Production Management Techniques: Push-Pull Classification and Application Conditions

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The new techniques of production management, developed and applied in important Japanese manufacturing firms in the seventies, have created a need for a completely new approach towards production management systems, which have been implemented over the years[1, 2, 3]. We refer particularly to the Japanese just-in-time philosophy[4, 5, 6] and its impact on Manufacturing Resource Planning systems (MRP II)[7, 8]. Starting with contributions to the literature our purpose is:

- **to establish a scheme which classifies different management techniques, within the planning and control production sub-systems, according to the logic which is the basis of different techniques. The sub-systems which will be studied here are all part of the wider production management system;**
- **to point out the application conditions which influence the use of a technique within a management sub-system.**

The aim of the scheme is to offer suggestions which will help to overcome the problems and confusion that arise when one compares different production management techniques. There are few universally accepted definitions of production management techniques. For example, in the literature, Material Requirements Planning is considered with both *push*[9] and *pull*[10] logic. Indeed, at seminars or conferences on these subjects, it is not unusual to hear questions such as:

— "What are the differences among Zero Inventories, Just-in-Time and Kanban?"
— "Are Just-in-Time and Manufacturing Resource Planning compatible?"
— "Why has Manufacturing Resource Planning been implemented when top management wants Just-in-Time?"
— "If a pull system is used, what is going to happen to Material Requirements Planning?"
— "Can Just-in-Time be applied to repetitive manufacturing?"
— "Are Just-in-Time and pull the same?"[10].

In response to these questions, and in order to classify the different production management techniques, three sub-systems are considered:

- inventory management;
- manufacturing priority assignment and material picking and moving;
- production planning.

With reference to the logic of the techniques, we will use the recognised terms in the production management field:

— *push* logic;
— *pull* logic;
— mixed *push-pull* logic.

The proposed classification scheme is a starting point for the application of every production management technique.

The Inventory Management Sub-system*

Two important inventory management techniques are:

— Reorder Point (ROP);
— Material Requirements Planning (MRP).

In the former case, an order for material is placed when the reorder point is reached. In the latter case, the order for material is determined from forecasts of future needs.

The ROP and MRP techniques respectively involve *look back* and *look ahead* logic. The former is based on previous consumption, the latter on calculated needs.

More precisely, when MRP is applied to independent demand codes (i.e. end items and spare parts), the technique is called time-phased order point[12].

There are four significant variables which determine the choice between the alternative techniques:

— the value of use;
— the relationship between lead time and planning time;
— the frequency of consumption;
— the number of levels in the bill of materials which are managed.

The value of use of a material is the used amount (or the amount that is supposed to be used) in the unit of time multiplied by the unitary value of the material. The *look back* criterion is preferable for low value of use materials. The *look ahead* criterion reduces goods in stock, generally speaking. For high value of use materials, a substantial financial reduction may be achieved through this latter approach[13].

* In this section inventory management techniques are classified according to the logic *look back* and *look ahead*[11]. The classification according to *push* and *pull* logic will be described in a subsequent section.

Lead time (*LT*) is the time needed to obtain ordered material from a supplier or a manufacturing department. Planning time (*PT*) is the period of time from when an activity plan is drawn up to when material must be made available. If $LT \leq PT$, it is possible to adopt the *look ahead* criterion. If $LT > PT$, the *look back* criterion must be used. These results are valid for both dependent and independent demand materials.

Figure 1 shows the relationships between lead times and planning times for end item *a*, which comprises components *b* and *c*.

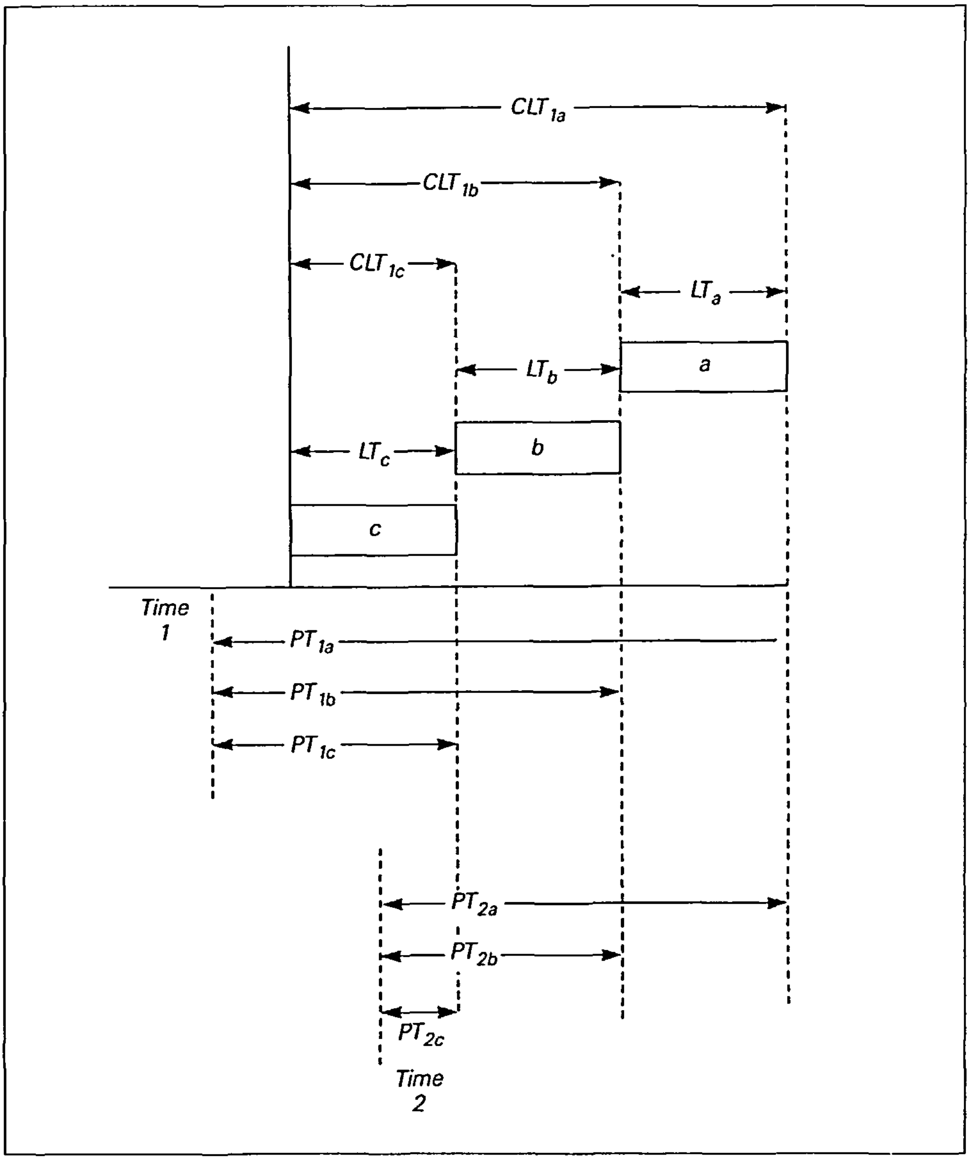

Figure 1.
Relationships among Times

The cumulative lead times (CLT) for both end item and components are shown in Figure 1. If the item lead times are compared with the planning times, which are determined by needs at time 1, it is clear that *a, b* and *c* can be managed through *look ahead* logic.

If needs are established at time 2, *c* must be managed within *look back* logic, since its lead time is longer than planning time. If item *c* cannot be managed by *look ahead* logic (for example because of its high value of use), the solution of the problem cannot be found within the inventory management sub-system, but in the production planning sub-system, since item *c* is something which has to be forecast. In this way a master production schedule has to be drawn up, not only for end items, but also for every component which will not be managed with the *look back* logic*.

How frequently a material is consumed assists in the forecast of its demand. In this case it is convenient to apply the *look back* criterion. Whereas if frequency of consumption is low, it is better to apply *look ahead* techniques.

The above mentioned variables enable one to identify the most suitable and convenient criteria to manage each item, whether these are items, components or raw materials.

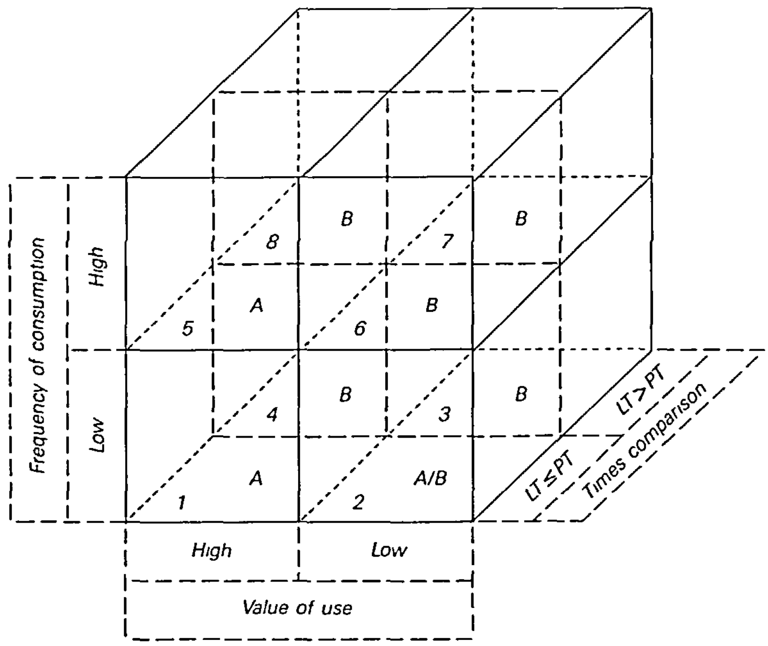

Figure 2.
Relationships among the Three Variables which Take Part in Inventory Management

* For example, in assemble to order a firm's components must be forecast because customer lead time is less than product cumulative lead time and it can be expensive to manage components within *look back* logic.

As can be seen from Figure 2, one can establish that:

- if item lead time is longer than planning time, *look back* must be used in any case;
- if item lead time is shorter than, or equal to planning time, three assumptions are made:
  - if value of use is high, it is convenient to *look ahead*;
  - if value of use is low and frequency of consumption is high, it is convenient to *look back;*
  - if value of use is low and frequency of consumption is low it is possible both to *look back* and to *look ahead*. However firms would rather *look back* in order to make inventory management easier.

The fourth and last variable, the number of managed levels in the bill of materials, cannot be treated like the other three variables. Indeed, it relates to both the structure of the bill of materials of the product (number of levels) and to the corporate decisions regarding which items are to be stocked. The greater the number of managed levels, the more *look ahead* techniques become convenient. The disadvantages of managing low level components (i.e. dependent demand items) with ROP techniques grow in proportion to number of levels[12, p. 26]. Since management techniques like MRP, rather than ROP, have been applied with dependent demand items, a remarkable reduction of inventory is achieved. However, the time necessary to produce the end item a is no longer the item lead time LT_a, but the cumulative lead time CTL_a (see Figure 1). Therefore, if the cumulative lead time is not acceptable to the market, the lower level components in the bill of materials must be managed within *look back* logic (unless one chooses to plan them). In this way the cumulative lead times of end items and higher level components decrease (see Figure 3).

At this point *look ahead* criteria are still feasible for end items and higher level components since planning times are observed.

The relationship between the number of levels of the bill of materials and the three previous variables leads to the relationships shown in Figure 2 becoming dynamic.

The greater the number of low level items which are managed *looking back*, the more higher level components and end items should be managed *looking ahead,* since the relationships between lead times and planning times change. In this way, an item migration takes place between the two depth levels of the cube of Figure 2. The lower the frequency of consumption and the higher the value of use, the more significant this rearrangement is. A compromise between *look back* and *look ahead* logic may be achieved through the use of a technique that we describe as "mixed". We refer to Material Requirements Planning (*look ahead* logic), which incorporates devices like safety stock, lot sizing and safety lead time, which are typical of *look back* logic.

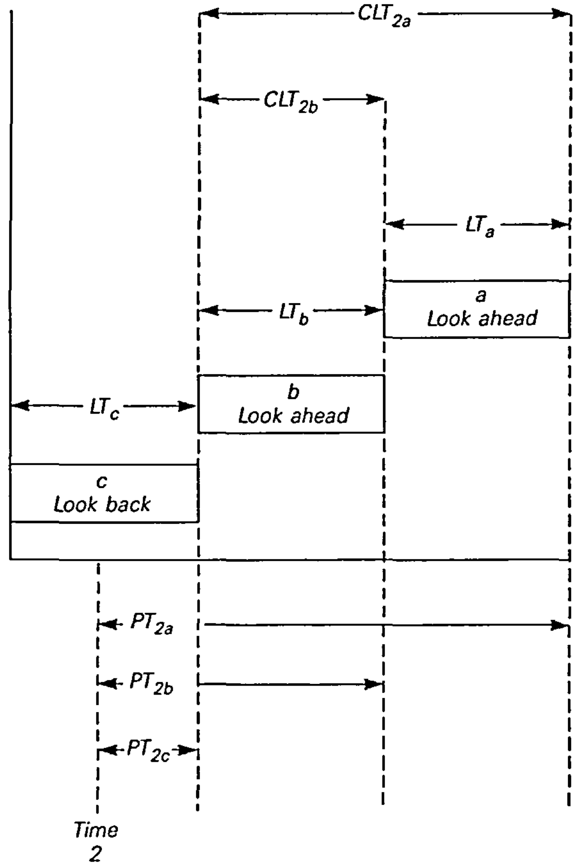

Figure 3.
Relationships among Times, as Code *c* is Managed with Look Back Logic

Uncertainties which affect MRP techniques are[14] that:

- requirements shift from one period to another;
- requirements are more or less than planned;
- orders are not received when due;
- orders received are more or less than planned.

Combinations of these factors can lead to considerable complexity. Safety stocks are the device used in order to cope with uncertainty in quantity. Safety lead time[12, p. 84] accommodates uncertainty in times. Lot sizing comes in, when a lot for lot order policy, which would mean zero inventories, is relaxed. In this case other criteria like fixed period requirements, period order quantity and least unit cost are adopted[12, pp. 120-38; 15]. Safety stock, safety lead time and lot sizing are typical variables of the *look back* approach. Safety lead time can also be considered a typical ROP variable. In this technique, the safety stock is determined by estimating two different factors[16]. The first factor deals with variation of consumption in unit time, the second with variation in supplier's lead time. As safety stock and safety lead time is incorporated within MRP it is correct to define the logic of the MRP systems, as a *look back-look ahead* mixed approach.

Initially MRP techniques tended to be associated with *look back* logic, since concepts like economic order quantity or safety stock predominated. Corke[17] for example, referred to free cover as the sum of stock plus outstanding orders less calculated requirements. When the methodology to calculate needs was stressed, MRP was more properly considered as a *look ahead* logic. Later, Corke[16, p. 86] replaces the paragraph about free cover with MRP. Therefore, we can make this distinction:

- MRP technique as *look ahead* logic, if safety stock and safety lead time are zero and ordering policies are lot for lot;
- MRP technique as *look head-look back* logic, if safety stock and/or safety lead time are not zero and/or ordering policies are not lot for lot.

With the above assumptions, a classification of inventory management techniques is shown in Figure 4.

Manufacturing Priority Assignment and Picking and Moving Sub-system

The purpose of an inventory management technique, whether ROP or MRP, is the satisfaction of manufacturing or purchasing orders. The ordering takes place at a scheduled time, once both manufacturing capacity and the supplier's availability to observe time and quantity requirements have been checked. In such circumstances, it becomes necessary to make use of a priority assignment system in order to decide which order, among those destined for the same manufacturing centre, is the most urgent.

The traditional device, which supports the manufacturing at a working station, is the Despatch List. With this, the urgency of an order is determined by a priority rule (i.e. critical ratio).

This priority assignment technique can be defined *push,* since it does not take into consideration the downstream centre demand but involves working out parameters like: due date of the order, running time, number of residual operations, length of operations.

The Material Requisition List authorises the movement from the warehouse to the first manufacturing centre. Then, once manufacturing is over, items are pushed on to the next station. In this way the operations in the Despatch List of the next station can be carried out to schedule. The act of moving may be viewed as *push*. Despatch List, Material Requisition List, and Material Movement to the next centre once manufacturing is over, will be called, as a whole, Despatching.

A different priority assignment technique, in contrast to the above mentioned, is that of the well-known Kanban manufacturing cards.

The purpose of the Display Board[18] is to give the centre manager manufacturing priority representation. The conceptual difference from the Despatch List

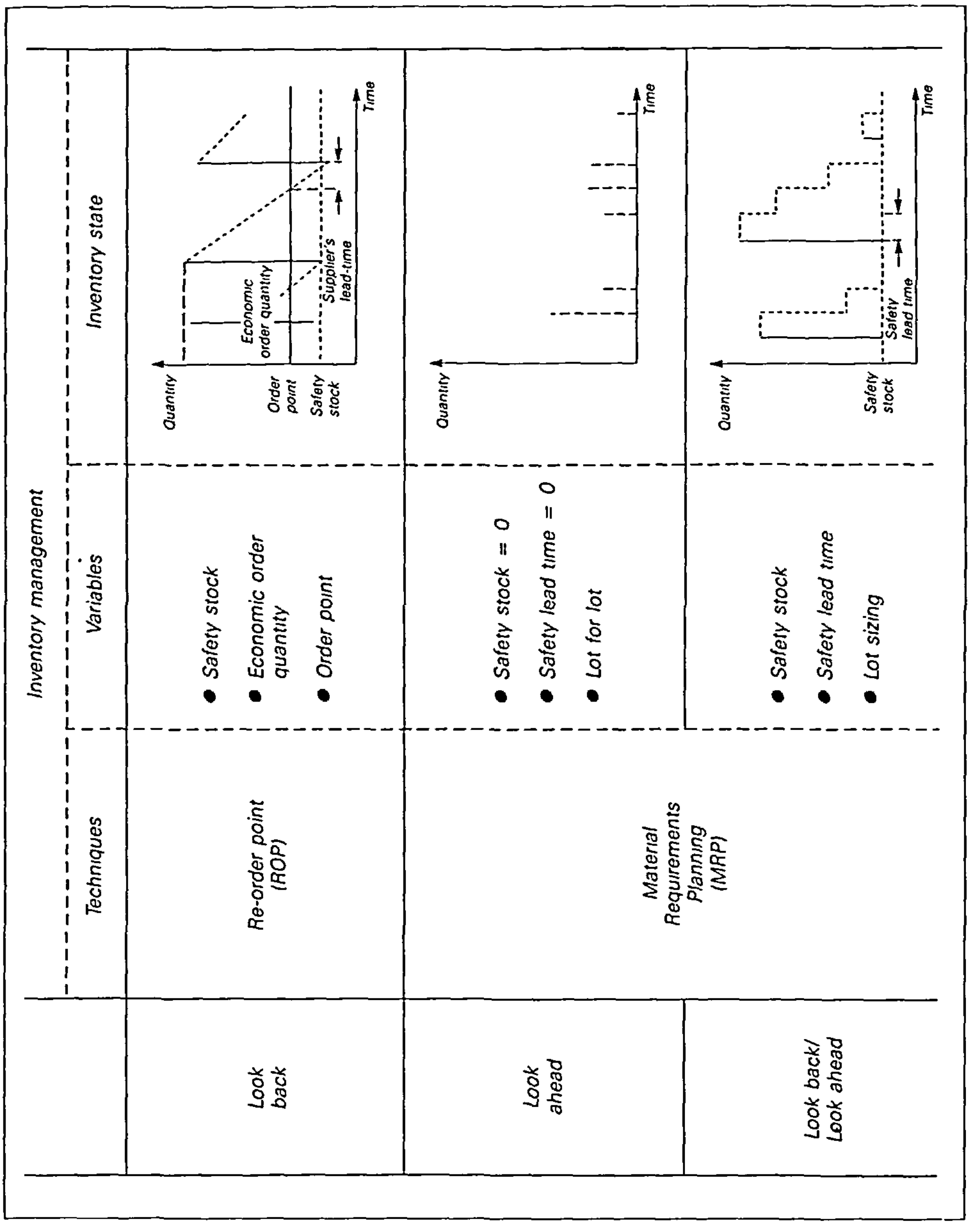

Figure 4
Classification of Inventory Management Techniques

is that priority assignment is based on the manufacturing Kanban cards themselves; that is, the real downstream centre needs. In this way this system can be considered *pull*. Material movement, carried out by movement of Kanban cards, is also *pull*. When the manufacturing centre managers pick some material, they cause the movement from upstream centre to downstream centre to start.

A technique which makes use of both a Despatch List and a Display Board is the Synchro-MRP. It is within a *push-pull* mixed logic. It was implemented at Yamaha Motor Co.[19]. The priority assignment function is carried out first by the Display Board, and then by the Despatch List. The purpose of the latter is to authorise manufacturing. Indeed, the actual manufacturing of another standard box of items is determined by a double condition:

- existence of manufacturing kanban cards, so called Synchro 2, for that item;
- existence of a specific order for that item on the Despatch List.

In order to make a correct analysis of the mixed logic it is convenient to distinguish the transitory state, in which Synchro 2 cards are changed, from the steady state, which lasts till the next issue output by PYMAC. PYMAC is the information system which implements Synchro-MRP. It means Pan Yamaha Manufacturing Control.

In the steady state, the logic is *push-pull:*

- *pull,* because it is based on the real downstream needs, as cards exist;
- *push,* because it also takes advantage of the Despatch List.

In the transitory state, the logic is only *push,* since operations are launched in anticipation of downstream needs. Therefore it is correct to define this priority assignment logic as a mixed *push-pull* one.

In the steady state, moving from and to centres is controlled by movement of Synchro 1 cards and therefore it is based on a *pull* logic. This is exactly what happens with a Kanban system.

In the transitory state, movement is carried out according to a *push* logic, since new movement Synchro 1 cards move some items in anticipation of the needs of downstream centres.

In conclusion the movement system is also based on a *push-pull* mixed logic as indicated in Table I. The Synchro-MRP system implements a *push* logic during the transitory state and, practically, a *pull* logic (as Kanban) during the steady state, assuming that there is a manufacturing authorisation (Despatch List).

State \ Sub-systems	Manufacturing priority assignment	Picking and moving
Transitory	Push	Push
Steady	Push/pull	Pull
Overall	Push/pull	Push/pull

Table I. State Logics in the Synchro-MRP System

Table II correlates the *push-pull* logics with the activities of both manufacturing priority assignment, and picking and moving, for the three techniques:

Table II.
Relationships among Push-pull Logics and Manufacturing Priority Assignment and Picking and Moving Sub-systems

Logics \ Sub-systems	Manufacturing priority assignment	Picking and moving
	Despatching	
Push	Despatch list	• Material requisition list • Moving when manufacturing is over
	Kanban	
Pull	Manufacturing Kanban cards	Movement Kanban cards
	Synchro-MRP	
Push/pull	• Display board with manufacturing Synchro 2 cards issued by PYMAC • Despatch list	Movement Synchro 1 cards issued by PYMAC

— Despatching
— Kanban
— Synchro-MRP.

Inventory Management Techniques and Push and Pull Logic

We have used the terms *push* and *pull* in the classic sense, as in literature[10]:

— *push* means to take action in anticipation of a need
— *pull* means to take action upon request.

These terms have been coined with reference to priority assignment and movement sub-systems. In respect of inventory management techniques, the logic has been classified[11] as *look back* or *look ahead.*

If *push* and *pull* concepts are to be extended to inventory management systems, the correspondence is as follows:

- *push* = *look back,* since the order for a material is launched in anticipation of needs, and therefore is pushed. The logic, according to which the order is launched, is the *look back* one, based on previous consumption.
- *pull* = *look ahead,* since the order for material is launched because of a known requirement. The logic, according to which the order is launched is the *look ahead* one, based on looking at requirements.

Therefore, we can show:

- Reorder Point is a *push* inventory management technique.
- Material Requirements Planning is a *pull* inventory management technique.

Indeed, it is not rare to find definitions completely opposite to those just given[9]. The misunderstanding comes from missing the distinction between inventory management sub-systems and priority assignment and/or picking and moving sub-systems. Since MRP is mistaken for Despatching (both being traditionally used together), and since Despatching is *push*, MRP has been wrongly supposed to be *push*. Conversely, ROP has been supposed to be *pull*.

Production Planning Sub-system

In our opinion it is also possible to classify production planning techniques, according to *push* and *pull* logic:

- A Master Production Schedule (MPS), which employs marketing forecasting, is a plan which determines the manufacture of end items in anticipation of needs. Therefore the logic is *push*. Usually MPS objects are families of items, in order to delay as much as possible the Final Assembly Schedule (FAS) of end items. However, if FAS is performed by forecasting, it is also within *push* logic.
- Both the Master Production Schedule and the Final Assembly Schedule, executed by order of customers, can be associated with *pull* logic, since they are carried out upon request. In this case Master Production Schedule and Final Assembly Schedule objects are end items.
- A Master Production Schedule carried out by forecasting and a Final Assembly Schedule by order are planning systems based on a mixed *push-pull* logic. In this case Master Production Schedule objects are planning bills; Final Assembly Schedule objects are still end items.

A Unitary Interpretation of Production Planning, Inventory Management, Manufacturing Priority Assignment and Picking and Moving Sub-systems

At this point, we are able to interpret with a unitary *push* and *pull* logic the production management sub-systems described in the previous sections. They are classified in Table III which incorporates Table II.

Within any set of production management sub-systems, the use of a technique with a particular logic in one sub-system does not necessarily mean the use of techniques with the same logic in other sub-systems. Indeed, within any sub-system, the choice of a technique is determined by application conditions, as will be seen in the next paragraph.

With this view, the time-phase order point technique can be classified on the one hand as a *push* planning technique, since the MPS is defined by forecasting, and on the other as an MRP inventory management technique within *pull* logic or *push-pull* logic.

The scheme, generally, enables the total production management system to be individualised according to the logic of the particular techniques employed.

Table III.
Unitary Scheme to Classify Production Management Techniques

Logics \ Sub-systems	Planning	Inventory management		Manufacturing priority assignment	Picking and moving
				Despatching	
Push	MPS and FAS by forecasting	Reorder point (ROP)		Despatch list	• Material requisition list • Movement when manufacturing is over
				Kanban	
Pull	MPS and FAS by order	Material Requirements Planning (MRP)	• Safety stock = 0 • Safety lead-time = 0 • Lot for lot	Display board with manufacturing Kanban cards	Movement Kanban cards
				Synchro-MRP	
Push/pull	• MPS by forecasting • FAS by order		• Safety stock ≠ 0 • Safety lead-time ≠ 0 • Lot sizing	• Display board with Synchro 2 cards • Despatch list	Synchro 1 cards

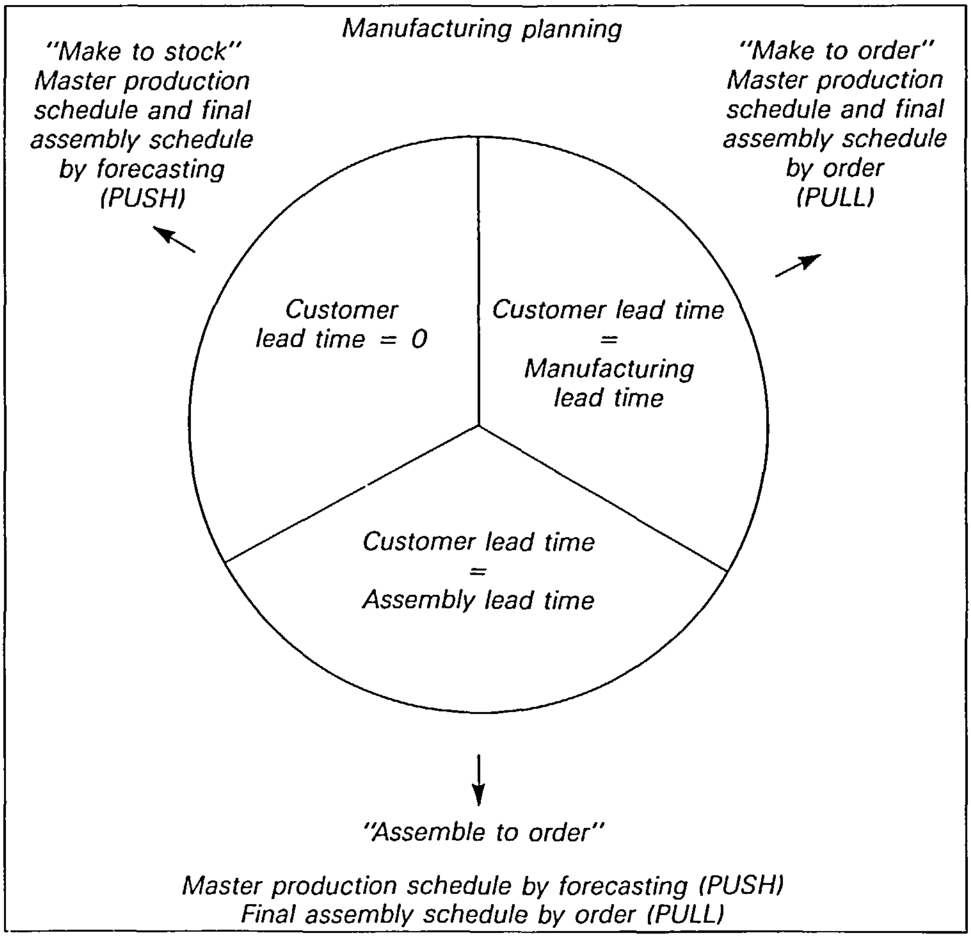

Figure 5.
Application Conditions for Manufacturing Planning Techniques

Application Conditions for Production Management Techniques

With reference to any of the techniques in Table III, the question posed is: "What are the conditions in which one management technique is better than another?". The answer can be found by pointing at some conditions which orient or necessitate the use of one technique as opposed to another.

With regard to the manufacturing planning sub-system, one must take into consideration the relationship between lead time (LT) accepted by the customer, and the lead times of the manufacturing system. Three alternatives are possible:

- Customer LT = 0 (*make to stock* firms): Master Production Schedule and Final Assembly Schedule are determined by forecasting.
- Customer LT = manufacturing and assembly LT (*make to order* firms): Master Production Schedule and Final Assembly Schedule are determined by orders.
- Customer LT = assembly LT (*assemble to order* firms): Master Production Schedule is determined by forecasting and Final Assembly Schedule by order.

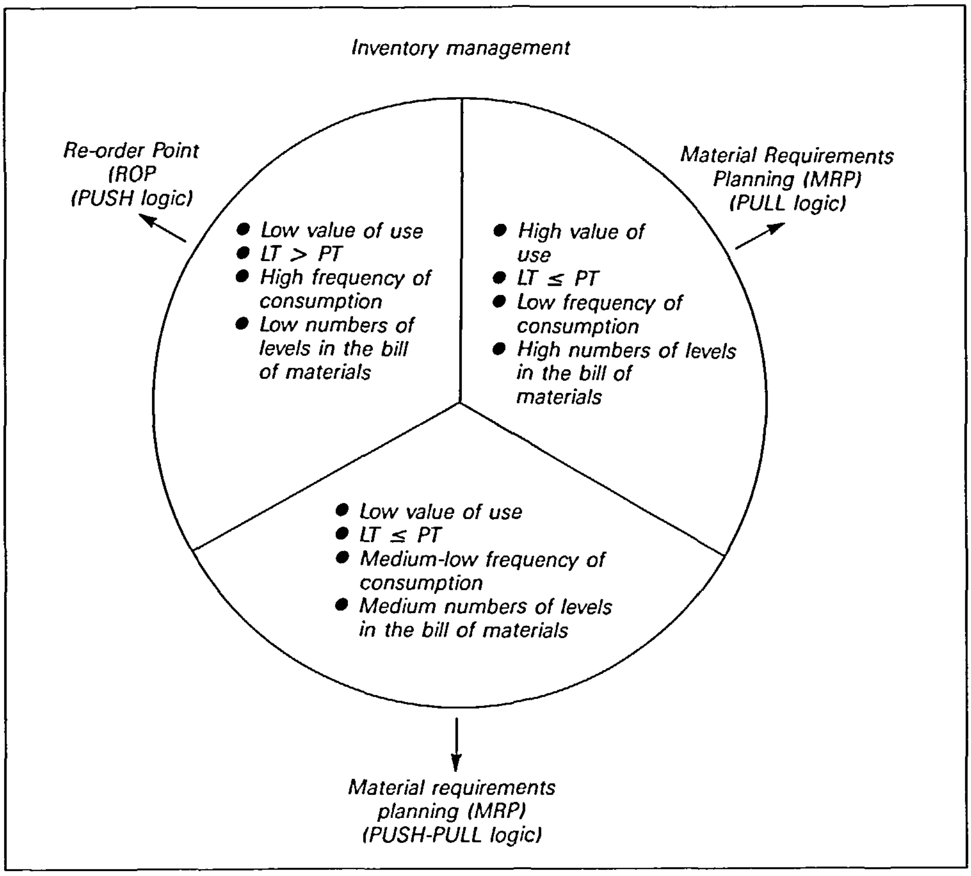

Figure 6. Application Conditions for Inventory Management Techniques

These concepts are shown in Figure 5.

As regards the inventory management sub-system, the variables which affect the choice of a management technique, have been discussed above. If in combining different values, extreme conditions are assumed, it is clear:

(1) If value of use is low, lead time is greater than planning time, frequency of consumption is high, and number of managed levels in the bill of materials is small, the inventory management technique to be used is ROP. In Figure 2, this condition, with the exception of number of managed levels in the bill of materials, is shown by cube number 7;

(2) If value of use is high, lead time shorter than or equal to planning time, frequency of consumption is low and number of managed levels in the bill of materials is high, Material Requirements Planning is the best technique (with safety stock and safety lead time equal to zero and ordering policies lot for lot). In Figure 2 this condition, with the exception of number of managed levels in the bill of materials, is shown by cube number 1;

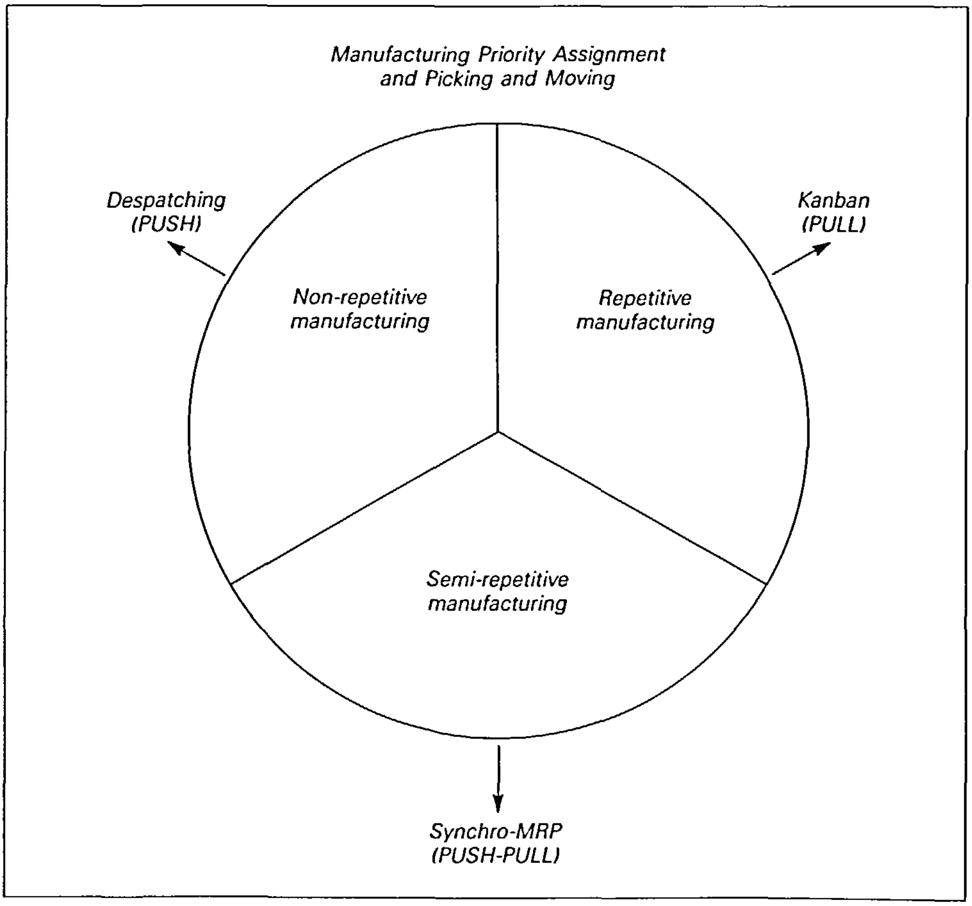

Figure 7.
Application Conditions for Manufacturing Priority Assignment and Picking and Moving Techniques

(3) If value of use is low, lead time shorter than or equal to planning time, frequency of consumption is medium-low, and the number of managed levels in the bill of materials is medium, MRP is the best technique (with safety stock and lead time different from zero and ordering policies different from lot for lot ones). In Figure 2, this condition, with the exception of number of managed levels in the bill of materials, is shown by cube number 2.

Application conditions of the different inventory management techniques are suggested in Figure 6.

In the end, as far as the problem of the application conditions of manufacturing priority assignment and picking and moving techniques is concerned, repetitiveness of operation is a key variable:

— if manufacturing is not repetitive, a Despatching technique is used;
— if manufacturing is repetitive, the Kanban technique is used;
— if manufacturing is semi-repetitive, the Synchro-MRP technique is used.

The concepts are shown in Figure 7.

JIT and the Production Management System

A short-term view of Just-in-Time is that it means getting the right part in the right place, at the right time, in the strictly necessary quantity. Taking a medium-long term view, the meaning of JIT is wider: JIT is a philosophy of improvement[20] in order to manufacture products of higher quality, within shorter lead times, at lower unitary costs.

The term JIT has been coined in Japan. It corresponds to the American terms Zero Inventories and Stockless Production. In order to fulfil these philosophies, a global approach is necessary. For example, visual control systems, quality circles, preventive maintenance systems, production management systems for reducing inventories, integration with customers and suppliers have to be implemented and technological limitations must be overcome (i.e. set-up times) and flexible manufacturing systems introduced.

As far as the production management system is concerned (the object of this article) the techniques which, for each sub-system in Table III, enable manufacturing with:

— high quality of service;
— inventories as low as possible;
— work in progress as low as possible;

are those based on *pull* logic.

These techniques make it possible for:

— the production planning sub-system to manufacture by order, with the best service for customers guaranteed;

— inventory management sub-system to work with minimum stocks of raw materials, components and end items;
— the priority assignment, picking and moving sub-system to work on downstream needs, with the lowest work in progress.

An MRP technique within pure *pull* logic enables materials just arrived at the warehouse to be taken out immediately. In this way managed warehouses carry out only a transitional purpose. In the JIT philosophy of improvement the next step is to eliminate warehouses of components. This fact means considering all the intermediate levels in the bill of materials as phantom codes[21] and delegating shop floor control to the priority assignment, picking and moving sub-system.

Therefore, from the JIT viewpoint a marriage between MRP (inventory management with *pull* logic) and Kanban (priority assignment and picking and moving with *pull* logic) is not only possible, but also desirable[22, 23, 24, 25].

Conclusions

The purpose of this article has been to propose a unitary scheme in order to interpret and classify, with *push* and *pull* logic, certain production management sub-systems.

Some application conditions for the techniques have also been considered. The application conditions themselves, and not the logic intrinsic to the techniques, determine the choice of the most feasible technique, given the characteristics of the manufacturing system. Therefore, within the overall production management system, techniques with different logic can coexist.

In order to achieve the goals of JIT philosophy, the techniques with *pull* logic guarantee the best results.

To answer some of the questions raised in the Introduction, one can conclude:

- JIT is the search for excellence in manufacturing with the aim of constant improvement.
- JIT means Zero Inventories and Stockless Production.
- Kanban is a priority assignment picking and moving technique. It is not JIT.
- Kanban lies within the JIT philosophy.
- MRP is an inventory management technique with a *pull* logic.
- MRP lies within the JIT philosophy.
- Kanban and MRP are consistent and their marriage is desirable in order to achieve JIT.
- JIT, which needs a global approach, is best carried out as far as production management activities are concerned, by *pull* logic techniques.

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