Pull Scheduling System – A Conceptual Algorithm

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Abstract

Although many people in production and inventory management have already discussed ‘push/pull’ systems for many years, the new term of 'pull scheduling' has not been thoroughly examined. The term is not yet widely recognised. However, it will be one of the key concepts for the SCM (Supply Chain Management) system in this decade. Since the pull system should not rely on any plan scheduled in advance, the wording of 'pull scheduling' apparently has a contradiction within its conventional definition.

First of all, this paper clarifies under what conditions the term of ‘pull scheduling’ becomes meaningful. Secondly this paper proposes a conceptual algorithm for a pull scheduling system. For both ‘make-to-order’ and ’make-to-stock’ production, a pull type of scheduling system can be adopted in designing a new production management system.

Currently no known factory uses only a pure pull scheduling system. Thus a creating a pull scheduling system must include other functions. Moreover, an abridged comparison with other systems such as TOC, PFS and Production Seat Booking system will make it easier to understand this paper’s proposed algorithm.

The proposed procedure can be summarised as follows: The system is started by backward scheduling based on the customers’ due dates, then, trying to adjust the production capacity to the workload as much as possible; finally execute a forward scheduling for issuing today’s dispatching or production instruction. The forward scheduling is also useful for checking the current loading status. Both backward and forward scheduling is executed on a time axis for each factory process. Since the system should be dynamic, reschedule the plan at least daily. Progress in computer and information technology has led to these advanced systems.

1. Definition of ‘Pull Scheduling System’

The APICS dictionary explains that a push system makes products by a given schedule planned in advance [1]. From another point of view, a pull system does not make any schedule in advance. If the system was scheduled in advance, there is no question about whether or not it can still be called a pull system. If the schedule is planned directly by the customer's requested due dates, there is a question if it can be a pull or push system.

By the APICS definition, a ‘pull system’ and ‘scheduling’ cannot coexist. If Toyota’s ‘kanban’ system is imagined, the definition is quite appropriate. However, even if some schedule is planned in advance and if the schedule is always pulled tightly by the customers’ requested due dates the system is described as pull scheduling.

To give rigour to the definition, the following three conditions are proposed for pull scheduling. [2]

1) A schedule does not exist when production is started too early. The production schedule should be planned backwards from the deadline, so that the production starts at the last moment to meet the customer's request. This is the image of a rope pulled tight by the customers’ needs.

2) Do not maintain higher use simply for production capacity. If any lot or job is allocated to the production schedule for raising labour and/or machine utilisation against capacity, it becomes a push type of

production. This interpretation for ‘push and pull’ is based on “*the distinction we believe is useful pertains to whether individual work centers are allowed to utilize capacity without being driven by a specific end item schedule* [3]”.
3) The production schedule is planned/reviewed in a short cycle. Pull scheduling must be dynamic. Pull means that all the production activities reviewed and amended according to customers' daily changing demands. The difference between static and dynamic is whether the schedule is amended immediately after something happens. However, in case of production scheduling real time schedule amendment is impossible even in advanced factories, so that daily rescheduling cycle can be called as ‘dynamic’. If the cycle is longer than a day, such as week or month, the scheduling system should be called ‘static’.

The above defined ‘pull scheduling’ is not same as a term ‘pull scheduling system’. The latter term rather focuses on ‘system’ and it indicates a whole planning aspect of production management. In other words, a whole planning system includes not only pull scheduling itself but also other functions. It should have a function of production capacity adjustment and even a function of forward scheduling. Otherwise, it cannot issue a daily production instruction or dispatching. Any system used in practice should have a forward scheduling function. ‘Pull scheduling system’ is, therefore, explained as follows. It is a system based on pull scheduling but it includes all the necessary functions to issue the daily production instruction. Details of the pull scheduling system is described at section 3 and 4.

2. Other Scheduling Systems

2.1 APS (Advanced Planning and Scheduling)

“*APS can show the whole view by having customers’ oriented consciousness. Since it starts from the customer’s order and allocate the work to the factory resources, it can be called a top-down approach* [4].” On the other hand, bottom-up approach makes the best use of each resource. The top-down approach is said to be a total optimisation. A question arises, then, what is the meaning of total optimisation. “*Broader meaning of total optimisation is to avoid partial optimisation. And it is considered to be the one which has no need to demonstrate that any better solution than the present final one does not exist* [5].” This definition must include evaluation for optimisation criteria. The primary criterion would be total lead-time through the whole supply chain.

Although the name of APS has become very popular in SCM, content details have not received enough publicity. It may be because APS systems are privately held. Some experts use TOC or Goal System to explain APS, however, TOC can be categorised by only one of various APS systems. Using similar logic the author of this paper also agrees to position the ‘pull scheduling system’ as one of various APS systems.

2.2 PFS (Process Flow Scheduling)

PFS is a scheduling concept which has each of the following three principles. [6]

- *Scheduling calculations are guided by the process structure.*
- *Stages are scheduled using processor-dominated scheduling (PDS) or materials-dominated scheduling (MDS) approaches.*
- *Process trains are scheduled using reverse-flow scheduling, forward-flow scheduling, or mixed-flow scheduling.*

According to these principles, the proposed pull scheduling in this paper may be categorised by MDS and reverse-flow scheduling. A system which has MDS and reverse-flow produces only the customers’ necessities, and not to fulfil the processors’ capacity. It is obvious to use for starting from the customers’ needs. As it is stated in the PFS explanation as “*forward-flow scheduling is the least likely alternative to occur*”, so reverse-flow or backward scheduling should be the first consideration. Only in exceptional cases is forward-flow scheduling advised.

The mixed-flow scheduling is similar to TOC, because it starts from the bottleneck process. The following processes after the bottleneck process are scheduled by forward-flow scheduling. On the other hand, the processes prior to the bottleneck are scheduled by reverse-flow scheduling.

2.3 TOC (Theory of Constraints)

It is said, “*with TOC, bottlenecks are scheduled to maximize their throughput of products and services* *while adhering to promised completion dates"*. And this system is summarised in the following five steps. [7]

Step 1. Identify the system bottleneck(s).

The bottleneck(s) restricting the firm's ability to meet the shipping schedule and hence total value-added funds is found.

Step 2. Exploit the bottleneck(s).

Create schedules that maximise the throughput of the bottleneck(s). That is, schedule the bottleneck(s) to maximise its utilisation and shipping commitments.

Step 3. Subordinate all other decisions to step 2.

Nonbottleneck resources should be scheduled to support the bottleneck schedule.

Step 4. Elevate the bottleneck(s).

After the scheduling improvements in step 1-3 have been exhausted and the bottleneck is still a constraint to throughput, management should consider increasing the bottleneck capacity.

Step 5. Don't let inertia set in.

Actions taken in step 3 and 4 will improve the bottleneck(s) throughput and may alter loads on other processes. Consequently, the system constraint(s) may shift.

Three things are noticed after examining the theory of constraints or the goal system.

1) Reason why only the bottleneck(s) is scheduled

The reason that the bottleneck(s) constraints the throughput and that other nonbottleneck resources can follow the schedule are evident. All the resources, therefore, are not scheduled. The best way is one that schedules all the resources at the same time. Thus it is not necessary to substitute 'time buffer', 'rod', etc. One reason to preserve the bottleneck conditions may be the decade older programming back when the TOC was first developed. Now there is no practical computing constraint.

2) Effectiveness of checking FDL (First Day Load) peak

To get FDL figure is quite essential for capacity adjustment, and this function is included in the system [8]. However, the time figure is just the accumulated overload volume on the first day of planning. The more important data requested are on which day, in which particular process and how much the production capacity should be increased for minimising the total lead time. The system does not exactly give these data.

3) Connection with the dispatching

The scheduled results cannot be directly used for daily dispatching, in particular, for nonbottleneck resources. TOC outputs seem are different matters regarding dispatching. Ideally say, the daily dispatching also should come from the scheduled plan, of course, considering it together with the status of actual production progress.

2.4 Production Seat Booking System

This system likens the daily production capacity to train seats or hotel rooms. And when an order comes from a customer, the order is immediately allocated to one of the seats. It is a unique concept of this production scheduling system and is fairly understandable not only for the planner but also for the customer. For this reason, it will become more popular among 'make-to-order' type industries. However, drawbacks gathered from a case study of a Japanese photographic film factory will prevent this from becoming a generally applicable system [9]. This system is successfully applicable to factory conditions that do not come under these three features:

1) Production seat is not same as train or flight seat.

Production seat means daily production capacity that is developed from the monthly production plan. But the seat is not like a hotel room. Even though an order is accepted at any time, it is a different matter whether the decision should be made on the production schedule at the arrival time. The question is if seat booking is an appropriate concept for production in this sense, or not. In case of train/flight booking or hotel booking, the planner cannot change the day/time, unless the customer agrees with it. The day/time designation is exclusively for the customer. On the other hand, the planner can shift forward production day/time without informing to the customer. The customer only cares about the due date, but does not care about the production schedule.

2) Seat booking may be categorised to static planning system.

The case study says that "*thanks to production seat booking system, there is no need to adjust the schedule any more*". If it is true that the user does not adjust the schedule, the system should be categorised as static. It is not popular today to resist change after receiving an order. Even if all the orders are allocated successfully without any vacancy, the orders didn't come by the sequence of due dates. For this reason, in reality all backlogs would be better shuffled and scheduled again from the beginning. If the schedule is not allocated by the sequence of due-date priority or any other meaningful priority, the resulted average lead-time of all the orders may become longer. The production schedule of this system can be used only for checking production capacity sufficiency. It cannot instruct the production schedule.

3) Only for the final assembly lines, it provides the precise answer to an enquiry.

An ideal system function is one that "*when an order comes, the promised delivery date is informed to the customer right away*." But it is not always possible to reply immediately to the customer's requested delivery date. By this system, it is possible when a customer asks for the final assembly line to check if any new enquired order can be allocated immediately. However, it is difficult to know precisely if the parts manufacturing departments has enough capacity to accept the new order or not. To be successful in this quick enquiry responding function, the most feasible way is to be ready to supply required parts according to any assembly schedule.

3. Features of the System

The pull scheduling system proposed here have these four characteristics:

(1) Scheduling allocation rules

The basic rule is LDD (Latest Due Date) for backward allocation and EDD (Earliest Due Date) for forward allocation to each operator or to each machine in each process.

1) For matching operator/machine with the work, each operator/machine has the skill data/the process data that give the possible works and the estimated efficiency. The allocation should consider all these data.
2) There are also the other restriction conditions such as set-up times, number of tools/jigs and so on.

(2) Detail scheduling for all the processes

Not only for the bottleneck(s), but also for all the processes including nonbottlenecks are scheduled in detail. By executing the detail scheduling not only for the bottlenecks but also for the nonbottlenecks, a substitute time element such as "buffer time" or "predetermined lead time" (the average estimated time to pass through the processes) is no longer necessary. This also enables the following (3) and (4).

(3) Daily dispatching and loading status checking

The scheduled results are utilised both for daily dispatching and for loading status checking. The former one is a daily regular action to instruct in detail what should be produced today, while the latter one is to see a macro view of the status. Until recently, it has been quite difficult in practice to combine these two different purposes into one system. However now the accumulated loading data comes from the detail scheduled results. Not only in the macro view, but also the detailed schedule data is shown at the same time.

(4) Effective recognition of the capacity insufficiency

By infinite loading, daily workload status is checked exactly. Some days are overloaded, while some days have some vacancy. This is the conventional method of workload control. However, this loading data does not tell which day and how much the capacity should be increased. It is quite common to shift forward the overload, if there is enough vacancy in upcoming days, instead of increasing capacity. Except for cases that have some 'make-day' restriction such as fresh food processing and others that are easy to increase production capacity in any day, it is usually preferable to shift forward rather than to increase the capacity. Because increasing capacity increases costs, for example, overtime wages, extra payments for temporary operators sent from other organisations and so on.

4. Conceptual Algorithm

Step 1. Execute backward scheduling.

Based on the customers' due dates, all existing orders are allocated backward to all necessary processes. At each process, start time of the next process becomes the priority for allocation. The order should be allocated backward earlier to plan for the latest start time.

Purposes of executing backward scheduling are:

1) First of all the system basically should be pull type which results the least lead-time or the least work-in-process and inventory in the whole supply chain. The best solution is for real production done exactly according to this backward scheduled plan. However, most industries do not allow execution of this kind of backward plan. The following two cases have to be considered: a) if too much vacancy in the production capacity occurs, shift some orders forward to the first day of schedule. b) If a first day load peak occur, the backward schedule cannot be used for the production instruction. In any case, the planning procedure is started by backward schedule.
2) The exact priority for forward scheduling is calculated. If no such priority is given then no appropriate forward schedule comes out at a multi-process factory. Needless to say, it is unrealistic nowadays to think about a single-process factory. For one particular process, the due date is the latest start time for the next process. The latest start time can be calculated only from the result of backward scheduling.
3) Sufficiency or insufficiency of the capacity at each process is clearly depicted in the time axis. It is quite essential to know the sufficiency/insufficiency in each daily process. Otherwise, adjusting the production capacity cannot be done. In other words, the net necessity of capacity increase/decrease can be clarified day by day in the time series, but not by the lump-sum figure. This is only possible by executing backward scheduling.

Step 2. Get the discrepancy of workload and capacity and adjust them.

This is a step for production capacity adjustment. For any process the production capacity cannot be increased nor decreased, this step is skipped.

1) Look at the capacity insufficiency figures for each process and identify the bottlenecked days for the process. Although there may be some days, which have too sufficient capacity, the following procedure is described only in case of insufficient capacity.
2) Beginning several days prior to the bottleneck and continuing through the bottleneck period consider increasing production capacity. The ways to increase production capacity are:
   - Increase overtime.
   - Work in the weekend.
   - Transfer some operators temporarily from other processes or other departments.
3) If the capacity increasing measures do not succeed, check the possibility of postponing the due dates.
   3-1) Look at the orders' list for a specified day or week.
   3-2) Find any customer and their order that might agree to a delay.
   3-3) Measure the effect of decreasing the weekly workload on the volume.

Step 3. Execute forward scheduling.

Although it should be basically a pull scheduling system, it is necessary to execute eventually a forward scheduling for the following two reasons.

1) The morning instructions decide the production items and the daily volume. Otherwise, the day may be a vacant day with nothing to work. This dispatching is the result of forward scheduling.
2) To respond to customers' enquiries if any new orders can be allocated in the schedule and satisfied with the customers' requested due dates, the forward scheduling results are needed as the status data which shows all the backlogs in the time axis.

Step 4. Release daily production instruction (dispatching).

The above backward scheduled results for the present and following day become dispatching to the shop floor. The dispatching is instructions for what should be processed on that day before actual production. Namely, all actual production data should be collected before executing the forward scheduling. Moreover, JIT instruction for outside suppliers' parts deliveries should be based on the forward schedule.

Step 5. Give the loading status in the future.

By executing forward scheduling for a longer period, the loading status can be displayed as long as the order data exist. This will be useful for checking overall utilisation of capacity and answering customer enquiries about new orders. Forward scheduling can calculate the loading status data to answer new order enquiries.

5. Conclusion

In most factories, it is difficult to release the production instructions only by backward schedule, although the basic idea of operation should be the 'pull type'. The reasons were summarised in this paper. A tentative conceptual algorithm to realise 'pull scheduling system' was proposed. The author of this paper has already designed the pull system for a precision machinery factory in Nagano, Japan and its development is now in the final stage. Implementation is expected soon.

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