Performance Analysis of Push, Pull, and Mixed Systems

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Abstract

The term "push" and "pull" have been used to describe a wide variety of production inventory systems. Even though it is generally known that a pull system shows higher performance in terms of low work-in-process and production lead-time than the other, there is still a question if it is true in any situation. There may be a situation where a pull system does not give such high performance. Further, mixed push-pull systems, presented as a combination between push and pull systems is considered. This paper gives an attempt to compare these three systems in the situation where there is a buffer in each station. The simulation result indicates that a push system is the most efficient system in terms of work-in-process and production lead-time where certain cycle times of work station are given. By introducing randomness in the system, a push system is efficient when the percentage of throughput is low. For a high percentage of throughput, a pull system turns out to be the better system.

Keywords: Push system, pull system, mixed push-pull system, production inventory systems

1. Introduction

A lot of techniques for production management have been developed in the literature, especially in production inventory systems. Classically, the systems are classified into push-type production systems and pull-type ones. The terms "push" and "pull" have been used to describe a wide variety of manufacturing environments. The distinction refers to a specific attribute which can be identified by observing the mechanisms for controlling material flow on the factory floor and a specific policy for the management of inventories and production schedules. In a "push" type, products are produced according to a schedule derived from estimated product demand. "Pull" type, on the other hand, is considered to be reactive oriented. Products are produced only as they are ordered by customers or to replace those taken for use. This paper then applies the concepts of push and pull systems to a repetitive manufacturing process. A repetitive manufacturing process is a process where many units of one product or several models of one basic product are produced. Moreover, this paper enhances the concepts by combining those systems into a

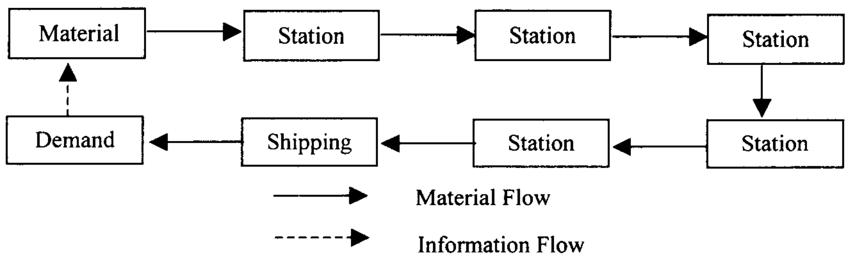


Figure 1: Push System

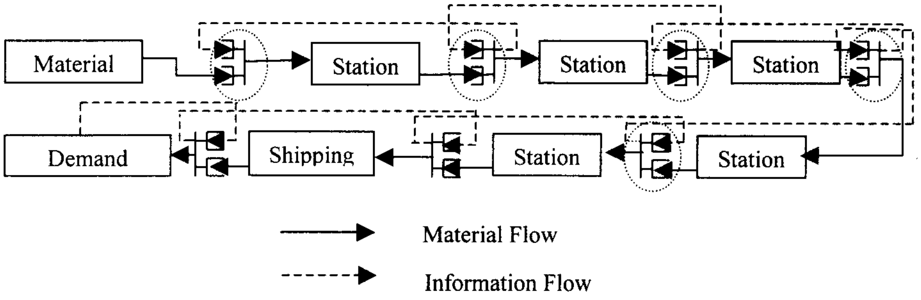


Figure 2: Pull System

"Mixed Push-Pull" system.

The purpose of this paper is to give a comparative study of commonly known push and pull systems in terms of work-in-process and production lead-time. In this paper, we first demonstrate its application by using ideal systems with bottleneck considerations. This paper then studies the integration of ideal system and bottlenecks in the view of production inventory systems. Second, the use of our framework is applied to a system considering randomness (cycle time is a random variable).

Many recent papers have focused on comparing push and pull systems (see for example, [1-4]) and several studies have been carried out on the implementation of push and pull type systems. Orlicky [5] gave an analysis of push system and proposed an improved push system. The study is probably a start-up of pull systems. Next, Huang *et al.* [6] presented simulation analyses of a pull system to investigate the effects of variable processing time, variable master production schedule, and imbalances between stations. Ebrahimpour and Fathi [7] studied the behavior of inventory level in a pull system. Later, Britran and Chang [8] and Fallow and Browne [9] presented a simulation study of a pull system in different conditions.

A performance comparison of pull and push systems was given by Sarkar and Fitzsimmons [10] and Spearman and Zazanis [11]. Olhager and Ostlund [12] discussed push-pull integration in relation to the customer order point, bottleneck resources, and the product structure in a semi-repetitive made to order environment.

Our framework can be used to clarify the distinctions between push and pull, and thus improve models of these systems. In this paper, these systems are studied by using two measurements, work-in-process and production lead-time.

2. Production Inventory Systems

The traditional way of production management is a push system. Information regarding demand forecasts or customer orders for end products are processed to all production stages. Usually, production orders are released

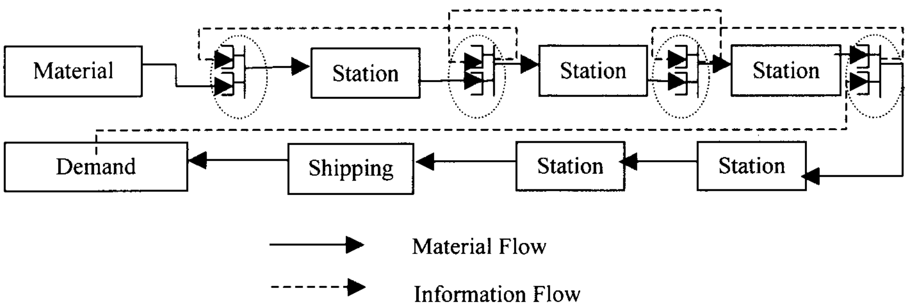


Figure 3: Mixed Push-Pull System

at the first stage and then the order is "pushed" through the production system. Figure 1 illustrates a push system.

In a pull system, information about customer orders (and forecasts) is processed to the finished goods inventory or to the last production stage. If demand cannot be satisfied directly, the stage will order and withdraw parts from the buffer storage of the preceding stage, and so on. Thus, a serial ordering system of successive production orders is incurred. A pull system can be illustrated in Figure 2.

For a mixed push-pull system, it presents an integration of push and pull principles. It implies that some parts of the system are pushed and others are pulled. In this paper, a mixed system is considered in the relation to the bottleneck resources. The bottleneck stage is the stage having a higher cycle time than the others. The early stages, the stages between the first stage and the bottleneck stage, may result in a number of work-in-process inventories. Hence, a pull system is applied to control work-in-process of these stages. The latter stages, the stages between the bottleneck stage and the last stage, can be controlled by a push system since the system is controlled by the bottleneck stage. The illustration of a mixed push-pull systems is shown in Figure 3. The effects of the system are studied by changing bottleneck positions. As seen in Figure 3, the bottleneck of the system is the third station. In a push system, customer order or demand is sent to the raw material stage and then processed forwardly to other stages while in a pull system, customer order or demand is sent to the last production stage. In a mixed push-pull system, customer order or demand is sent to the bottleneck stage. If the demand can be satisfied, the production is processed forwardly till the last process. If not, the stage will order and withdraw parts from the buffer storage of the preceding stage and so on.

3. Assumptions

Two cases are considered in this paper. The first is the case of an ideal system with bottleneck consideration and the second is the case of integrating randomness in the system.

In the ideal system consideration, the system has 5 stations and the cycle time is 10 seconds. Three cycle time levels of bottleneck station are considered. They are 105%, 120%, and 140% of the normal cycle time. Moreover, four positions of bottlenecks are considered. The first position is at the first station. The second one is at the second station and so on.

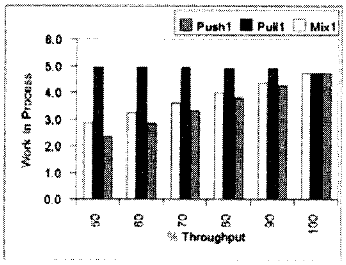
In processing the system, it is assumed that there is no limitation of raw material but the system produces only in the amount of customer demand. The customer demand is based on the percentage of throughput, which varies from 50% to 100% in order to investigate the effects of the percentage (or customer demand). It is assumed that there are 8 working hours per day. Hence, a working period is 8 hours or 28,800 seconds and the warm-up period is assumed to be zero. To make the pull system smooth, it is assumed that the buffer in each station is equal to one.

When considering randomness, the assumptions above remain but the cycle time are log-normally distributed with mean = 10 and standard deviation = 10, and the bottleneck is in the 3rd station. The reason of having the 3rd station to be the bottleneck is to let the mixed system show its performance. As discussed earlier, there are two parts of the mixed system. First is a push system and the latter is a pull system. Since there are five stations, the first two stations use push systems, the 3rd is the bottleneck, and the last two stations use pull systems. Therefore, both push and pull systems are mixed equivalently.

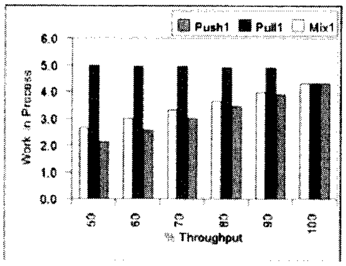
Three cycle time levels (105, 120 and 140 %) of bottleneck are also considered. The simulation runs with 30 replications. Based on the runs, the results give low confidentce interval half-width values. Hence, the accuracy of output is trustable. Two types of measurement, work-in-process and production lead-time are the main consideration of both cases.

4. Results

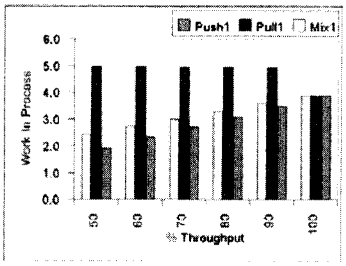
Results and analyses in this paper are based on the simulation method through a simulation program called ARENA version 3.01. Assuming the cycle time of 10 seconds in each station and changing the level of bottleneck percentage (percentage of ideal cycle time), the 100% throughput is shown in Table 1. By varying the throughput percentage from 50% to 100%, the comparisons of production systems on work-in-process and production lead-time are shown in Figures 4-6.



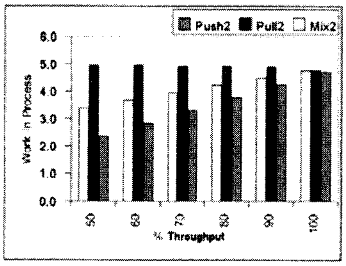
a) BT at 1st Position with 105%



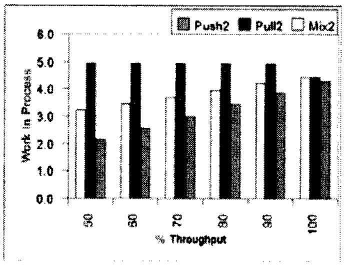
b) BT at 1st Position with 120%



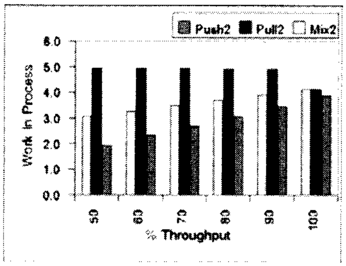
c) BT at 1st Position with140%



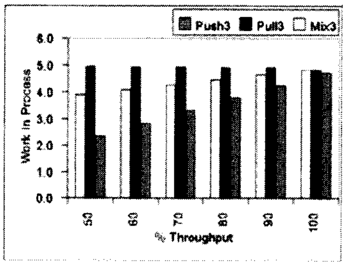
d) BT at 2nd Position with 105%



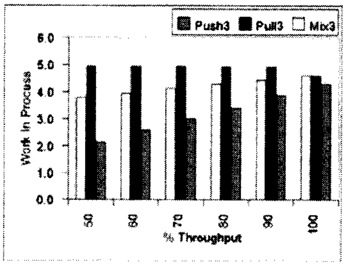
e) BT at 2nd Position with 120%



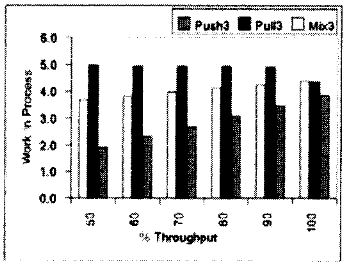
f) BT at 2nd Position with 140%



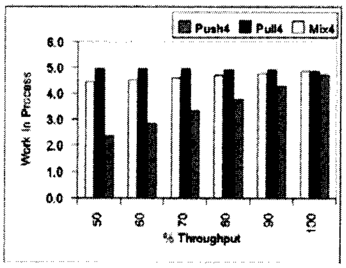
g) BT at 3rd Position with 105%



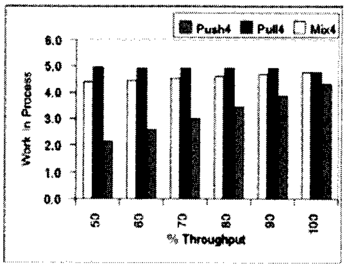
h) BT at 3rd Position with 120%



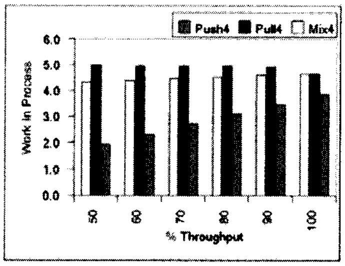
i) BT at 3rd Position with 140%



j) BT at 4th Position with 105%

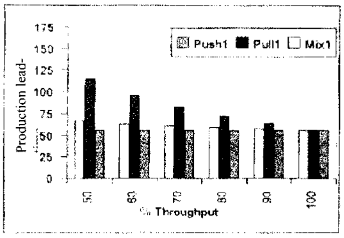


k) BT at 4th Position with 120%

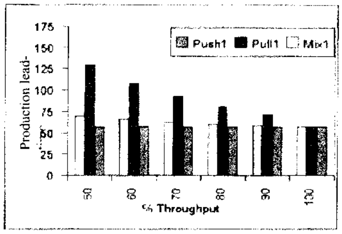


l) BT at 4th Position with 140%

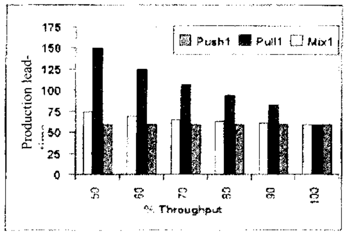
Figure 4: Work-in-process



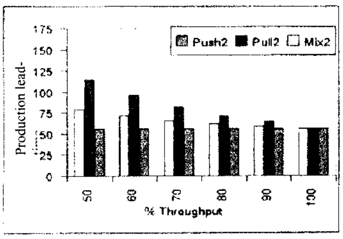
a) BT at 1[st] Position with 105%



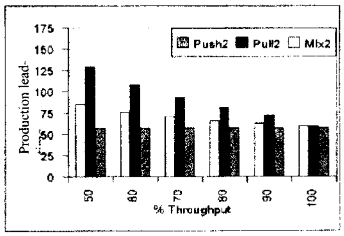
b) BT at 1[st] Position with 120%



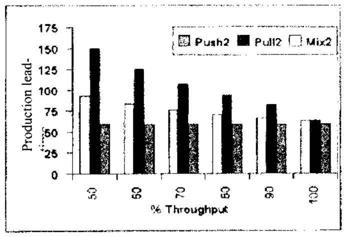
c) BT at 1[st] Position with 140%



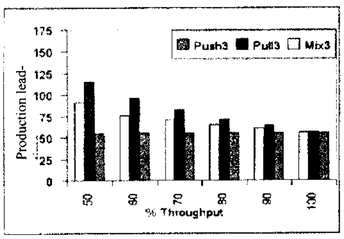
d) BT at 2[nd] Position with 105%



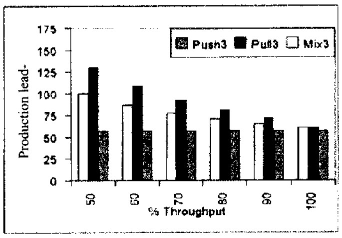
e) BT at 2[nd] Position with 120%



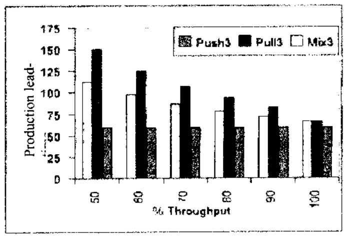
f) BT at 2[th] Position with 140%



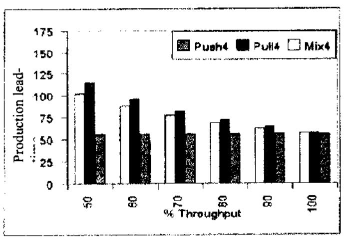
g) BT at 3[rd] Position with 105%



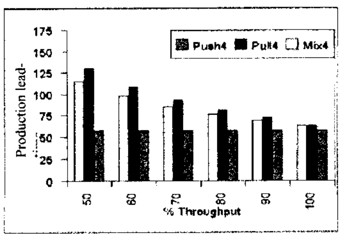
h) BT at 3[rd] Position with 120%



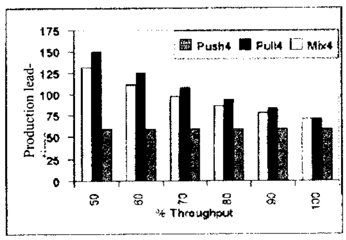
i) BT at 3[rd] Position with 140%



j) BT at 4[th] Position with 105%



k) BT at 4[th] Position with 120%



l) BT at 4[th] Position with 140%

Figure 5: Production lead-time

Table 1: 100% Throughput of Ideal System

Level of bottleneck percentage	105%	120%	140%
100% throughput (units/hour)	313	276	240

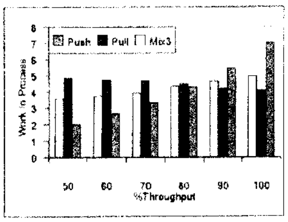
Table 2: 100% Throughput when Considering Randomness

Level of bottleneck percentage	105%	120%	140%
100% throughput (units/hour)	233	225	210

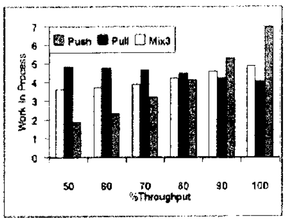
Based on Figure 4, considering a push system, work-in-process is varied upon the throughput rate. When the throughput rate is high, work-in-process is also high and when the throughput rate is reduced, work-in-process is also decreased. Moreover, a higher level of bottleneck gives a lower work-in-process. In a pull system, it can be seen that the bottleneck position and level of bottleneck percentage affect the quantity level of work-in-process especially when the throughput rate is 90-100%. The effect of a mixed system on work-in-process shows the combination of push and pull systems. When the throughput rate is reduced, work-in-process is also decreased but the declining rate of work-in-process depends on the bottleneck position and level of bottleneck. The highest declining rate happens when the bottleneck position is on the 1st position and the second highest rate is on the 2nd position and so on. It may be because most of the system is in a push way. The result tends to be similar to that of a push system. Comparing the three systems, it can be said that the push system gives a lowest quantity of work-in-process in any throughput rate and next is a mixed system.

Based on Figure 5, it can be seen that both the bottleneck position and the level of bottleneck percentage give no effect to the production lead-time in a push system. In a pull system, the production lead-time and throughput rate have an inversely proportional relationship. It may be because a pull system tries to retain the work-in-process quantity. Hence, when the throughput rate is decreased, the production lead-time is increased. This simulation result actually corresponds to the Little formula ($L=\lambda W$) where L is work-in-process, λ is throughput and W is production lead-time. For a mixed system, the effect on the production lead-time is similar to that of a pull system but the incremental rate is lower. Comparing those three systems, it can be said that a push system gives the lowest production lead-time in any throughput rate and next is a mixed system.

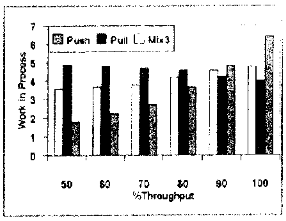
By considering randomness, which is the second case, the 100% throughput is shown in



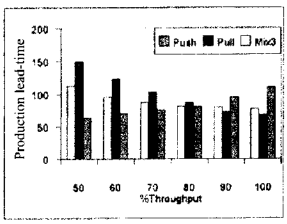
a) BT=105 %



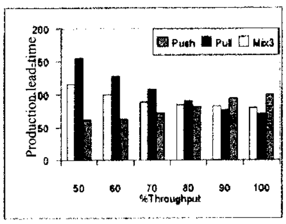
b) BT=120 %



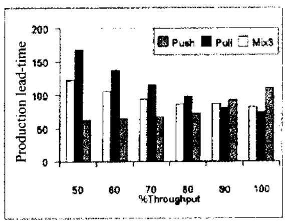
c) BT=140 %



a) BT=105 %



b) BT=120 %



c) BT=140 %

Figure 6: Work-in-process and Production lead-time when Considering Randomness

Table 2. By varying the throughput percentage from 50% to 100%, the comparisons of production systems on work-in-process and production lead-time are shown in Figure 6.

When the percentage of throughput is low, a push system seems to be the best among the others and when the percentage of throughput is high, a pull system turns out to be the better one. Levels of bottleneck slightly affect work-in-process and production lead-time. Work-in-process and production lead-time of a mixed system is about the average of the other two systems. In the randomness consideration case, even though the means of cycle time of each station are equal, the real cycle times may be different. That may lead to the need of internal control especially when throughput is high. Since internal control is a characteristic of pull system, a pull system seems to be better when throughput is high.

5. Conclusion

Bottleneck positions, levels of bottleneck percentage, and percentages of throughput are given considerations. Based on the first case, which is the ideal system with bottleneck consideration, the results and analyses show that in any bottleneck position, levels of bottleneck percentage, and percentages of throughput, a push system is the most efficient system in terms of work-in-process quantity and production lead-time. Note that the study assumes one unit of buffer in each station in pull system so the measurement of work-in-process in a pull system shows about 5 (5 stations). Comparing with a push system, there is no limitation of the buffer in each station. Hence, a push system may result in lower work-in-process than a pull system.

For production lead-time, work-in-process generally affects the time. Therefore, a push system, which gives lower work-in-process, should provide a lower production lead-time as well.

Based on the second case, which considers randomness, it is shown that a push system is an efficient system when the percentage of throughput is low. In contrast, when the percentage of throughput is high, pull system turns out to be a better system. That may be because a push system does not have any internal control in the system. Hence, when throughput rate is high, work-in-process is also high and that gives a long production lead-time. While a pull system has an internal control, work-in-process of a pull system seems to be lower than that of a push system and that makes the production lead-time under control. Therefore, when there is some randomness in the system, control may be needed. The need for control depends on the percentage of throughput. Higher percentage of throughput needs a higher control. Again, the results of mixed system stay between push and pull systems.

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