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IN LEAN PRODUCTION: SEMANTICS MATTERS

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Manufacturing, Planning, and Control (MPC) systems are commonly categorized as either push or pull production systems. The most common example of a push system referred to is a MRP system, while the example of a pull system most commonly referred to is JIT, or more specifically a Kanban system (Sawaya et al, 1992). We have found that the use of this terminology regarding different forms of MPC systems can be confusing to the novice as well as the more experienced management practitioner or researcher. In this paper, we make an argument for the importance of using more precise MPC terms and concepts to foster a more universally consistent understanding of MPC systems. In response to inconsistencies of definitions, explanations, and examples, we provide a framework for classifying MPC systems; a brief discussion of the types of performance measures to monitor or control for effective performance and continuous improvement in either a push or pull system.

INTRODUCTION

The classification of push and pull production systems is commonly based on types of rules used to trigger or control the movement of products between workstations on the shop floor. We contend that categorizing a system as push or pull should be based on a system-wide factor. Many of the definitions currently used to categorize push and pull systems may not be accurate as system definitions, but may actually define components or sub-processes within the system.

A system wide factor that can be used to classify a system as either a push or pull system should be a measurable attribute or a management policy as observed by Pyke and Cohen (1990), which can exert influence over the system as a whole and not just components or system sub-processes. The order review and release (ORR) function is a system wide factor. It exerts influence over the entire system. The ORR function determines whether jobs are released on a predetermined time schedule (time-based, push) or whether they are released depending upon the conditions existing shop floor such as the level of work-in-process (WIP) levels or bottleneck conditions (workflow-based, pull).

We analyzed existing research to develop a framework for identifying and classifying MPC systems based upon the location and type of ORR mechanism and number of WIP control mechanisms. To do this, this paper clarifies the terminology used to define and explain MPC systems and its subcomponents. It then clarifies the concepts and components of push and pull systems, similarities and differences. It identifies the determinants for categorizing push and pull systems and developing a classification framework. It also identifies the appropriate monitoring and controls constructs for performance measurement of push and pull systems.

Clarifying MPC Terminology

Manufacturing Planning Control systems are categorized as either push or pull, commonly based upon the types of mechanism used to control movement between workstations on the shop floor. Common definitions (Dilworth, 1992; Gaither, 1996; Markland, Vickery & Davis, 1998; Nicholas, 1998; Schmenner, 1993) refer to push systems as those with fixed production schedules for jobs at each workstation throughout a production facility, covering a given time period. These production schedules are based upon the quantity and timing of demand for finished products, factoring in availability of materials, cycle times, capacities and demand for operations at each workstation. The jobs are processed and moved to the next station based upon a predetermined time schedule, regardless of the conditions of work-in-process at the next workstation in the system.

Melnyk & Denzler (1996) and Render & Heizer (1997) defined push systems as those that move orders to the next operation or work center immediately upon completion of the current activity, whether or not that work center can begin processing the order. Pull systems are defined as those with jobs that move to the next workstation when the next station is ready to work on it and signals for the job. In essence, this means that downstream operations trigger work in upstream operations (Dilworth, 1992; Gaither, 1996; Markland,

Vickery & Davis, 1998; Nicholas, 1998; Schmenner, 1993). Another definition is when workstations look to the next station downstream and determine what is needed for production demands at the downstream station, and then producing only what is needed for the next station (Gaither, 1996).

A fairly common postulate in operations textbooks and research is to use the term MRP as the classic example for the push-type MPC systems (Karmarkar, 1986, Markland, Vickery & Davis, 1998; Nicholas, 1998; Schmenner, 1993). Even though many authors properly define MRP and Kanban as control functions within push and pull systems, there are still an abundance of references to MRP being a push system and JIT/Kanban being a pull system.

These references can lead to confusion concerning exactly what MRP and Kanban really are, much less what push and pull systems are (give example of confusion). To be semantically correct, the terms MRP or JIT should not be used as classical examples of push or pull systems since technically they are planning or control functions within push and pull systems. Only when these functions are integrated with an order release mechanism (either time-based release or workflow-based release) can the true nature of the system be determined, whether push or pull.

We offer the premise that MRP in and of itself is not a "push" system. Materials requirements planning (MRP) is a tool for determining when materials and manufacturing components are needed in the production system based on a master production schedule, which may be fixed or flexible. The master schedule and bills of materials files are used to determine what materials or resources are needed and when they are needed.

From this, a schedule is developed for ordering materials and manufactured components in accordance with supplier lead times or cycle times at workstations. If a facility releases jobs to the shop floor based upon specific times or calendar dates (what we will term time-based order release), then the MRP developed schedule can be fixed for scheduling material ordering and component processing at workstations.

In this situation, the MRP output (order schedule) is integrated with a push-type time-based order release mechanism and the dates on the MRP schedule are considered fixed. Thus, the key factor in defining the system as a push system is not the fact that MRP is used, but how it is used to facilitate a time-based order release system. As a result, we conclude the MRP is not a push system, but it is merely a planning tool that may be integrated into and in support of a push system.

More importantly, MRP is used in all forms of production systems, whether they are push or pull in nature. Scmenner (1993) indicates in his definition that a MRP system of materials management can exist in a JIT or Kanban pull system, but should not be used to authorize the release of work in the system. It should be used only for planning or material needs. The order release triggering mechanisms in pull systems such as JIT, CONWIP or TOC, are based on the nature of the workflow on the shop flow, which is what we term workflow-based order release. It is the flow of work through or out of the system that triggers the release of new work into the system, along with triggering material orders to outside suppliers and product movement between workstations.

Even though the workflow actually triggers the orders, MRP is still necessary to determine what, how much, and when materials are needed for lot sizing, inventory management and providing information to outside suppliers to support effective supply chain inventory management. What, when, and how much processing is needed at workstations is also required for capacity planning, shop floor layout planning and employee training and utilization planning.

The notion that MRP is a push type system or is used exclusively in push type production systems has led to references indicating that MRP is not utilized in pull type systems. Barker (1994) refers to MRP as a (push type) production control system, which is complex and expensive compared to a simple (pull type) Kanban card or replenishment by observation (reorder point) method. He states, "Indeed, for those people who use a simple pull system to trigger production activity it is difficult to understand why someone would need the burden of centralized push type control" (Barker, 1994).

In very simple production systems with little product differentiation, bills of materials with very few levels, low variation in processes, and a limited number of materials and processes to keep track of, a simple pull system using the reorder point method may be sufficient.

Barker's example of a fast food chain not using a push type ordering is just such a system. But, what is not covered is that basic MRP techniques with pull type workflow-based order releases can be uncomplicated and also work well. The critical issue here is that the time-based order release mechanism in conjunction with fixing the order schedule dates in MRP is creating problems that are addressed. What is being addressed here is not the fact that MRP is used, but how it is used and what order release mechanism it is used in junction with. Barker goes on to state, "The removal of a computer based

'push' type production control (MRP) and replacement with pull systems is a key area of consideration in simplification and the changes needed to become lean" (Barker, 1994).

More importantly, he refers to MRP as being very inflexible and infers that MRP encompasses both the time-based order release and material management roles. The basic confusion is created when these two separate functions are combined. Most researchers failed to mention that MRP could be made flexible by simply decoupling the two functions and combining the materials management function with a workflow-based order release triggers instead of utilizing a time-based order release triggering.

Milenburg (1997) examined the relationship among JIT, MRP, and TOC. In this work, he stated, "It is not always necessary to dismantle an existing MRP system to implement JIT or TOC. The three approaches have many common elements and MRP is so flexible that it is not difficult to make it behave like JIT or TOC". Mileburg's work indicates that switching to a workflow-based order release, such as the drum schedule based on bottleneck workflow in TOC, is very compatible with the materials management functions built into most MRP systems.

Using Kanban as the classic example of a 'pull' system can also be misleading. Kanban is a shop floor control (SFC) tool for controlling the release of work between every workstation in a given facility. The Kanban system is an information system that harmoniously controls the production quantities in every process (Monden, 1993). A Kanban may be an example of a pull system, but that is only true because jobs are pulled between workstations on the subsystem level. What should actually determine that it is a pull system is the manner in which jobs are released into the production system. In the case of Kanban, jobs are released into system using release triggers (Kanban cards) based upon WIP levels at the initial workstations or actual demand for the product if there are fluctuations (workflow-based order release).

Even if an authorization card is generated to begin producing a given product, the work release can be delayed if there is an anticipated lack of demand, resulting in the product not being called for in the master production schedule (Hopp & Spearman, 1996). In the case of Kanban controls, the order release control and product movement controls are the identical, making it an easy system to identify and to define. But, the workflow-based order release mechanism, which is the gateway influence on the system dynamics, is not included in the definition of the system.

The omission of this critical defining concept is what could lead to confusion in understanding what really differentiates push from pull systems. Further, the Kanban SFC system itself becomes too limited to be considered the classic example of an MPC pull-type system. A number of other pull type SFC systems are increasingly becoming common, such as CONWP and TOC bottleneck focused systems. Both systems utilize pull type order release mechanism but do not use Kanban cards for controlling flow between work centers.

While they are fundamentally pull systems due to the nature of the workflow-based order release mechanism, the subsystem product movement controls within these systems may be a hybrid of push and pull controls. Another area of confusion regarding MRP semantics relates to the use of the term MRP to define the concept of material planning, techniques used in materials planning, as well as a computerized tool for total production planning and control. Again we refer you the following statement by Barker (1994).

"The removal of a computer based 'push' type production control (MRP) and replacement with pull systems is a key area of consideration in simplification and the changes needed to become lean".

Barker infers here that MRP is a computerized tool that incorporates both the order release mechanism and materials management roles. Confusion could be created when a computerized system that incorporates the multiple tasks of MRP functions and order release functions is referred to simply as MRP, rather than a complete MPC tool which utilizes a specific type of order release function whether it be push or pull along with compatible MRP functions.

The use of MRP in this way is more a marketing ploy than science, just as the use of the term Windows is for Graphic User Interface (GUI) technology. The source of the confusion is that such an approach fails to clearly state whether or not the order release mechanism is time-based and the corresponding MRP schedule dates are fixed constituting a push system or the MRP schedule dates are flexible and combined with a workflow-based order release mechanism to create a pull system.

Another potential rationale for defining MRP as a classic push system may be due to the fact that the scheduling output from a MRP system consists of material and production orders with specifically assigned release times. Further, the time sequenced material ordering schedule gives the appearance of being rigid, especially if the master production schedule dates are fixed due to a time-based order release mechanism being in place. Since pull systems such as JIT and TOC use

MRP planning for material order lists, order quantities, and approximate dates, but do utilize the exact order dates, it may be assumed it is not a true MRP system.

Even if MRP is utilized in a pure push system, due to the effects of system variability through machine variability (Hopp & Spearman, 1996) along with the effects of system nervousness as minor changes in production schedules or order receipts can cause significant changes to MRP plans (Vollman, Berry & Whybark, 1997). Not every MRP schedule can be followed exactly even if desired, requiring some type of flexibility in rescheduling.

We assert that whether the desire is to strictly adhere to the order due dates (as in a push management policy) or use them as a flexible guide for ordering (as in a pull management policy); a true MRP system is utilized in either case. A study by Finch and Cox (1988) analyzed six firms and "examined a broad range of planning and control systems. Some used MRP systems, some used the MRP techniques, and some used neither". Their definition of MRP, supported by Wemmerlov (1979), states that: "MRP systems are production planning and control systems that include master (production) scheduling and various levels of capacity planning and use the MRP technique to determine priorities for manufactured and component parts. The MRP technique is a method of exploding an end-item into its components, computing net requirements for each one, and backward scheduling from the end-item's due date to determine components' due dates. A company can use the MRP technique without having a MRP system."

The types of material planning systems or procedures utilized in the firms that employed neither MRP systems nor techniques (non-MRP) were not clarified. As a result, confusion could be created when referring to non-MRP systems without offering any description of these systems. While describing the types of systems utilized by the six firms in the Finch & Cox study, all six utilized MRP systems or techniques for planning and ordering materials from outside suppliers and four firms used MRP for planning internal production orders (internal priority planning).

Concepts of Push and Pull Systems

With the above clarification in mind, we now turn our attention to the basic structure of push and pull MPC systems to solidify what was covered and to identify the critical elements that define push and pull systems. Manufacturing Planning and Control (MPC) or Production Planning and Control (PPC) systems, whether push or pull, are composed of similar functions including some type of MRP activity.

Figure 1 below provides a side-by-side comparison of a MPC and a PPC system. The MPC system is representative of a push type production environment (Vollman, Berry & Whybark, 1997), while the PPC depicts a typical pull type production environment (Hopp & Spearman, 1996).

Next, in figure 2 below, we compare and contrast the main activities to illustrate the major similarities and differences between the two systems. The principal differences between the two systems revolve around the timing of the customer order planning, capacity planning and initial master production scheduling activities and the addition of a WIP quota level setting activity in the pull system.

The two systems have more similarities than dissimilarities, as both systems perform the same activities, with only a few exceptions. One main difference between the systems is timing of activities, in terms of the order they actually take place. Each system considers all possible sources of orders and may utilize forecasting for comprehensive demand planning.

Push systems conduct forecasting doing preliminary and final planning in the first phase, while pull systems do preliminary planning for capacity in the first phase and do final planning during demand management in the second phase. With actual and forecast demands compiled, both systems do some form of aggregate capacity/resource planning (facility, equipment and labor) in phase one to determine their current and future levels of production capabilities versus demands. This stage of aggregate planning is used with both environments for short and long-range facility, equipment, and labor needs, along with production leveling if desired.

Push systems then place actual and forecast jobs into a trial Master Production Schedule (MPS) based upon due dates. The pull system differs from the push system in this phase by doing a more detailed facility, labor, and equipment capacity availability evaluation before compiling an initial production plan called an aggregate plan. This aggregate plan can be a trial MPS or it may be an indication of feasible product mixes and production levels developed in conjunction with current customer demands and production capacities to facilitate production scheduling in phase two.

This detailed capacity availability planning helps to create more reliable and precise production scheduling later on in the process. Push systems conduct detailed Capacity Requirement Planning (CRP) in phase two, to test the MPS for feasibility after it is compiled. Any

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adjustments made to the MPS have to include recalculations of capacity requirements for feasibility testing until a final, acceptable MPS is established.

The second phase of the MPC/PPC systems involves more in-depth planning for capacity requirements (push system only) and material requirements (both systems). Push systems take the initial MPS and test its due dates for feasibility using detailed capacity requirement planning for both equipment and labor. In contrast, pull systems differ by performing detailed capacity analysis in phase one and then use this information to assist in production scheduling.

Detailed MRP is then used in push system to test the trial MPS due dates for feasibility based on availability and lead times for producing or ordering parts and materials. The MPS due dates may be adjusted until recalculations of both CRP and MRP plans show it to be feasible. At this point, the time frames for job due and release dates are set, and the calendar based order releases for parts, materials and production steps in the facility are solidified into a final production plan.

In phase three, the production plan is put into action with fixed schedules for material orders from vendors and production starts for shop floor processing are in place. Changes in scheduling and sequencing may be done when needed, based upon acceptable short-term material and capacity availability. Essentially, a production schedule is developed based upon current and forecast orders, which is then tested for adequate capacity and material availability. In contrast, pull type systems perform detailed capacity analysis sooner in the process and then use the capacity information to assist in production scheduling, which is covered next. In pull systems, the second phase has several differences with the push systems described previously. They are:

- Timing differences already noted include the detailed capacity analysis is completed before the aggregate planning stage in phase one for pull systems.
- Another difference occurs during the development of the aggregate plan in phase one.

Similar to push systems, the demand management and sequencing/scheduling modules in phase two of the pull system include MRP and job order management activities. In these two modules, pull systems either create the trial MPS or fine tune the trial MPS created in the aggregate plan, adjusting according to availability and lead times of material flows from suppliers or by filtering and adjusting customer orders to match level production and material supply rates. Detailed capacity planning has already been performed in phase one. The MRP function is used to create flexible material order release dates based upon approximate production process dates.

The principal activity difference between the two systems is during phase two of the pull PPC system and that is the addition of the WIP quota setting function. Furthermore, control parameters in pull system revolve around managing WIP levels, which is performed in the WIP quota setting module. The purpose for setting WIP levels is to ensure constant and adequate level of work flowing through the facility.

Thus, neither starving work centers to cause reduce throughput, nor overloading the shop floor with WIP causing congestion, excessive queue waits and increased variability. Critical WIP levels are determined based upon demands at bottleneck work centers, which control facility throughput. When the WIP is held relatively constant and above the critical WIP level, throughput can be maximized and shop floor congestion minimized.

With a work schedule completed that matches capacity and material availability, the actual production order releases to the shop floor or order release mechanism is controlled at the shop floor control module. The shop floor control module has the capacity to adjust the ordering and work schedules as necessary to account for variations in processing and materials delivery.

The defining difference between pull and push systems is that in a pull system the calendar release dates for jobs and materials from the MRP output are not solidified into strict order release dates as in the case of push system. As a result, two unique conditions existence in pull systems that are not present in push systems:

- First, the output from MRP is used for planning materials needs (amounts and approximate dates) to order from suppliers, and to help fine-tune the schedule of order release to the shop floor.
- Second, production orders are controlled by WIP levels on the shop floor, which may be close to the release times scheduled by MRP, but are controlled by the scheduled release times indicated in the MRP output.

There are different types of shop floor control (SFC) tools used to control WIP levels within a given facility. These include: Kanban, CONWIP, and the DBR aspect of TOC bottleneck management. The main benefit of these tools is that changes in scheduling and sequencing may be performed as needed, based upon acceptable short-term material and capacity availability, and the specific requirements for order completion performance.

Categorizing Push and Pull Systems

In this paper, we contend that release mechanism of the ORR function is the critical factor which distinguishes the operations push and pull production systems. Furthermore, we contend that the order release mechanism influences workflow throughout the whole system by managing the volume and timing of work released to the shop floor. The types of subsystem or shop floor controls, in conjunction with the type of order release mechanism determine the nature of the workflow through the system, but the subsystem controls alone do not consistently have the capability of influencing the nature of the system as a whole.

Given that the order release function controls the behavior of workflow into the system at the gateway process, it is the sole function that can consistently influence workflow behaviors throughout the entire system. In addition, there are two types of triggering mechanism that characterize the ORR function. They are:

- Time-based order release triggers which characterize push systems,
- And workflow-based order release triggers that characterize pull systems.

Finally, we contend that the sequencing of jobs and dispatch rules have an effect on production performance measures, but are not primary factors in determining whether or not the systems is push or pull. Once jobs are released into the shop floor using calendar dates in the case of a time-based order release or by shop floor indicators in the case of workflow-based order release, how they move between workstations can be controlled by subsystem push or pull release mechanisms which may differ from the ORR release mechanism.

As a result, a production facility with multiple product lines or production subsystems could conceivably be using both push and pull subsystems throughout the plant depending upon the type of local dispatching rules employed throughout the facility. For example, CONWIP and TOC shop floor systems have pull type order release mechanisms, but may utilize push type dispatch rules for jobs once they have been released into the shop floor for processing. Even though, push dispatch rules or subsystem release mechanism control flow between workstations, they do not dictate the behavior of the overall system and as a result they should not be used as a basis for defining the nature of the system as a whole be it push or pull.

Role of the ORR Release Mechanism

Melnyk and Regatz (1988) evaluated research that examined the ORR function and its impact on the shop floor and found disagreement among practitioners and researchers concerning the relative importance of ORR and dispatching rules on shop floor performance. An earlier work by Nicholson & Pullen (1972) argued that good shop floor performance could be achieved by using simple dispatching rules in combination with carefully controlled order release procedures.

This work indicated that an order release mechanism with adequate control was important to shop performance, and if properly utilized, the dispatching rules could be very simple and still yield good on-time delivery performance. Studies by Betrand (1983) and Baker (1984) found the order release mechanism to be less important than dispatching rules in achieving on-time delivery.

Both studies utilized only one type of first-come-first-serve order release mechanism (ignoring order due dates) in conjunction with a cap limiting the workload on the shop floor. Several other studies argued that good shop floor performance could be achieved using several dispatching rules as long as they were in conjunction with a controlled order release mechanism (Irastorza & Deane, 1974; Shimoyashiro, Isoda & Asane, 1984; Ragatz & Mabert, 1988; Bobrowski & Park, 1989).

Later works, such as Kim & Bobrowski (1995) tested for WIP levels, on-time delivery, job tardiness, and costs of early/late order completion utilizing four order release mechanisms and four sequencing rules in combination. One of the four release mechanisms was structured as a pull mechanism, utilizing WIP levels on the shop floor and backward flow of information for making job release decisions.

The other three release mechanisms integrated push structures using forward information flows and based job releases on average capacities, average job requirements, and schedule accordingly without considering shop floor WIP. Performance differences among the three push type order release mechanisms were not significant, while differences between the push and pull type mechanism were very significant.

This implies that two different types of system dynamics is at work based upon the type of order release mechanism utilized, whether push or pull in nature. Philipoom, Malhotra & Jensen (1993) compared a pull type (PPB), a controlled push type (MIL), and an uncontrolled push type (IMM) order release mechanism, all in combination with two scheduling rules, to compare

productivity using different due-date settings and capacity utilization levels.

Using performance measures similar to Kim & Bobrowski (1995), they concluded that approximately 50 percent of the results through a variety of settings indicated no difference between the two push type release mechanisms (MIL & IMM), while nearly all the results indicated significant differences in performance between the controlled push (MIL) and pull (PPB) release mechanisms. Again, these results support the argument that a different set of system dynamics is experienced depending upon whether a push or pull type of order release mechanism is utilized.

One factor that appears to be at the root of the disagreement among studies reviewed by Melnyk and Ragatz (1988) and later studies concerning the importance of ORR revolves around the nature of the comparison being conducted. These works compared a variety of dispatch rules in combination with order release techniques, but some results were based on only one type of order release technique, usually push.

Others compared push type as controlled versus uncontrolled release techniques, while still other results were based on comparing a greater variety of both pull and push as controlled and uncontrolled release techniques. The variety of performance results could be expected due to the inconsistent makeup of the order release and sequencing tools compared. Yet, the findings consistently indicated similarities among push type order release mechanisms and differences between push and pull type mechanisms.

All of the previously cited studies are supportive of our contention that distinctions in systems dynamics of push and pull systems are driven in large part based upon the type of order release mechanism employed. Disagreement over the ORR function and its impact on the operation of a shop floor was due to the lack of a comprehensive and unifying framework for the function. A comprehensive framework was developed by Melnyk and Ragatz (1988) and is depicted in figure 3 below. Melnyk and Ragatz's framework divides the ORR function into three distinct activities:

- Timing conventions determine when a release can take place, whether releases can be performed continuously or only at specific periodic intervals (determines time buckets, lot sizes).
- Triggering mechanisms determine when a release should, or will take place, within timing conventions limits. There are two kinds of triggers:
    1. Pooled-based which is determined by information about the jobs in the pool, such as pre-assigned release dates (time-based order release mechanism).
    2. Shop-based which is determined by current shop conditions such as workload or WIP (workflow-based order release mechanism).
- Selection rules determine which job(s) to release based upon either local or global information (sequencing).
    1. Local selection rules are based on information about jobs in the pool only.
    2. Global selection rules consider information about jobs in the pool along with conditions on the shop floor.

The timing conventions determine whether jobs will be released continuously or at specific intervals, thus, setting the length of the time buckets between releases and consequently the size of the lots released to the shop floor. Lot sizing and time bucket selection can definitely affect performance parameters, but do not determine the underlying nature of system operations as push or pull as the same or similar rules can be used in either system. The selection rules determine what information will be used to determine the ordering or sequencing of jobs released to the shop floor. This information can come from several possible sources, whether strictly concerning characteristics of jobs in the pool, or including information about the shop floor conditions.

The sequencing rules also affect performance parameters, but given that either system can utilize similar sequencing rules they also do not determine the underlying nature of system operations. The triggering mechanism, which determines when a release should take place based on time-based pre-assigned release dates (pooled based) or workflow-based shop floor conditions (shop based), is the mechanism that we contend is the factor which determines the underlying nature of the system operations whether push or pull.

Neither push nor pull systems can utilize the same order release rules and as noted by Melnyk & Ragatz (1988), "Order review and release preceded these other shop floor activities. ORR determines what orders are released to the floor, at what time these orders are released, and the conditions for the release. How these decisions are made influences the subsequent operation of the other SFC activities." Next, we develop a classification framework for the different systems that is

consistent with our premise that the order release mechanism being the determining factor of the underlying nature of the overall system dynamics.

MPC System Classification Framework

Our classification framework is provided in figure 4 below. This framework is based upon the critical order release elements that distinguish each system. The framework focuses on two dimensions:

- The location and type of the system's order release triggering mechanism within the shop floor parameters.
- The complexity of the WIP controls, or capping mechanism employed throughout the system.

As pointed out by Nicholas (1998), many of the other attributes of the various MPC systems are merely a matter of emphasis, having little or no effect on the underlying nature of the system. One of the key advantages of this framework is that both dimensions as based upon things that are tangible and easy to identify. It is simple matter to walk through a plant and determine the location of the order release mechanism and to determine the number of WIP control mechanisms being employed.

As the framework indicates, time-based order release mechanisms common to push systems are located at the front end of production systems and utilize information flows that are parallel with the movement of products and materials through the system. Pure, non-hybrid, time-based systems do not utilize WIP control mechanism with the exception of capacity and schedule planning procedures.

In contrast, pull systems structures can appear in a variety of configurations. The theory of constraints drum-buffer-rope system utilizes an order release mechanism located at the bottleneck process somewhere within the production system. Information flows in reverse from the bottleneck process to the front of the system where the job pool is waiting to release jobs into the system. An adequate amount of work is required to keep the bottleneck process operating effectively.

On the other hand, overloading the bottleneck area is undesirable. Therefore, the specific WIP level required for effective bottleneck operation determines the WIP cap for the system.

The order release mechanism in CONWP and Kanban systems is located at the end of the production system. As jobs are completed and removed from the production system, CONWIP triggers new jobs to enter the system utilizing reverse information flow from the end of the system to the front. The WIP cap is based upon calculating a critical level of WIP required for optimum system effectiveness and is controlled by releasing a new job or batch into the system only when a job or batch finishes and leaves the system.

The Kanban order release trigger is also at the back end of the system. Similarly, it functions based upon jobs finishing and leaving the system and utilizes reverse information flows from the back end to the front end of the production system to draw new work into the system. The main difference with Kanban is the multiple WIP caps operationalizes as Kanban cards are used at each work center to control WIP at every stage of the process rather than at a single work center such as the bottleneck or final process step.

This classification framework is intended to aid in the identification of the different types of production systems, without delving into their subsystem characteristics. Next, we provide a framework for identifying the appropriate monitoring and controlling constructs that should be utilized to insure optimum process effectiveness and efficiency.

Identifying Monitoring and Control Measures

Historically, the real significance of push versus pull systems lay in the linkage between a firm's continuous improvement efforts and the basic factory physics equation expressed Little's Law as covered by Hopp & Spearman (1996). Firms that utilize push systems with their time-based order release mechanisms tended to focus on improving the firm's planning and computing capabilities, while firms which employed pull systems focused on improving the actual shop floor operations. Hopp and Spearman (1996) describe the challenge with push ("MRP") systems as follows: "...the original, laudable goal of MRP was to explicitly consider dependent demand, rather than to treat all demands as independent and use reorder point methods for lower level inventories. This requires performing a bill-of-material explosion and netting demands against current inventories - both tedious data-processing tasks in systems with complicated bills of materials. Hence there was strong incentive to computerize."

By focusing on the WIP control mechanism used in each system, this allows researchers to link their evaluations directly to a plant's Factory Physics through the application of Little's Law. Little's Law provides a robust means of evaluating systems performance in terms of WIP, cycle time, and throughput (Hopp & Spearman, 1996).

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The ideal performance measure is one that measures the underlying physics of a given operation. Figure 5 below depicts the hierarchical objectives used in a typical manufacturing operation. Notice that unit costs, consumer service, and short cycle times form a strategic triangle at the heart of the of the manufacturing profitability equation. Furthermore, short cycle times form a point of integration between low inventory, product quality, and fast response (Hopp & Spearman, 1996).

A careful examination of this chart reveals how Little's Law factors into the typical manufacturing firm's profitability tree. High throughput, low variability, and low inventory (with its direct link to short cycle times) are the principal drivers in a typical manufacturing operation's profitability equation. You need to help the reader with this. Researchers should be mindful of the importance of this critical relationship when choosing performance measures.

In addition, good performance measures are those that are supportive of the general manager's integrated view of manufacturing and promote a clear link between policies and objectives. Unfortunately, much of the research conducted in operations management utilized performance measures which are based more on what's convenient for the researcher than sound management practice (LaForge, 1998). Finally, in Figure 6 below we provide our view of the fundamental relationship between MPC systems, the ORR function, and the basic factory physics in the typical manufacturing firm.

CONCLUSION

Our research indicates that pull systems are designed around managing WIP levels on the shop floor with improvement efforts directed toward upgrading processes and reducing cycle times to increase product quality and throughput. Conversely, push systems are designed around managing cycle time for processing products with improvement efforts directed toward upgrading processes and increasing throughput while at the same time trying to reduce WIP levels.

In light of these concepts, the order release function becomes the gateway control for determining whether or not the system is push or pull, revolving around pushing workflow into the production process according to a set of due dates (time-based order release) or pulling workflow into the production process while maintaining desired WIP levels (work flow order release).

Finally, given that there are pull type systems that do not utilize Kanban (i.e. CONWIP and TOC techniques) and given that both push and pull systems utilize some form of MRP, using these terms to describe or define the system type in which they operate can only lead to create confusion. To eliminate such confusion, the researcher should always keep in mind that "semantics matters".

REFERENCES

Baker, K. 1984. The effects of in/out control on the performance of a simple scheduling model. **Journal of Operations Management,** 4: 99-112.

Baker, K. 1994. Production systems without MRP: A lean time based design. **Omega: International Journal of Management Science,** 22: 349-360.

Betrand, J. 1983. The effect of workload dependent due-dates on job shop performance, **Management Science,** 29: 799-816.

Bobrowski, P.M. & Park, P.S. (1989). Work release strategies in a dual resource constrained job shop. **Omega: International Journal of Management Science**, 17: 177-188.

Dilworth, J. 1992. **Operations management: Design, planning, and control for manufacturing and services.** New York: McGraw-Hill, Inc.

Evans, J. 1997. **Production/operations management: Quality, performance, and value.** St. Paul: West Publishing Co.

Finch, B., & Cox, J. 1988. Process oriented production planning and control: Factors that influence system design. **Academy of Management Journal,** 31: 123-153.

Gaither, N. 1996. **Production and operations management.** Pacific Grove: Duxbury Press.

Hopp, W., & Spearman, M. 1996. **Factory physics: Foundation of manufacturing management.** New York: Irwin McGraw-Hill.

Iratorza, J., & Deane, R. 1974. A loading and balancing methodology for job shop control. **AIIE Transactions,** 6: 302-307.

Karmarkar, U. 1986. Push, pull and hybrid control schemes. **Working Paper No. QM8614**, University of Rochester, Rochester, NY.

Kim, S., & Brobowski, P. 1995. Evaluating order release mechanisms in a job shop with sequence-dependent

setup times. **Production and Operations Management,** 4: 163-180.

Krajewski, L., King, B., Ritzman, L., & Wong, D. 1987. Kanban, MRP, and shaping the manufacturing environment. **Management Science,** 33: 39-57.

LaForge, R. Seminar in manufacturing planning and control systems. **School of Business and Behavioral Sciences, Clemson University**, Spring 1998.

Markland, R., Vickery, S., & Davis, R. 1998. **Operations management: Concepts in manufacturing and services.** Mason: South-Western College Publishing.

Melnyk, S., & Denzler, D. 1996. **Operations management: A value driven approach.** New York: Irwin.

Melnyk, S., & Ragatz, G. 1988. Order review/release and its impact on the shop floor. **Production and Inventory Management Journal,** 29: 13-17.

Miltenburg, J. 1997. Comparing JIT, MRP and TOC, and embedding TOC into MRP. **International Journal Production Research,** 35: 1147-1169.

Monden,Y. 1993. **Toyota production system.** Norcross: Industrial Engineering and Management Process.

Nicholas, J. 1998. **Competitive management.** New York: Irwin/MCGraw-Hill.

Nicholson, T., & Pullen, R. 1972. A practical control system for optimizing production schedules. **International Journal of Production Research,** 16: 219-227.

Philipoom, P., Malhotra, M., & Jensen, J. 1993. An evaluation of capacity sensitive order review and release procedures in job shops. **Decision Science,** 24: 1109-1133.

Pyke, D., & Cohen, M. 1990. Push and pull in manufacturing and distribution systems. **Journal of Operations Management,** 9: 24-43.

Ragatz, G., & Mabert, V. 1988. An evaluation of order release mechanisms in a job shop environment. **Decision Science,** 19: 167-189.

Render, B., & Heizer, J. 1997. **Principles of operations management.** Englewood Cliffs: Prentice-Hill, Inc.

Giauque, W., & Sawaya, W., 1992. Strategies for production control. **Production and Inventory Management Journal,** 33: 36-39.

Schmenner, R. 1993. **Production/operations management.** Mc Henry: Macmillan Publishing.

Shimoyashiro, S., Isoda, K., & Awane, H. 1984. Input scheduling and load balance control for a job shop. **International Journal of Production Research,** 22: 597-605.

Vollman, T., Berry, W., & Whybark, D. 1997. **Manufacturing planning and control systems.** New York: Irwin.

Wemmerlov, U. 1979. Design factors in MRP systems: A limited survey. **Production and Inventory Control,** 20: 15-35.

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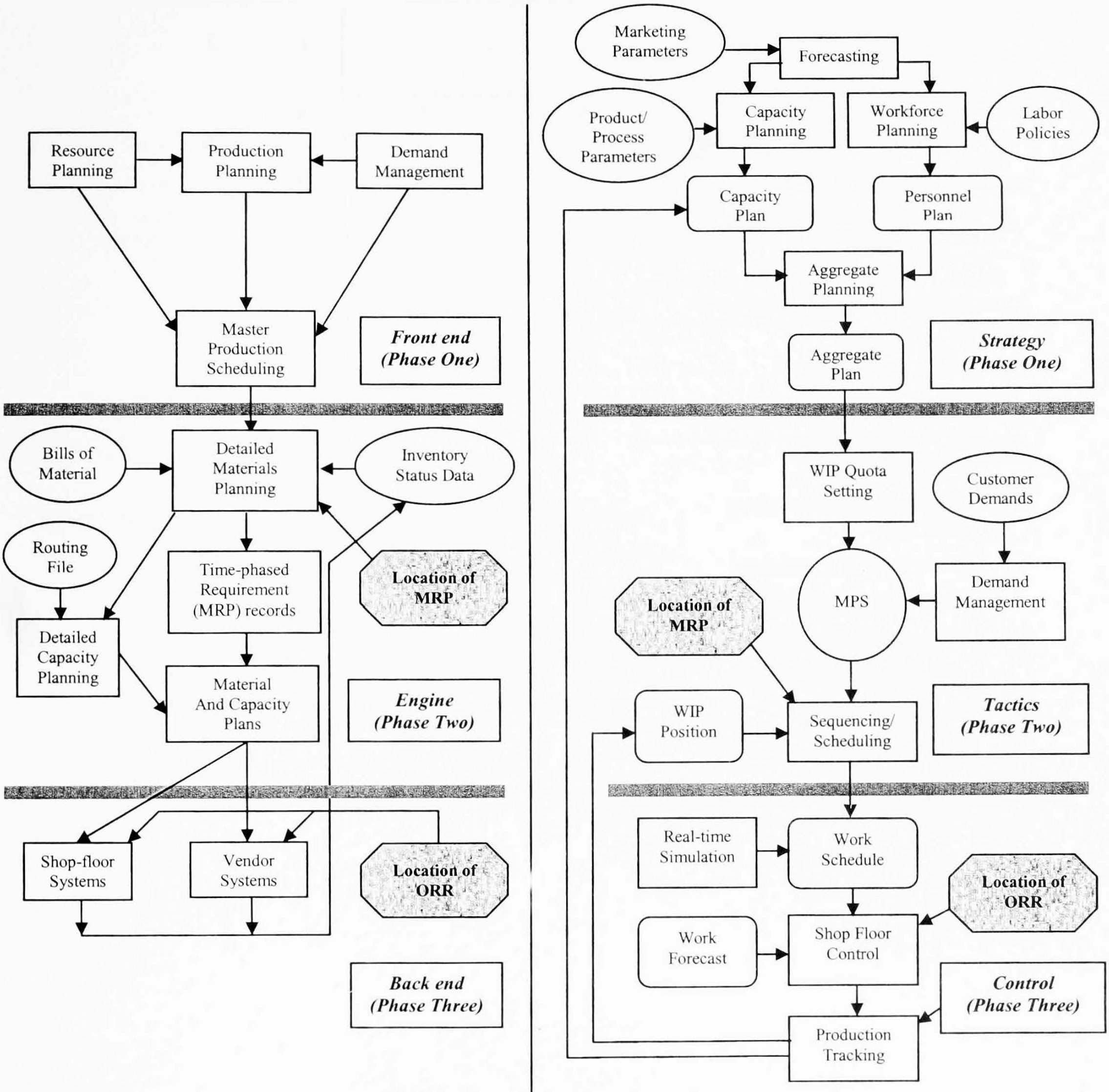
Figure 1: Push and Pull MPC/PPC Systems Compared



Typical Push Production MPC System
Source: Vollman, Berry & Whybark, 1997, p.15

Typical Pull Production PPC System
Source: Hopp & Spearman, 1996, p.388

Figure 2: Comparing Activities and Locations by Phase for Push and Pull Systems

	Push System Phase			Pull System Phase		
Activity	1	2	3	1	2	3
Demand management*						
Forecasting	X			X		
Customer order planning*	X			X	X	
Aggregate planning	X			X		
Rough capacity planning						
Facility	X			X		
Workforce	X			X		
Detailed capacity planning*						
Facility*		X		X		
Workforce*		X		X		
Master Production Schedule (MPS)*						
Initial MPS*	X			X	X	
Final MPS		X			X	
Detailed materials planning (MRP)		X			X	
Sequencing & scheduling		X			X	
Order review and release (ORR)		X			X	
WIP quota level setting**	-	-	-		X	
Shop floor control/systems			X			X
Vendor systems			X			X
Production tracking			X			X

*Main timing differences between push/pull systems
**Main activity differences between push/pull systems

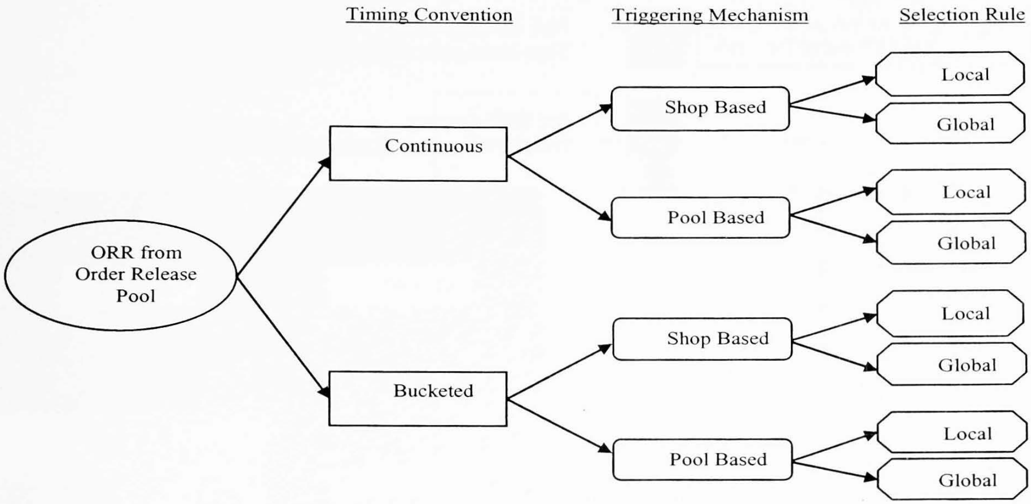


Figure 3. Melnyk & Ragatz's (1989) Order Review/Release Framework

Figure 4: MPC Classification Framework

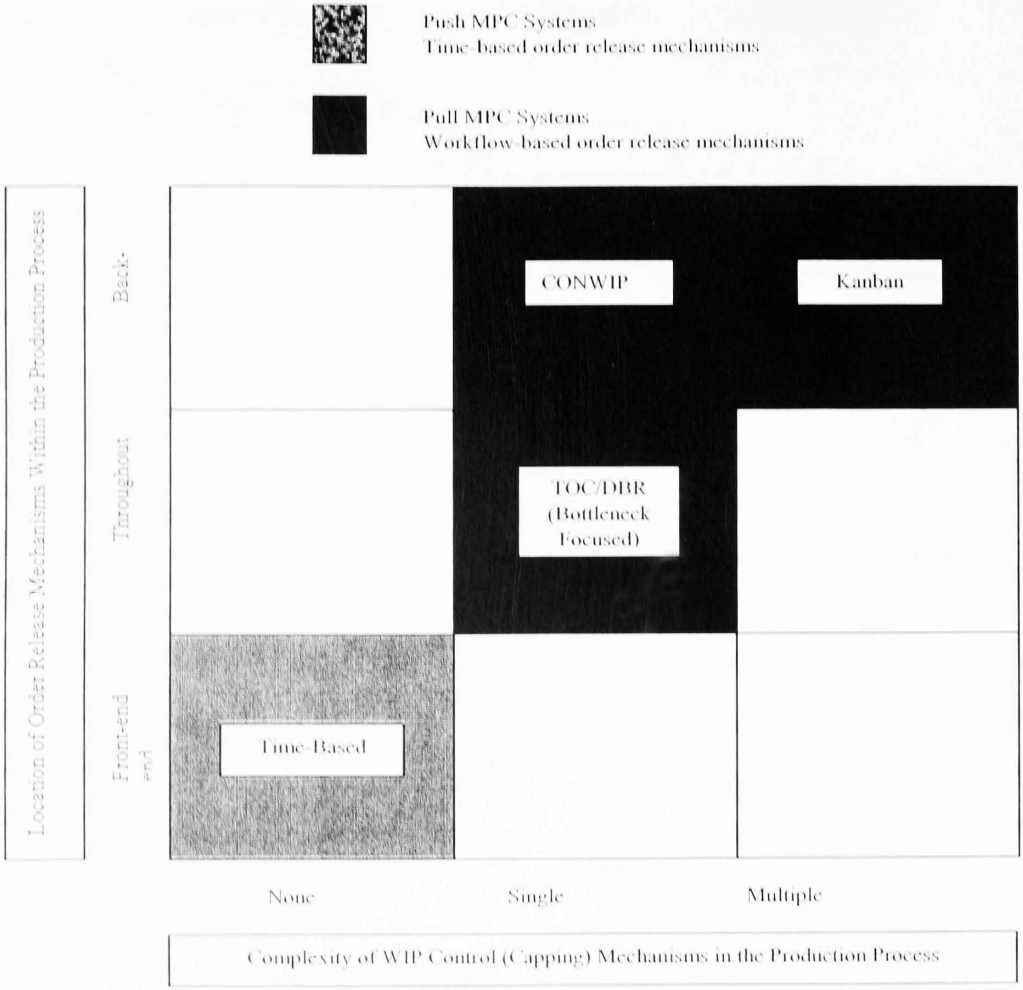


Figure 5: Hierarchical Objectives in a Manufacturing Organization.

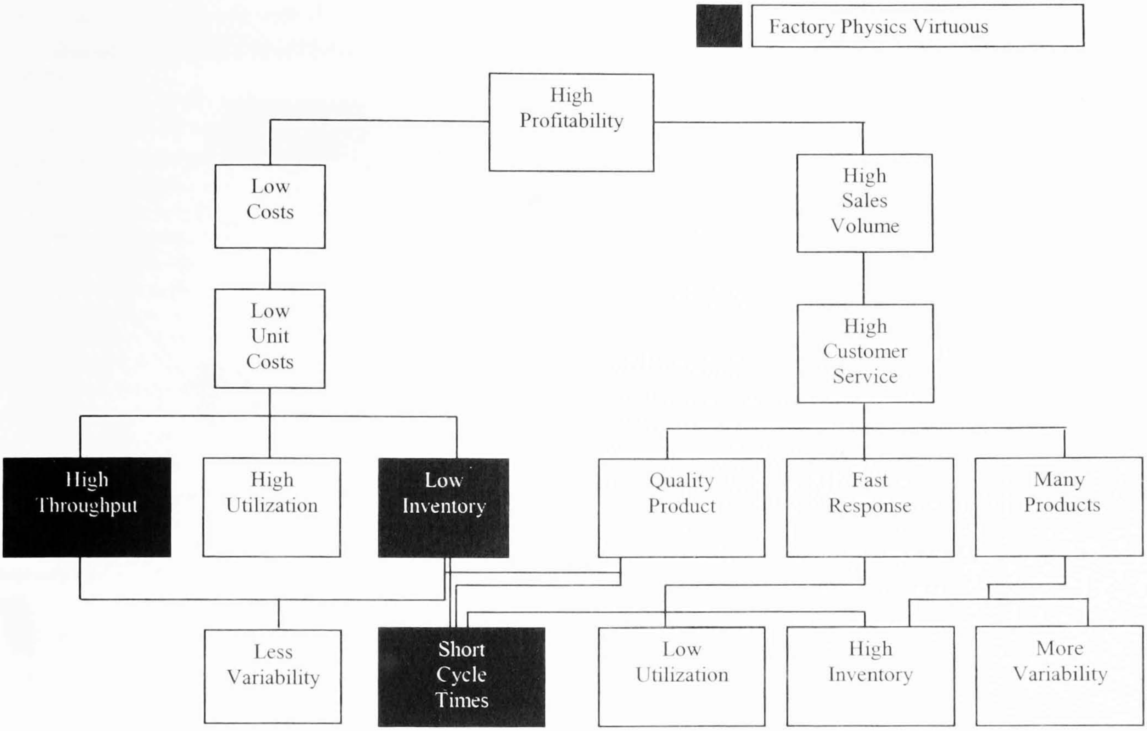


Figure 6: Performance Constructs for Push and Pull Order Release Systems