PRODUCTION PLANNING & CONTROL, 1997, VOL. 8, NO. 5, 500–508

Repetitive manufacturing planning and control systems: a framework for analysis

ALBERTO DE TONI and ROBERTO PANIZZOLO

Keywords Operations management, repetitive manufacturing, production control, MRP-II, backflushing, case studies

Abstract. The operational characteristics and management logic of repetitive production greatly differ from those of intermittent manufacturing. Notwithstanding this, there are still few packages specifically developed for manufacturing planning and control in repetitive contexts, and often those that are available have been derived from adaptations and/or extensions of packages originally designed for intermittent manufacturing. Starting from an in-depth examination of three cases, a framework for the analysis of the characteristics of manufacturing planning and control (MPC) systems utilized in repetitive contexts has been developed. The proposed framework includes all three basic production control sub-systems, i.e. planning, inventory control and shop floor control. Based upon this framework the main functions that characterise production planning and control systems for repetitive manufacturing are examined. Among the most important functions described are: production planning with 'control orders' and 'flow orders' versus 'work orders', picking lists for 'floor stocks by daily rate' versus 'work centre by work order', resources and materials consumption by 'backflushing' versus 'work order'.

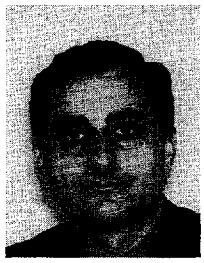
1. Introduction

This article examines how manufacturing planning and control (MPC) systems for repetitive manufacturing are designed and used. The subject of the study is of particular interest insofar as the structural-logical model on which software packages for the management of repetitive manufacturing has not yet been completely consolidated. There are still very few packages specifically designed for the support of repetitive manufacturing available on the market today (Grievo 1988, Rao 1989a and 1989b, Sangjin 1989, Langford 1990).

On the other hand, most of the works in the literature which deal with this topic, are not theoretical and research-orientated (Rao and Scheraga 1988, Quillen 1985, Webber 1990). The research carried out in these

Authors: A. De Toni and R. Panizzolo. Department of Electric, Managerial and Mechanical Engineering, University of Udine, Italy. Department of Industrial Innovation and Management, University of Padua, Italy.

ALBERTO DE TONI is associate professor of production and logistics management at the Faculty of Engineering, University of Udine. He received his degree in industrial engineering and his PhD in science of industrial innovation from the University of Padua (Italy). He has published numerous papers in *International Journal of Operations and Production Management, International Journal of Physical Distribution & Logistics Management, Logistics Information Management, Integrated Manufacturing Systems, Omega, International Journal of Production Economics, Small Business Economics, International Journal of Production Research.* He has presented a number of papers in conferences in Italy, United Kingdom, United States, Sweden, Finland, Netherlands, Austria and Greece. His areas of interest include production planning and control, manufacturing strategy, performance measurement, supply chain management.



ROBERTO PANIZZOLO originally trained as an electronic engineer. He received his PhD in 1992 based on research on manufacturing innovations management. He is currently assistant professor at the Department of Industrial Innovation and Management of the University of Padua. His current research and teaching are in operations management and technology management areas with particular emphasis on product design and production interfaces in manufacturing firms. On these issues he has published various articles in international journals and has participated in a number of international conferences. In addition to his academic tasks, Dr Panizzolo is involved in a wide range of industrial management research project including some funded by CNR (National Research Council of Italy) and has run several courses for industrialists.

0953-7287/97 $12·00

papers generally lacks an overall vision of the problems, focuses on only a few characteristics of MPC systems and does not critically examine the totality of requirements asked by an MPC system in a repetitive context.

In this article, building upon a previous work by the authors (De Toni and Panizzolo 1993) and the results of an in-depth examination of three case studies developed from on-site interviews and on-site visits, the study of the characteristics of production planning and control systems for repetitive manufacturing is carried out through the development of a framework for analysis which includes the three basic production control sub-systems—planning, inventory control and shop floor control (SFC). The firms investigated were studied in order to identify both the methods used to plan and control production and the current problems that were being encountered in utilizing the functions of the production planning and control systems.

The rest of the paper is organised as follows: the following section presents the three case studies; Section 3 examines the case studies and develops a framework for the analysis of the characteristics of production planning and control systems for repetitive manufacturing; finally, based upon the framework developed, the main software functions of a control system for repetitive production contexts, regarding each of the three sub-systems of production management: planning, inventory control and shop floor control, are described.

2. The case studies

The case studies are presented as follows. First a brief description of the production process is given, then a discussion of the production planning environment is developed. The firms examined are European multi-site companies with plants situated in the EU countries. The unit of analysis is the single plant.

2.1. *Case study A*

The company produces evaporators. Production volume is over 4000 units per day and there are about 700 part numbers for finished, packaged products.

The plant is characterized by a product layout with machinery and equipment grouped in cells according to group technology principles. The cells are structured in such a way as to permit a balanced production flow. Routeings are fixed for each end product and throughput time is 3–4 days. Actual manufacturing time is less than 8 hours.

Formal production planning begins with an annual sales forecast which is broken up into quarterly forecasts, with the first 90 days taken as the basis for the master production schedule (MPS) which is updated monthly. The MPS is stated in terms of the rate of production per day. Along with the monthly master production schedule process, capacity planning is carried out. This is a very important activity as no short-term capacity adjustments are possible because the factory operates at maximum capacity.

Once the MPS has been approved, it is transmitted to the material requirements planning (MRP) software procedure. Because of both the product layout used, with the reduction of set-ups at operations, and the flow of production created, no planned production orders are used to plan components priorities and the MRP procedure is used only to determine purchase orders. Priority planning is a function in the master production schedule rather than a shop floor activity.

Production is carried out according to a daily rate and the material flows through operations on a continuous basis without customer lot identification. A pull method is used among machine centres in order to synchronize the flows of materials, excluding those to and from the warehouse. Lists of materials which have to be withdrawn from the warehouse and sent to workstations are drawn up on the basis of the daily production rate set by the MPS.

No formal SFC system is used. Production is monitored on a daily basis by manufacturing supervision and various reports are created. These reports provide management with information about production status versus the master production schedule. A backflush method is employed to record material and capacity requirements.

2.2. *Case study B*

The company is a producer of mills for the food industry. There are about 25 base models with about 300 major options. Annual sales are approximately $50 million. The plant has several separate workcentres arranged in a functional layout and two assembly lines. There are about 2000 different parts which are routed to various machine centres in the fabrication areas. Material moves to the assembly and subassembly areas from fabrication and from purchased stores. Usually, lead times are less than one day for most subassemblies.

Formal production planning starts with the development of a production plan from sales forecasts. This production plan is adjusted, on a monthly basis, for capacity considerations in order to develop the master production schedule.

The MPS is managed based on the rate of production per time period. Production is compared against the plan by materials management on a daily basis. This

report lists the daily build objective, quantity produced, and accumulated build for each line. A final assembly schedule (FAS), based on customer orders, is prepared and executed on the basis of the MPS. The FAS is also monitored daily.

A report is developed from the MPS which is used to update the MRP system. The MRP system is primarily used for ordering purchased finished components and raw materials. The MRP calculation loses its identity as the explosion and netting process occurs because lead times are usually less than one day for most assembly and subassembly components and less than one week for most fabrication components. The MRP is used to release material into the shop, but it is not used to set priorities between machine centres or to establish due dates. The actual prioritization of parts across machine centres is done primarily by Kanban based on the final assembly schedule. In the MRP system there is no identification of parts going to the assembly lines.

As final products are assembled, components are withdrawn from the tote bins located along the assembly line. As Kanbans are collected in fabrication, shop supervision checks existing material availability against the final assembly schedule and adjusts build priorities as needed. First come first produced is often the basis for priority.

Various reports are produced by the MRP system for supervision purposes. A daily open order exception report is used to alert management to raw material unavailability. A shortage list from the final assembly based on unpicked shop orders is used to advise shop supervision that parts may need to be expedited.

2.3. *Case study C*

The company produces heaters, equipment and accessories for heating, cooling and plumbing. The plant manufactures about 400 end items and has annual sales of $140 million. The factory is structured according to a product layout. Routeings for components require unique processing. A total of about 7000 different components are used to make the entire product mix.

Formal production planning starts with the elaboration of a 6-month sales forecast which is developed by marketing, master scheduling and purchasing based on the previous 2-year performance. The production schedulers break the forecast into top part number requirements and load the MPS for each production line. The MPS is stated in terms of the daily production rate which is set according to line capacity. Capacity planning is carried out as part of the monthly MPS process. The bill-of-resources method (Vollmann *et al.* 1992) is used to determine the work load for a particular line rate.

The MPS feeds the MRP module in daily time periods for the first four to six weeks where actual orders replace forecasted quantities. The MRP system generates requirements for the purchasing system and for material release for about 25% of the part numbers. A pull system is used to control the movement of both the lots among intermediate operations, and of those part numbers from the purchased finished stores areas to the seven product assembly lines that are not released using the MRP system.

The daily shop schedule is used to determine the relative priorities for orders not yet launched onto the lines. Once a production order is released to the factory no updates are carried out on the MRP system except to report the finished order. Priorities of the orders in process cannot be modified because of the nature of the product layout.

The daily production rate is monitored by the master schedulers and compared to the planned daily production rate in order to maintain the validity of the MPS. Consumption occurs by backflush when the order is reported into finished goods status. Detailed capacity requirements are not drawn up. Capacity is monitored by the manufacturing teams on an ongoing basis and are based on the actual production accomplished during the week.

3. Repetitive manufacturing planning and control: a framework for analysis

In this paragraph, a comparative analysis of the three case studies described above is carried out in order to develop a framework for the study of the characteristics of production planning and control systems for repetitive manufacturing. Starting from an examination of the three case studies the following observations can be made.

Production planning plays a vital role in ensuring regular production flow. Therefore, the formulation of the production plans, in particular the MPS and the FAS, aims at obtaining as continuous and uniform as possible a flow of materials through the factory (Lee 1993). In intermittent production, these plans are composed of a collection of production orders (also called job-orders or work orders), formulated on a bucket basis, that are then passed on to the MRP procedure with the aim of formulating a time-phased plan for materials.

However, in repetitive manufacturing, definition of both the MPS and the FAS requires specification of a 'rate of production per time period' as in case studies A,

B and C. This means the formulation of two different types of orders sometimes called 'control orders' and 'flow orders' in the literature (Hall 1981, Jain 1989). The control orders state the total quantities to be produced in a given time, whereas flow orders specify daily production quantities with reference to the control order. The quantities specified in the different flow orders cannot be arbitrary but must be consistent with the potential daily capacity of the line.

Thus these programmes that specify the quantities to be produced in a given time period are the true regulators of repetitive manufacturing systems (Gessner 1988). The production rate and the flows of different materials through the plant are the real focus of control activities and not the completion of the various orders as in the job-shop system.

As regards material requirements planning within repetitive manufacturing, the examination of all three case studies has highlighted that the MRP procedure is 'reduced' to a simple calculation of requirements for raw materials or for components to be purchased thus, usually, only purchasing orders, not production orders, are issued (see for example Bromberg and Mann 1981). In repetitive manufacturing, the components of intermediate levels of the bill-of-materials are not normally managed at the warehouse level and calculation of net requirements for them is not used. Bills-of-material with phantom components at intermediate levels, enable the so-called flat bills to be drawn up (Sillince and Sykes 1993).

This situation is very different from that of intermittent manufacturing, where after the formulation of the MPS, the MRP procedure generates both work orders and purchasing orders. The work order is the fundamental instrument for the regulation of the entire production process as it enables a lot, moving through the various workshops on the different machine tools, to be accurately identified.

Shop floor control activity too, differs in the two contexts. In intermittent manufacturing, warehouse issues are carried out using a picking list which is automatically generated by the information system for each work order. The accounting records of the materials, issued from the warehouse and sent to the various workcentres, is carried out in concomitance with issuing. Moreover, the work order, by registering the evolution of lot life during its passage through the various phases of the production process, is the only means of providing cost analysis, of analysing deviation from standards and of monitoring the level of work-in-progress (WIP).

In repetitive manufacturing, as shown in the descriptions of case studies A, B and C, the quantities of materials that flow along the lines are specified on daily production programmes and not according to precise work orders. Therefore, issuing is based on

Table 1. The framework for the analysis of the characteristics of production planning and control systems for repetitive manufacturing.

	Categories of production	
Operation management subsystems	Intermittent manufacturing	Repetitive manufacturing
Production planning	• MPS and FAS with job-order formulation	• MPS and FAS with formulation of control order and flow order (production daily rate)
Inventory control	• MRP with formulation of job-orders and purchasing order	• MRP with purchasing order formulation (requirements calculation)
	• Multilevel bill-of material	• Flat bill-of-material
Shop floor control	• Work order as principal key to obtain information	• Part number as principal key to obtain information
	• Picking list for workcentres by work order	• Picking list for floor stocks on the basis of production rate
	• Warehouse issues on the basis of quantity released to the first workcentre	• Warehouse issues of raw materials and components on the basis of number of finished product receipts (backflushing)
	• Record of material movements among workcentres	• Resource consumption by work centre
	• Resource consumptions by work order	

plans and since the subassemblies move continuously along the line not all the movements through the various phases of the production process have to be recorded.

Moreover, in the repetitive context, raw materials and purchased components may be temporarily stored in special areas or 'floor stocks' at the bottom of the line for fast access. In this case, the movement of materials between the central store and floor stocks is regulated by a picking list which is no longer drawn up on the basis of work orders but, rather, is defined by floor stocks on the basis of the daily production rate.

As seen in case studies A and C, the rate of consumption of raw materials, components and resources, rather than being measured at the moment of issue, can be deduced from output volume through the bill-of-materials and production routeings. This technique, which permits retrospective calculation of issuing on the basis of part receipts, is known as 'backflushing' or 'post-deducing' (Didsbury 1988, Krepchin 1988) and requires the preliminary choice of 'pilot operations' on the line where recording is going to take place.

The above observations regarding the management of repetitive manufacturing systems in comparison with intermittent systems, are represented schematically in the framework shown in Table 1, which has been drawn up so as to better describe the characteristics of production planning and control systems for repetitive manufacturing (see De Toni *et al.* 1988 for more details about the framework of Table 1).

In the following sections, building up the proposed framework, the main software functions that must be available in a control system for repetitive manufacturing (regarding each of the three sub-systems of production management: planning, inventory control and shop floor control), are given. This paper does not seek to offer an exhaustive list but, rather, to describe the several modifications that have been made, over the years, to the MRPII system in the three companies studied, in order to better planning and control production. The description is carried out with the aim of providing the basis for the development of production planning and control systems for repetitive environments.

4. The planning sub-system

In repetitive production systems, the definition of the MPS and FAS requires, as previously stated, that the quantities planned at the weekly or monthly level must be revised before being released to the shop, in order to permit the formulation of daily production programmes which, by taking into account the diverse throughput times of the different codes that pass along them, will allow the lines to be correctly balanced.

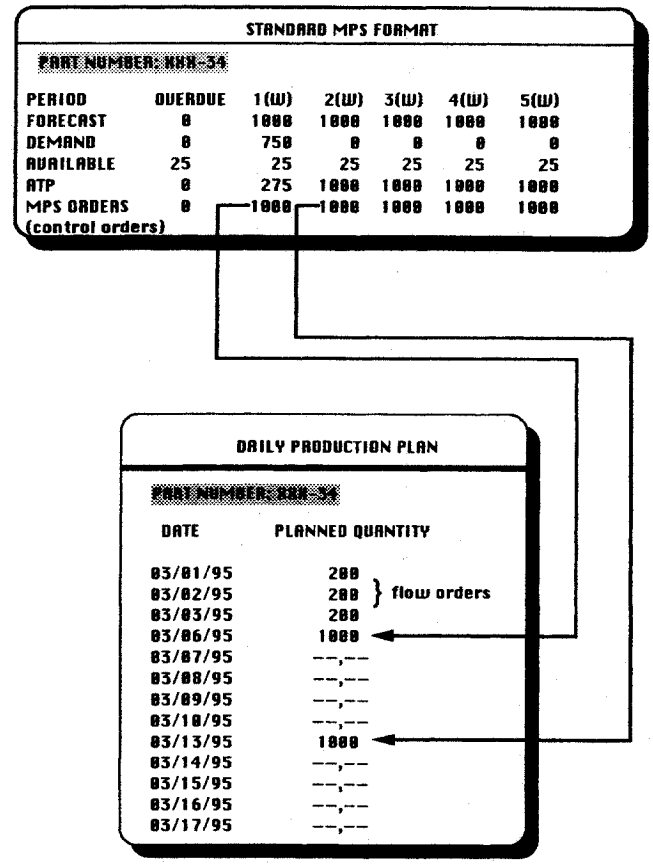


Figure 1. Formulation of production programmes by flow orders.

The formulation of an MPS based on daily quantities, so as to ensure regularity of production flows, means that new functions must be available within the MPS module of an MPC system. The most distinctive aspect of these functions is that they must operate on the basis of part number and/or workstation and not of the work order as usually happens in intermittent manufacturing (Cincom 1990).

In all three companies studied, the MPS module has been modified to take these requirements into account. In particular, a new software function, used for drawing up a daily production plan for one part, has been developed. As shown in Figure 1, after entering the part number, the system suggests the total quantity that should be produced for each period (usually a week) defined by the MPS control order, and allows the planner to specify the daily production rate (flow order). Naturally, when possible, there will be an automatic method for subdividing the control order which will save the planner from having to introduce a large amount of data.

However, the generation of the flow order is critical in levelling material and resource requirements in order to obtain a regular production flow. In the three companies examined, complex computerized sequencing algorithms were being used to help planners to develop production plans.

It is clear that the setting up of a function for drawing up a daily production plan is not a complex task. However, it is important to take into account some problems which may arise if this function is simply added to the existing ones. One of these problems regards the management of the exception messages which 'in MRP systems are used to separate the vital few from the trivial many' (Vollmann *et al.* 1992).

If the control order is simply subdivided into flow orders, as in Figure 2, the first flow order of the week will not be able to cover all the requirements for that week (defined by the control order). Therefore, if further changes are not made, it will cause the system to produce an exception message informing that the quantity of this first flow order should be increased, while for the other flow orders, the system will suggest bringing the due date forward to the first day of the week. One possible remedy for this situation could be that of using 'exception dampeners' but, usually, the software routines will have to be modified more drastically.

Once the daily production rate has been formulated on the basis of flow orders, an accurate feasibility check must be run on it both in terms of materials and of available resources. This check is also carried out in intermittent systems, but in the repetitive systems studied, the fact that there is no work order has led the firm to develop specific software functions so as to highlight, by part number, those requirements for materials and capacity that cannot be met by the resources available.

Lastly, once the daily plan for a specific period has been checked and become active, those functions that permit total visualization of the actual state of production become fundamental. As various authors have highlighted, some functions must, for example, allow the production plan to be represented through a 'cumulative' method (Quillen 1984). These cumulative figures allow fast and effective evaluations of production activity to be made.

5. The inventory control sub-system

Once the daily production plans have been defined (through flow orders), it is important that these latter should be aligned with the material requirements plan, because materials must reach the production areas on the basis of daily consumption and not on the basis of weekly or monthly orders. In other words, the MRP must be able to handle daily scheduling. In this situation, first of all, it is necessary to build up a MRP procedure whose primary function is to explode a levelled and rate-based, master schedule into requirements for purchased components and raw materials. In this way, the requirements for intermediate components may still be displayed for planning purposes, but are not released. Therefore, all the activities associated with releasing orders need to be disable: material availability checking, pick-list preparation and shop paper generation (Putnam 1983).

However, in order to guarantee optimum management of material flows, not only are these changes in MRP necessary, but also new software functions must be used that are able to operate on the basis of the material requirements that derive from the daily production programme.

In all the cases examined, companies have developed various functions which can be used by central warehouse operators on a daily basis to outline the list of materials that should be sent to the line in order to ensure it is correctly fed. More specifically, these functions, on the basis of quantities planned for in the daily production programme, note the components and the quantities that should be withdrawn from the central stocks and sent to the floor stock locations along the line.

Along with these functions, in company A and C another type of function was used. This latter function may be used to show, for a specific period and a specific floor stock, all the raw materials and components necessary to maintain the flow of production with details of the supply location of the central warehouse from which the materials must be withdrawn. The knowledge of which materials are required in each floor stock location in order to ensure correct feeding of the line, allows the number of consignments of materials to the same place on the line to be reduced and their routes rationalised.

Lastly, with reference to the inventory control subsystem, examination of the three cases studied has revealed the presence of innovative functions used to record the movements of materials between the supply locations (of the central warehouse) to the floor stock location. The term 'movement' and not 'issue' has been used because, in repetitive contexts, warehouse issues are automatically updated by backflushing (see below).

In this case, given the high production volumes involved, in order to minimize the number of transactions that have to be loaded into the system, it is important to use software functions which facilitate the rapid registration of such movements.

In companies B and C, such a function was used to

highlight the planned material requirements based on the daily production plans. If the quantities actually withdrawn from the supply location coincide with planned requirements, then only a simple confirmation is required for the planner to record all the movements. Otherwise, it is necessary to specify the exact quantity transferred.

6. The shop floor control sub-system

The fundamental objective of an SFC system in repetitive manufacturing is to control the uninterrupted flow of materials through the plant (Sepehri and Raffish 1986). The control and registration of production details cannot be carried out using traditional methods because it would be too expensive and not practicable. Basically a high degree of simplification is needed here (Hewlett Packard 1988).

Given this, only the most critical phases, the key operations and the most important events are subject to control. Examination of the three companies has revealed that the data collection method known as 'checkpoint operations' instead of the 'operation by operation' method typical of job shops is being used. With this latter method, a number of key points must be selected at which to collect data both regarding the quantities produced daily and the materials and resources consumed (Melnyk *et al.* 1985).

This method makes it possible to minimize the number of transactions that have to be recorded in the information system, thus making data entry much easier. If the backflushing technique is also used, then all activities concerning the control of flows are greatly simplified.

Clearly, the possibility of operating with the method described above is directly tied to the use of software functions that are not usually included in traditional software packages. The absence of a work order means that information about production events must be gathered from workcentres and by part number. The individual workcentres are cardinal points of shop floor control: the new control and reporting functions record the progress of production using data gathered by them.

For example, in the companies, in order to record data on finished product, a function was being used that, once a workcentre had been specified, showed all the part numbers that have one or more operations scheduled on that centre on that day, along with the specification of planned production quantities. The machine operator can then specify the number of pieces actually made by part number, without having to refer to work orders.

Data on scraps too, have to be collected at the workcentre and not through work orders. In this case it is possible to use a function that, after having selected the workcentre, requires the specification of the part number of the component that has been processed and the number of scraps obtained. The same also happens for data about the consumption of resources (labour and machine hours). After having specified the workcentre and the part number, the standard data regarding the set-up and run times for that part number relative to the operation(s) performed in that workcentre are visualized. Then, the operator simply has to specify the actual consumption of resources.

However, analysis of these three case studies has highlighted the fact that the software functions described above are usually only utilized at certain key points of the production process, where 'visibility' is necessary (such as at the end of the line) and not during all the different phases. This is why, in repetitive production, machine centres are dedicated to a product and are customized to a process, also, routeings are fixed for each end product and all of the end items are produced essentially in the same way.

This empirical research also revealed that a variety of factors were taken into account by firms when selecting checkpoints along the line. It is common practice to prioritize those centres that are at a point where the line branches, or those where particularly complex operations that do not adhere to standard resource requirements are carried out, or those where especially valuable components are used.

In these cardinal points, control and data collection are direct and immediate (i.e. with direct communication from the operator involved in production), while it is indirect (ex-post) at other points along the line. Here, data collection regarding all consumption of raw materials and components, is not effected at the moment of consumption, rather, it is extrapolated from the volume of output by means of the backflushing, or 'post deducting' technique.

Backflushing functions by means of the mechanism represented in Figure 2. By recording the quantity of product X as it passes the end of the line, and with knowledge of the deduction list associated to each key point (which is obtained by integrating information contained in the bill-of-materials and in the production routeing), the system will automatically update the quantity of:

- finished products X received in the warehouse;
- components A, B and C respectively in the floor stocks (Å), (Å, Ω, Ç) and (Ω, Ç).

For example, if 2000 pieces of X are produced each day,

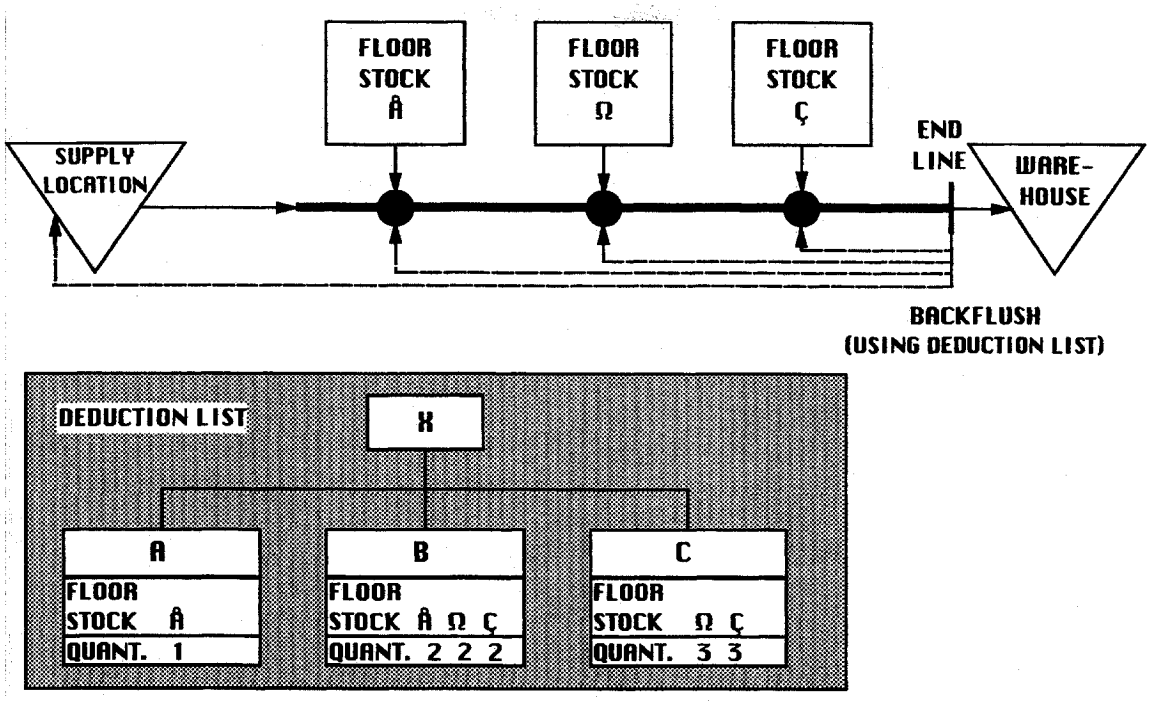


Figure 2. Backflushing technique and deduction list.

then 2000 pieces of component A, 12000 pieces of component B and 12000 pieces of component C will be issued from floor stocks each day.

Central stores always uses the backflushing technique when issuing those materials that are not stored directly along the line, but which are initially sent to one or more central stores and only later forwarded to centres on the line. This fits with an earlier point made here, which stated that only movement and not withdrawal is registered when materials are sent from the supply location to the floor stocks.

What is special about backflushing is its ex-post characteristic: the components are 'consumed' only after the products has been received and not vice versa. In fact, this is the only truly practicable method, given the low throughput times in repetitive production (Rice and Yoshikawa 1982). Analysis of the three companies has revealed that, in order to apply the backflushing technique correctly, the following factors must be clearly defined:

- The points on the line where direct control is required; these are defined as key points or 'milestone operations'. The backflushing procedure involves all the upstream centres as far back as the preceding key point.
- The so-called deduction lists, one per key point defined in the production process, for each product made on the line.

Knowledge of the deduction list is fundamental for the backflushing procedure. When there are some milestone operations in the line, backflushing can take place only if the system knows the exact quantities of materials and components consumed and the respective stock points for all the operations between two milestone operations. This information is what we have defined as the 'deduction list' for that particular milestone operation within which the backflushing process is primed.

7. Conclusions

In this paper the authors have proposed a framework for analysis which has been used to study the characteristics of the production planning and control systems in repetitive manufacturing, where products are produced in volume by dedicated processes and facilities.

The fast pace of the repetitive environment requires an information system that emphasizes close control of capacity and materials yet, also, simplifies and streamlines the operations of the production system. The purpose is to streamline the production management process so that the schedule can be managed as an integral whole rather than as a collection of independent orders.

To facilitate repetitive schedule control, to enhance the material handling capabilities and to automate the activity-reporting function from the production floor,

the software functions described in the paper provide daily scheduling capabilities, reduce dependence upon manufacturing order numbers, supply point-of-use material handling support and minimise activity reporting through backflush activity for material and resource usage.

The model proposed could be useful in diagnosing the correct operating environment and evaluating the applicability of a package for production planning and control. The development of the software functions described requires real changes in the standard modules of a classical MPC system and not simply modifications. For example, the following must be carefully considered:

- control and flow orders to develop the MPS and FAS;
- backflush methods to support manufacturing control;
- resource consumption by workcentre;
- picking lists developed in the daily production programmes.

Moreover, these new software functions require the addition of data fields to the principal files of the information system data base, for example to part, bill, workcentre and production routeing files.

The proposed framework does not seek to examine all the characteristics of repetitive production insofar as it is based on an examination of the literature and the empirical study of only three cases. However, further research and empirical studies could broaden the scope of such a study and reveal other, new methods and techniques adopted for the management of repetitive production.

References

BROMBERG, H., and MANN, J. A., 1981, Classical MRP in a repetitive environment. *Repetitive Manufacturing Seminar Proceedings* (APICS, Las Vegas), pp. 51–57.

CINCOM, 1990, *Repetitive Manufacturing Control: User Manual* (Cincom Systems, Cincinnati, OH).

DE TONI, A., CAPUTO, M., and VINELLI, A., 1988, Production management techniques: push–pull classification and application conditions. *International Journal of Operations & Production Management*, **8**(2), 35–51.

DE TONI, A., and PANIZZOLO, R., 1993, Operation management techniques in intermittent and repetitive manufacturing: a conceptual framework. *International Journal of Operations & Production Management*, **13**(5), 12–32.

DIDSBURY, B. M., 1988, The key elements and concepts of a repetitive manufacturing control system. *Production and Inventory Management*, **29**(3), 51–56.

GESSNER, R. A., 1988, *Repetitive Manufacturing Production Planning* (John Wiley & Sons, New York).

GRIECO, P. L., 1988, Establishing the standard repetitive manufacturing software. *Production and Inventory Management Review*, **8**(2), 41–51.

HALL, R. W., 1981, *Driving the Productivity Machine: Production Planning & Control in Japan* (APICS Repetitive Manufacturing Group, Falls Church, VA).

HEWLETT PACKARD, 1988, *HP-JIT User Manual* (Hewlett Packard Company, Fort Collins).

JAIN, A. K., 1989, Software requirements for JIT manufacturers. *Systems/3X & AS World*, **17**(9), 112–114.

KREPCHIN, I. P., 1988, How software must change to meet JIT demands. *Modern Materials Handling*, **43**(14), 72–74.

LANGFORD, P. W., 1990, Moving to repetitive manufacturing: the way and how. *Seminar One Proceedings* (APICS, Thurbridge, MA), pp. 175–180.

LEE, C. Y., 1993, A recent development of the integrated manufacturing system: a hybrid of MRP and JIT. *International Journal of Operations & Production Management*, **13**(4), 3–17.

MELNYK, S. A., CARTER, P. L., DILTS, D. M., and LYTH D. M., 1985, *Shop Floor Control* (Dow Jones-Irwin, Homewood, IL).

PUTNAM, A. O., 1983, MRP for repetitive manufacturing shops: a flexible Kanban system for America. *Production and Inventory Management*, **24**(3), 61–88.

QUILLEN, L. D., 1984, Repetitive manufacturing information systems. *Readings in Computers and Software, 27th Annual International Conference Proceedings* (APICS, Las Vegas), pp. 45–54.

QUILLEN, L. D., 1985, Repetitive manufacturing assembly scheduling, *28th Annual International Conference Proceedings* (APICS, Toronto), pp. 73–75.

RAO, A., 1989a, Manufacturing systems-changing to support JIT. *Production and Inventory Management Journal*, **30**(2), 18–21.

RAO, A., 1989b, A survey of MRP-II software suppliers' trends in support of just-in-time. *Production and Inventory Management Journal*, **30**(3), 14–17.

RAO., A., and SCHERAGA, D., 1988, Moving from manufacturing resource planning to just-in-time manufacturing. *Production and Inventory Management*, **29**(1), 44–49.

RICE, J. W., and YOSHIKAWA, T., 1982, A comparison of Kanban and MRP concepts for the control of repetitive manufacturing systems. *Production and Inventory Management*, **23**(1), 1–16.

SANDRAS, W. A., 1981, You don't need to be high volume to enjoy the benefits of repetitive manufacturing. *Repetitive Manufacturing Seminar Proceedings* (APICS, Las Vegas), pp. 59–66.

SANGJIN, Y., 1989, An information system for just-in-time. *Long Range Planning*, **22**(6), 117–126.

SEPEHRI, M., and RAFFISH, N., 1986, Developing and implementing control systems for repetitive manufacturing. *Industrial Engineering*, **18**(6), 37–44.

SILLINCE, J. A. A., and SYKES, G. M. H., 1993, Integrating MRPII and JIT: a management rather than a technical challenge. *International Journal of Operations & Production Management*, **13**(4), 18–31.

VOLLMANN, T. E., BERRY, W. L., and WHYBARK, D. C., 1992, *Manufacturing Planning and Control Systems* (Business One Irwin, Homewood, IL).

WEBBER, A., 1990, Using push and pull strategies in combination to manage a high volume repetitive operation. *33rd Annual Conference Proceedings* (APICS, Chicago), pp. 432–434.