment such as type 4, the shop floor layout is in most cases line oriented. In this kind of environment, it is of paramount importance that the flow of semi-finished items and sub-assemblies is carefully coordinated with the manufacture of the end products. This means that there is not much space for the foremen on the shop floor to take locally influenced decisions concerning the sequencing of operations. Accordingly, sequencing by foremen is not an appropriate method in type 4 environments. The foreman has a good grasp of the department's capabilities, efficiency of order sequencing and the actual conditions in the work center. Allowing the shop foreman to take sequencing decisions is, therefore, of greater importance in environments where the manufacturing demands are more unpredictable and where it is difficult to achieve accurate schedules. This is especially the case in environment 1, and consequently a poor match can be expected for this combination.

The main difference between priority rules and dispatch lists is that the priority rule method does not allow as frequent updating of the current status as does sequencing based on dispatch lists. Also, the current loads in various work centers and the status of work in progress along the routings can only be taken into account to a lesser degree when using the priority rule method. Priority rules differ, for example, in terms of whether they are static or dynamic, or local or global (Melnyk *et al.*, 1985). Dispatch lists could be based on priority rules or be more detailed and, for example, focus on capacity constraints. The most volatile situation from a scheduling point of view can be found in planning environments 1, 2 and 3. In these environments the dispatch list method can be expected to perform more effectively than the priority rule method. This is especially the case in environments 1 and 3 where complex products, routings with many operations and long lead-times add to the importance of considering the current status of the entire scheduling situation when sequencing. Another advantage of these centralized dispatch methods is that they can improve communications among dispatchers (Fogerty *et al.*, 1991).

3 Methodology

The fit between planning environments and planning methods was analyzed conceptually in Section 2 as well as empirically in Section 4. Here, the methodology of the empirical study is discussed.

3.1 The sample

A mailed survey was sent to 380 members of the Swedish Production and Inventory Management Society (PLAN), each representing different manufacturing companies. The distribution of PLAN members in manufacturing companies is in line with the Swedish average for the industry (i.e. about half of the companies are in the mechanical engineering industry). A reason for sending the questionnaire to PLAN members was that it could be expected that they would be interested in manufacturing planning and have common knowledge about the terminology used in the survey. PLAN membership is personal. Therefore, the studied companies were not expected to employ more advanced planning methods than the average Swedish manufacturing company. Only one person per company was approached, and they were requested to answer only those sections with which they were familiar and to pass on the questionnaire to colleagues in a better position to answer certain sections.

Of the 380 companies surveyed, 84 responded. This is equivalent to a response rate of 22 per cent. The questionnaire was rather long, which may explain the relatively low response rate. Almost half of the respondents were in the mechanical engineering industry and more than half were employed by large companies (Table III). Companies with a turnover under 100 million Swedish Kronas (MSEK) or less than 50 employees were defined as small. Those with a turnover of between 100 and 300 MSEK and with more than 50 employees were defined as medium-sized companies.

	Respondents	%
Size		
Small	10	13
Medium	26	33
Large	42	54
Industry		
Food manufacturing and chemistry	20	24
Mechanical engineering	36	43
Other industries	28	33

Note: The food manufacturing and chemistry industries include the food manufacturing, pulp and paper, chemistry and plastic industries. Other industries include the timber and iron/steel industries

Table III. Characteristics of respondents

3.2 Measures used

There are three types of variables in this study. The first measures the use of the respective planning methods. The second describes the planning environment in each of the studied companies, and the third type evaluates the perceived level of satisfaction with the planning methods used.

Planning methods. The respondents were given four alternatives when evaluating the use of planning methods:

(1) The method is not used.

(2) Complementary use.

(3) Main method.

(4) Don't Know.

Respondents marking alternatives 2 or 3 were coded as users.

Planning environments. A classification system was developed and used to characterize the type of planning environment in the 84 studied companies. Only a few companies belonged to more than one environment, and several could not be included in any of the four defined generic planning environments. Of the 84 studied companies, 54 could be linked to specific types of environments and were therefore included in the analysis (see section 4.1).

The small number of respondents within each planning environment made it hard to use statistical methods when analyzing the data. The number of users and the number of satisfied and dissatisfied users in the four planning environments, were statistically tested (Chi-square). The proportion of satisfied and dissatisfied users were also identified within each environment and compared between environments, without testing for statistical significance.

Perceived satisfaction. The perceived satisfaction with planning methods was based on the question "How well do you consider that the method works in its practical application?". The answers were measured on a five-point Likert scale, where "1" was equivalent to "bad", "3" to satisfactory, and "5" to "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. This is not an objective measure, as it only measures the perception of the manager. It is, for example, not directly related to relevant operations performance metrics.

3.3 The reliability and validity

The questionnaire was pre-tested and some questions were adjusted before being distributed to the respondents. All respondents were members of PLAN.

A 12-page document with definitions and descriptions of the studied methods for materials planning, capacity planning and shop floor control was attached to the survey with the aim of further improving the understanding and reliability of the study.

The materials planning section of the survey had been tested and successfully used in a previous study (Mattsson, 1993). The capacity and shop floor control sections were formulated in a similar way to the materials planning section, which increases the validity of the survey instrument.

4 Empirical findings

Section 2.4 discusses and explains why some planning methods can be assumed to be more common than others, regardless of the planning environment. It also indicates that the choice of method should depend on the environment and that the perceived satisfaction with a method should be higher if the method fits the environment. This section empirically identifies generic planning environments and analyzes the empirical fit between planning methods and planning environments.

4.1 Identifying generic planning environments

In order to characterize the four basic types of planning environment, it was considered sufficient to use seven of the most important environmental variables in Table I (see Table IV). A simple classification system based on the answers in the questionnaire was then used to classify a company as belonging to one of the included types.

For each of the seven environmental variables in Table IV, different possible "values" were defined as described in the Appendix. The respondents selected one of these alternatives to characterize their environments. Each variable was also allocated a number of points up to three, reflecting how well that specific "value" characterized the respective environmental types (see Appendix). The value "more than five levels in the bill of material" is for instance very typical of type 1 environments and is allocated two points. The total score for every company and each environmental type was calculated.

A company's environmental type was then calculated, based on the highest score. Companies with an identical or similar score for more than one environmental type were eliminated from further analyses. Companies for

	Planning environment			
	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				
Volume/frequency	Few/small	Many/medium	Many/large	Call-offs
Manufacturing process characteristics				
Production process	One-off		Batch	Mass
Shop floor layout	Functional	Cellular/line	Cellular/functional	Line
Batch sizes	Small	Small	Medium/large	
Through-put times	Long	Short	Medium	Short

Table IV. Classification of planning environments

which the variable “degree of value added at order entry” did not match the specification in Table IV were also eliminated. The purpose of this procedure was to ensure that only companies with planning environments closely resembling the four main types were included. Out of the 84 companies that responded, 30 were eliminated from further investigations. Of the remaining 54, 11 belonged to type 1 (complex customer order production), 22 to type 2 (configure to order products), 14 to type 3 (batch production of standardized products), and seven to type 4 (repetitive mass production).

4.2 Empirical matching of planning environments and planning methods

The utilization of the methods in different environments and the number of satisfied and dissatisfied users in the four main types of environments were tested with Chi-square statistics. The levels of satisfaction and dissatisfaction with each individual method in the respective environment were also studied empirically, although not statistically tested, owing to too few counts in some of the analyzed data cells.

Table V shows the number of satisfied and dissatisfied users in the four planning environments (irrespective of planning method). Configure to order products (type 2) has significantly less satisfied and more dissatisfied users compared to the other environments. In particular, the capacity planning methods have greater proportions of dissatisfied users in the type 2 environment. Batch producers of standardized products (type 3), on the other hand, have significantly more satisfied and less dissatisfied users than in the other environments. This can be interpreted to mean that most satisfied users are to be found in stable planning environments, while dissatisfied users tend to be found in dynamic environments (Table V).

Detailed materials planning. The use of, and perceived satisfaction with the materials planning methods studied are distributed among planning

Table V.
Satisfied and dissatisfied users in the planning environments

	Planning environment			
	Type 1	Type 2	Type 3	Type 4
Satisfied	24	51 (-)	51 (+)	16
Dissatisfied	9	27 (+)	4 (-)	8

Notes: The table shows the number of satisfied and dissatisfied users in respective planning environment. Chi-square = 13.94 ($p = 0.003$). The sign within the parentheses indicates cells that differ significantly ($p < 0.05$) from the expected values. (-) is significantly lower and (+) is significantly higher than expected

environments, as illustrated in Table VI. Re-order point and MRP are the two most commonly used planning methods. MRP, however, is by far the most widely used "main method". All four types of planning environments contained planning methods with which the majority of the users were satisfied (Table VI).

The re-order point system is an important complementary method in most environments. The empirical analysis also reveals that it is one of the most widely used methods in all environments, except that of repetitive mass production. It is not used to a significantly greater extent in any one environment. Batch production of standardized products is the only environment where more than half (64 per cent) of the users were satisfied with the chosen method, and none were dissatisfied. This is the environment where the method has a strong conceptual match. In all the other environments, only 34 per cent of users were satisfied and between 11 and 33 per cent were dissatisfied.

Runout-time planning, where orders are initiated when the runout-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 is not a very common method. It has significantly ($p < 0.20$) fewer users in the type 1 environment and significantly more in the type 3 environment (where it has a strong conceptual match) compared to the other two environments. It has an overall higher proportion of satisfied users than the re-order point system. In the type 3 environment, for example, 80 per cent of the users were satisfied. None were dissatisfied with this method.

MRP is one of the most common methods in all environments. Its use is not significantly higher in any one environment. Kanban is significantly less common in the type 1 environment ($p < 0.05$), where a conceptual mismatch was identified and significantly ($p < 0.20$) more common in repetitive mass production, where it has a strong conceptual match. MRP and kanban control are the only methods where more than 50 per cent of the users were satisfied and only a small proportion were dissatisfied, irrespective of the planning

Table VI. Material planning methods with satisfied users

Planning methods	Total	Planning environment Type 1 Users	Satisf	Dissat	Type 2 Users	Satisf	Dissat	Type 3 Users	Satisf	Dissat	Type 4 Users	Satisf	Dissat
Re-order point system	40 (74)	8	37	12	18	33	6	11	64	0	3	33	33
Runout-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
Order-based planning	23 (43)	8**	38	12	8	63	0	6	50	0	1*	100	0

Notes: "Total" measures the number of users, and the proportion of users among all 54 companies (within parentheses), "Users" measures the number of users of respective method. "Satisf" measures the percentage of satisfied users. "Dissat" measures the percentage of dissatisfied users. Chi-square = 15.8 ($p = 0.20$). * Significantly different from the expected value (evenly distributed among environments) at the $p < 0.20$ level ** Significantly different from the expected value (evenly distributed among environments) at the $p < 0.05$ level environment (the only exception being kanban control, which has a mismatch and is not used at all in the complex customer order environment).

Most kanban users in the type 2, 3 and 4 environments were satisfied with the method. Configure to order products (type 2) and repetitive mass production (type 4) are typical "Kanban control environments" and include most of the satisfied and less dissatisfied kanban users.

The high overall level of satisfaction with MRP is somewhat surprising, in view of the fact that the method has been subject to much criticism over the years and that it requires more accurate planning data than the other methods. Of all MRP users 61 per cent were satisfied with the method, and only 12 per cent were dissatisfied. It has most satisfied users (75 per cent) in the batch production of standardized products environment, which is a typical "MRP environment". The large difference between the proportions of satisfied and dissatisfied users also verifies that the method fits in this environment.

MRP also has the highest proportion of satisfied users and has no dissatisfied users in the complex customer order production environment. This seems to indicate that the ability of MRP to deal with high bill-of-material complexity is more important than the ordering of customer specific items.

Order-based planning, which is considered to be a more appropriate method in complex customer order environments, has significantly ($p < 0.05$) more users in that environment compared to the other environments, but only 38 per cent were satisfied with the method and 12 per cent were dissatisfied. Order-based planning 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 a complementary method.

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

The overall level of user satisfaction with capacity planning methods is much lower than for materials planning methods. Of the users 22 per cent were satisfied and 33 per cent dissatisfied. Corresponding figures for materials planning methods are 31 per cent and 13 per cent, respectively.

Configure to order products is the environment with the least number of satisfied and the most dissatisfied users. Accordingly, it would appear that capacity planning does not add any value in situations with small batch sizes and short through-put times and that frequent customer orders of customized product variants drastically complicates capacity planning (Table VII).

The use of capacity planning with overall factors does not differ significantly between environments. About half (45 per cent) of the overall factors users were satisfied with the method (Table VII). It is the simplest method to use, which may explain why it has the highest proportion of satisfied

Table VII. 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

Notes: "Total" measures the number of users, and the proportion of users among all 54 companies (within parentheses), "Users" measures the number of users of respective method. "Satisf" measures the per centage of satisfied users. "Dissat" measures the per centage of dissatisfied users. Chi-square = 7.66 ($p = 0.57$). * Significantly different from the expected value (evenly distributed among environments) at the $p < 0.20$ level. ** Significantly different from the expected value (evenly distributed among environments) at the $p < 0.05$ level users. All of its users in the repetitive mass production environment were satisfied. This is the typical "overall factors environment", with a strong conceptual match. The statistical testing could not, however, reveal any environment where the method was significantly more popular. For overall factors, a large proportion of satisfied users (67 per cent) were found among complex customer order producing companies (type 1). This, however, is contradictory to the conceptual matching, but may be owing to the use of the method for long-term resource planning.

Capacity bills have only sporadic users, and few of them are satisfied. The method has significantly fewer users ($p < 0.20$) in the type 1 environment, where it has its poorest conceptual match, compared to the other environments. The resource profiles method has significantly more users ($p < 0.10$) and is the second most common method in the type 1 environment, which is its typical planning environment (with a strong conceptual match), compared to the other environments. Two out of five users were satisfied with the method and none were dissatisfied, which indicates that the method fits the environment.

As expected, capacity requirements planning is also the most frequently used capacity planning method in all environments. The use of the method does not differ significantly between environments. It has the highest proportion of satisfied users (40 per cent) in the type 3 environment, which is the typical "CRP environment" (strong conceptual match). This is the only environment in which it has more satisfied than dissatisfied users. The method is frequently used, perhaps owing to its existence in most enterprise resource planning (ERP) software, but it requires more accurate planning data than other methods, which may be a reason for user dissatisfaction.

Shop floor control. Infinite capacity scheduling is the most commonly used scheduling method, and dispatch lists is 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 of materials planning and capacity planning methods. The statistical testing could not reveal any significantly different patterns of use between environments. Overall, scheduling and sequencing methods have the highest proportion of satisfied users among batch producers of standardized products and the highest proportion of dissatisfied users among configure to order and repetitive mass producers. Obviously, the methods (especially sequencing) fail to properly manage and control shop floor activities in dynamic planning environments with short through-put times. Furthermore, the four types of planning environment are not very discriminating in respect of shop floor control methods. Therefore, it is hard to draw too many conclusions from the data in Table VIII.

The proportion of satisfied users of the three scheduling methods are 33 per cent, 30 per cent and 56 per cent, respectively. Corresponding figures for the three sequencing methods are 33 per cent, 50 per cent and 38 per cent. Input/output control is the least common but most satisfactory scheduling

Planning methods	Total	Planning environment											
		Type 1			Type 2			Type 3			Type 4		
		Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat	Users	Satisf	Dissat
Scheduling													
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

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

Table VIII.
Shop floor methods with satisfied users

method. Sequencing with dispatch lists is the most popular sequencing method and also the one with the highest proportion of satisfied users.

Infinite capacity scheduling requires low demand and capacity variations in order to be used successfully and is therefore most applicable to the type 4 environment. It is, however, the most frequently used method in environments 1, 2 and 3 (although the differences are not statistically significant). This is quite contradictory to the expectations. Possible reasons may be that the method is very simple to apply and that companies do not possess the necessary software for finite capacity scheduling or input/output control. The small number of respondents from the type 4 environment makes it 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 more efficient way than infinite scheduling and, therefore, it fits the type 3 environment even better. Batch producers of standardized products (type 3) are the most satisfied and least dissatisfied users of infinite as well as finite capacity scheduling. This supports the conceptual fit for finite scheduling in the environment, as well as indicating that infinite scheduling could also be an appropriate method. Input/output control should fit environments with cellular layouts, but the small number of users makes it hard to statistically analyze the usability of the method.

Dispatch lists are applicable to, and used in all environments. The types 3 and 4 environments contain the highest proportion of satisfied and lowest proportion of dissatisfied users, although/despite the fact that, in the type 4 environment, this method has only a poor conceptual match.

5 Conclusions and discussion

It should be possible to identify any of the four main types of planning environments (complex customer order production, configure to order products, batch production of standardized products, and repetitive mass production) in manufacturing companies. Each type has various product, demand and manufacturing process characteristics. The appropriateness of manufacturing planning and control methods depends on the characteristics of the actual product, demand and manufacturing process. Consequently, each planning method is applicable in varying degrees to the various planning environments.

Most of the proposed conceptual matches between planning environment and materials planning methods were identified empirically. (The conceptually derived appropriateness and the empirical use of the planning methods in the four planning environments are summarized in Table IX. The percentages of satisfied users are shown in Tables VI-VIII). Several matches could be verified for capacity planning methods, although the empirical data could not verify any strong match between environment and planning methods for shop floor control methods. The four environments are consequently most relevant for

Planning method	Type 1 CM	Type 1 EM (%)	Type 2 CM	Type 2 EM (%)	Type 3 CM	Type 3 EM (%)	Type 4 CM	Type 4 EM (%)
Detailed material planning								
Re-order point system		73	+	82	++	79	+	43
Runout-time planning		**0**	+	18	++	**36**	+	29
Material requirements planning	+	55	++	73	++	86	+	100
Kanban	-	**0**	+	41	+	43	++	57
Order-based planning	++	**73**	+	36		43	-	**14**
Capacity planning								
Overall factors	-	27		45	-	36	++	29
Capacity bills		**0**	+	18	+	21	+	14
Resource profiles	++	**45**	+	18	+	7	+	14
Capacity requirements planning	+	91	+	77	++	71	+	29
Scheduling								
Infinite capacity scheduling		73		64		50	++	14
Finite capacity scheduling	+	45		27	++	43		43
Input/output control		18	++	18	+	7	++	29
Sequencing								
Sequencing by foremen	+	36		32		50	-	43
Priority rules		18	+	23		14	+	14
Dispatch lists	++	91	++	64	++	71	+	43

Planning environment: Type 1, Type 2, Type 3, Type 4

Note: CM = Conceptual match, EM = Empirical match, ++ Strong conceptual match, + Poor conceptual match, - Conceptual mismatch, % = Percentages of the respondents that use the method. Percentages in bold differ significantly from the percentages of the method in the other environments

Table IX. Summary of matches between planning environment and planning methods

differentiating between materials planning and capacity planning methods. More manufacturing process related variables should be used for differentiation of shop floor control methods (Table IX).

5.1 Use and level of satisfaction with planning methods

MRP is the most applicable planning method at a detailed materials planning level. It is used as the main planning method in most companies, irrespective of the planning environment. At least half of its users were satisfied with the method, regardless of the planning environment. It is close to a perfect match between the method and the environment characterized by the batch production of standardized products. The empirical study further indicates that MRP also functions well in complex customer order production. However, order-based planning is equally appropriate to that environment, and it has significantly more users, although fewer are satisfied and more are dissatisfied. Consequently, the ability to control bill of material complexity seems to be more important than allowing for customized engineering.

Most kanban users are satisfied with the method, irrespective of the planning environment. It is appropriate for the repetitive mass production environment, but not for the production of complex customer-order products. Runout-time planning, which is an alternative to the re-order point system, is most appropriate for the batch production of standardized products, and it has an overall higher proportion of satisfied and a lower proportion of dissatisfied users compared to re-order points.

The overall level of satisfaction with capacity planning and shop floor control methods is lower than with materials planning methods. Capacity planning with overall factors is the simplest capacity planning method and the one with the highest proportion of satisfied users. Although capacity requirements planning is the most complex and also the most common method, it is only in the batch production of standardized products environment that it has more satisfied than dissatisfied users.

Infinite capacity scheduling is the most popular loading method, despite being too simple for some environments. Input/output control should be an appropriate method in product oriented environments, but it is the least common loading method.

Sequencing by dispatch lists is the sequencing method with the highest proportion of satisfied and lowest proportion of dissatisfied users. It is the most advanced sequencing method and it should fit most environments.

5.2 Planning environments

The proportion of satisfied users differs between planning environments. Batch production of standardized products has a significantly higher proportion of satisfied users and a significantly lower proportion of dissatisfied users compared to the other planning environments. The make-to-stock and deliver-from-stock strategies result in stable planning environments, which are consequently very important for planning method applicability.

Configure to order manufacturing is the only environment with significantly less satisfied and significantly more dissatisfied users, compared to the other environments. This indicates that it may be hard to carry out priority and capacity planning in dynamic environments with short time-to-consumer.

5.3 Future research

The aim of the paper was to explain the appropriateness and fit of planning methods in four different planning environments. Several of the conceptually derived matches between environments and material and capacity planning methods were verified in the empirical study. For shop floor control, however, some other environmental variables (especially manufacturing process related variables) should be used to differentiate between planning methods. The empirical study was based on a limited number of respondents, which made it difficult to test for statistical significance. Therefore, a replication study including a larger number of respondents and environmental variables more relevant to shop floor control, would be of great value.

Configure to order products and complex customer order production are the environments with the lowest proportion of satisfied users. This study did not identify the major reasons behind this finding. Therefore, explorative case studies are important in order to gain a deeper understanding of the appropriateness of various planning methods in any given environment and perhaps to develop new planning approaches for turbulent and dynamic environments.

Choosing a planning method that fits an environment and that is applicable to the planning situation does not necessarily result in a satisfactory utilization of the method. It only improves the chances of user satisfaction with the method. The method also needs to be applied in a proper manner, i.e. with correct parameter settings, planning frequency, etc. The people responsible for planning need the correct training and knowledge, and the computer system needs appropriate hardware and software. The present study did not evaluate the modes of application or any other variables that may affect the satisfactory usage of the planning methods. The measure of satisfaction that was used in the present study could also be developed and linked directly to companies' objective operational performances. Studies that focus on the modes of application of methods and that link various modes to objective and operational levels of satisfaction and performance, would therefore be interesting. Such studies would further fill some of the gaps in the literature and provide practical knowledge of manufacturing planning and control methods.

References

Amaro, G., Hendry, L. and Kingsman, B. (1999), "Competitive advantage, customisation and a new taxonomy for non make-to-stock companies", *International Journal of Operations & Production Management*, Vol. 19 No. 4, pp. 349-71.

Ang, C., Luo, M., Khoo, L.P. and Gay, R. (1997), "A knowledge-based approach to the generation of IDEFO models", *International Journal of Production Research*, Vol. 35 No. 5, pp. 385-413.

Bergamaschi, D., Cigolini, R., Perona, M. and Portioli, A. (1997), "Order review and release strategies in a job shop environment: a review and classification", *International Journal of Production Research*, Vol. 35 No. 2, pp. 399-420.

Berry, W.L. and Hill, T. (1992), "Linking systems to strategy", *International Journal of Operations & Production Management*, Vol. 12 No. 10, pp. 3-15.

Blackstone, J.H. (1989), *Capacity Management*, South-Western Publishing, Cincinnati, OH.

Bobrowski, P.M. and Mabert, V.A. (1988), "Alternative routing strategies in batch manufacturing: an evaluation", *Decision Sciences Journal*, Vol. 19 No. 4, pp. 713-33.

Bregman, R.L. (1994), "An analytical framework for comparing material requirements planning to reorder point system", *European Journal of Operations Research*, Vol. 75 No. 1, pp. 74-88.

Burcher, P.G. (1992), "Effective capacity planning", *Management Services*, Vol. 36 No. 10, pp. 22-7.

Fogarty, D.W., Blackstone, J.H. and Hoffmann, T.R. (1991), *Production and Inventory Management*, South-Western Publishing, Cincinnati, OH.

Gianque, W.C. and Sawaya, W.J. (1992), "Strategies for production control", *Production and Inventory Management Journal*, Vol. 33 No. 3, pp. 36-41.

Hill, T. (1995), *Manufacturing Strategy: Text and Cases*, Macmillan, London.

Howard, A., Kochhar, A. and Dilworth, J. (2002), "A rule-base for the specification of manufacturing planning and control system activities", *International Journal of Operations & Production Management*, Vol. 22 No. 1, pp. 7-29.

Jacobs, F.R. and Whybark, D.C. (1992), "A comparison of reorder point and material requirements plan", *Decision Sciences*, Vol. 23 No. 2, pp. 332-42.

Jonsson, P. and Mattsson, S.-A. (2002a), "The selection and application of material planning methods", *Production Planning and Control*, Vol. 13 No. 5, pp. 438-50.

Jonsson, P. and Mattsson, S-A. (2002b), "The use and applicability of capacity planning methods", *Production and Inventory Management Journal*, Vol. 43 No. 3/4.

Jonsson, P. and Mattsson, S-A. (2003), "Produktionslogistik", Studentlitteratur, Lund, (in Swedish).

Karmarkar, U.S. (1989a), "Capacity loading and release planning with work-in-progress (WIP) leadtimes", *Journal of Manufacturing and Operations Management*, Vol. 2 No. 2, pp. 105-23.

Karmarkar, U. (1989b), "Getting control of just-in-time", *Harvard Business Review*, Vol. 67 No. 9, pp. 60-6.

Krajewski, L., King, B., Ritzman, L. and Wong, D. (1987), "Kanban, MRP, and shaping the manufacturing environment", *Management Science*, Vol. 33 No. 1, pp. 39-57.

Land, M. and Gaalman, G. (1998), "The performance of workload control concepts in job shops: improving the release method", *International Journal of Production Economics*, Vol. 56-57, pp. 347-64.

Mattsson, S-A. (1993), "Materialplaneringsmetoder i svensk industri", (Institute for Transportation and Business Logistics), Växjö University, Växjö (in Swedish).

Mattsson, S-A. (1999), *Produktionslogistik: Planeringsmiljöer och planeringsmetoder*, Permatron, Malmö (in Swedish).

Melnyk, S.A. and Ragatz, G.L. (1989), "Order review/release: research issues and perspectives", *International Journal of Production Research*, Vol. 27 No. 7, pp. 1081-96.

Melnyk, S.A., Carter, P.L., Dilts, D.M. and Lyth, D.M. (1985), *Shop Floor Control*, Dow Jones-Irwin, Homewood, IL.

Newman, W. and Sridharan, V. (1992), "Manufacturing planning and control: is there one definite answer?", *Production and Inventory Management Journal*, Vol. 22 No. 1, pp. 50-4.

Newman, W. and Sridharan, V. (1995), "Linking manufacturing planning and control to the manufacturing environment", *Integrated Manufacturing System*, Vol. 6 No. 4, pp. 36-42.

Olhager, J. (2000), *Produktionsekonomi*, Studentlitteratur, Lund (in Swedish).

Olhager, J. and Rudberg, M. (2002), "Linking process choice and manufacturing planning and control systems", *International Journal of Production Research*, Vol. 40 No. 10, pp. 2335-52.

Plenert, G. (1999), "Focusing material requirements planning (MRP) towards performance", *European Journal of Operations Research*, Vol. 119, pp. 91-9.

Reed, R. (1994), "Plant scheduling for high customer service", in Wallace, T. (Ed.), *Instant Access Guide: World Class Manufacturing*, Oliver Wight Publications, Essex Junction, VT, pp. 377-85.

Rohleder, T.R. and Scudder, G. (1993), "A comparison of order release and dispatching rules for the dynamic weighted early/late problem", *Production and Operations Management*, Vol. 2 No. 3.

Schroeder, D.M., Congden, S.W. and Gopinath, C. (1995), "Linking competitive strategy and manufacturing process technology", *Journal of Management Studies*, Vol. 32 No. 2, pp. 163-89.

Stockton, D.J. and Lindley, R.J. (1995), "Implementing kanbans within high variety/low volume manufacturing environments", *International Journal of Operations & Production Management*, Vol. 15 No. 7, pp. 47-59.

Vollmann, T., Berry, W. and Whybark, C. (1997), *Manufacturing Planning and Control Systems*, Irwin/McGraw-Hill, New York, NY.

Further reading

Haddock, J. and Hubicki, D. (1989), "Which lot-sizing techniques are used in material requirements planning?", *Production and Inventory Management Journal*, Vol. 30 No. 3, pp. 29-35.

Hendry, L. (1998), "Applying world class manufacturing to make-to-order companies: problems and solutions", *International Journal of Operations & Production Management*, Vol. 18 No. 11, pp. 1086-100.

LaForge, L. and Sturr, V. (1986), "MRP practices in a random sample of manufacturing firms", *Production and Inventory Management Journal*, Vol. 27 No. 3, pp. 129-36

The Appendix follows overleaf.

Appendix

Table AI.
Classification of planning environment

	Type 1	Type 2	Type 3	Type 4
Product (BOM) complexity				
1-2 levels in the bill-of-material and few included items	0	0	0	2
1-2 levels in the bill-of-material and several included items	0	2	1	2
3-5 levels in the bill-of-material	1	1	2	0
More that 5 levels in the bill-of-material	2	0	0	0
Degree of value added at order entry				
Make-to-stock and deliver from stock	0	0	3	2
Assembly-to-order or plan	0	3	0	2
Manufacturing-to-order	0	3	0	0
Engineer-to-order	3	0	0	0
Volume/frequency				
Few large customer orders per year	2	0	0	0
Several customer orders with large quantities per year	0	0	2	0
Large number of customer orders with medium quantities every year	0	2	2	1
Frequent call-offs based on delivery schedules	0	0	0	3
Production process				
Continuous process production	0	0	0	2
Continuous mass production	0	0	0	2
Frequent batch production (more frequent than monthly)	0	0	2	0
Batch production (less frequent than monthly)	0	0	1	0
One-off or infrequent batch production	2	0	0	0
Shop floor layout				
Functional layout (process layout)	2	0	0	0
Cellular layout (flow layout)	0	2	0	0
Continuous line layout	0	2	0	2
Batch sizes				
Equivalent to customer order quantities/call-off quantities	2	2	0	0
Small, equivalent to one week of demand	0	0	0	0
Medium, equivalent to a few weeks of demand	0	0	2	0
Large, equivalent to a months demand or more	0	0	2	0
Through-put times in manufacturing				
Short through-put times, a week or less	0	2	0	2
Medium through-put times, a few weeks	1	0	2	0
Long through-put times, several weeks	2	0	0	0