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Comparison Between the Performances of Pull and Push Systems Using Discrete Event Simulation

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ABSTRACT

This study considers push and pull strategies to control production systems with random processing times for multistage manufacturing inventory systems. In this paper, the behavior of push and pull production systems is examined to explain the superior performance of push systems. On the production system, the phrases "push" and "pull" have been defined to explain a variety of production and distribution environments. To some, the difference refers to an important attribute that can be defined by observing the methods for managing material flow on the production lines. To others, pull and push can be considered in phrases as a special method for managing production schedules. This paper considered the push and pull systems and developed a framework to compare multistage production systems based on work-in-process (WIP) and throughput (TP) tradeoffs. In this paper, according to the way of defining the systems and the desired criteria in evaluating the efficiency, the push system is a better option. Finally, the proposed model with generated different examples is simulated in Arena software to analyze the model performance. The results obtained from models and simulation proved the push system is the suitable method for this problem. The pull system also appears more general in its applicability than traditional pull systems.

Keywords

Job shop, Pull system, Push system, Buffer.

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1. Introduction

In production systems, products are very different, so there may be two modes of intermittent production. The first case is that most products have a fixed production sequence, and the production equipment is also established based on this method. This state of the system is called the production flow process. In the other case, the production method varies in a wide dimension compared to the products, and the equipment and machinery are established according to the machine's performance. This state of periodicity is called job shop production, which has more management problems than the first method. In this case, production is done in a small volume and a wide range of products. The production unit needs highly flexible production capability to make different products. Hence, flexible equipment and skilled labor are needed to perform various activities (Ndayisaba et al., 2020).

Production systems are divided into two general categories: pull and push. In push systems, the stations are working as long as the resources are available, the main focus is on the system's output, and the buffer is infinite. In this system, the entire product or inventory may not be used during the manufacturing process due to demand rate changes, demand content, seasonal changes, etc. However, in the pull system, production begins after receiving a signal based on customer demand, and the limited buffer means that the inventory in the construction process is low (Hirakawa, 1996). In this paper, we have proposed a new model for the push-pull manufacturing system and introduced some parameters and variables to compare two systems, like buffers, which have not been presented in the literature.

In a production process controlled by a push system, items are produced at times determined by a certain schedule. In this system, when a station prepares its parts according to the program, it pushes it to the next station. Sometimes push systems are considered synonymous with systems such as material requirements planning (Puchkova et al., 2016).

In a production process controlled by a pull system, an item is produced only when a signal is received from the customer. Pull systems, which are assumed to be synonymous with just-in-time production methods, fundamentally differ from push systems. In this case, the main production driver is no longer planning, but the signal is reaching the system from the customer. In practice, a final assembly program based on customer orders follows the parts and products during the production process. Only the last station is given a copy of the final assembly schedule. This station fulfills its requirements by itself. In the same way, with the help of cards, empty containers, or empty squares carved on the floor of the factory, the information related to the requirements is transferred to the first station in a backward manner. The need for less production planning and production reports is only one of the benefits of pull systems (Yeboah et al., 2021).

Companies that have used push systems to pull systems have reported that there has been a significant reduction in inventory costs, production, and lead times, and at the same time, the level of quality and customer satisfaction has increased. There are many potential benefits of traction systems, but practically many companies do not use them. The reason is that creating the right environment for a traction system may take years, and in some cases, it seems almost impossible. The main prerequisites of a pull system are:

(1) The possibility of equipment failure should be very low.
(2) The quality of manufactured parts and products must be very high.
(3) Setup times should be very short for the economic production of small batches.
(4) The quality of raw materials and purchased parts must be very high. Suppliers must also be able to deliver required items in small quantities as soon as requested.

Most of the systems that exist are a combination of pull and push systems; these systems take advantage of both. For example, the fixed inventory system is one of the combined systems with a fixed amount of inventory in the production line, and as soon as a product is completed and exits the line, inventory immediately enters the line to make a product (Betterton and Cox, 2009).

A buffer is different from work in process inventory. The buffer is not a physical inventory but a period during which the volume of the inventory can be brought to the assumed value. For this reason, it is called a time buffer in the theory of constraints. In production scheduling based on the theory of constraints, buffers are used at two points of the production line: Before the bottleneck and at the end of other lines where there is no bottleneck (before assembly).

The built-in buffer before the bottleneck ensures that the bottleneck will not remain idle due to possible disturbances of the stations behind it. The buffer at the end of other lines also considers the safety that we will have an output equal to the number of pieces processed in the bottleneck, and the amount of output will not decrease due to defects in other non-bottleneck lines. The amount of these buffers also determines the volume of materials entering the system and the rate at which materials are injected into the system (Grosfeld-Nir and Magazine, 2002).

Push and pull are approaches both designed to gain control of production planning. In this paper, we have two defined systems within a Pull environment to assign the best production policy to the parts within the production lines. This paper aims to develop the chance of using flexibility in simulation to cope with the different product varieties by defining a Push/Pull production for internally produced parts. The novelty of the research is represented by the proposed simulation model to properly set the Push or Pull policy for each part to minimize work-in-process and maximize throughput. A key element of the proposed paper is the similar element in both simulation models.

The purpose of the research is to compare the effect of the implementation of two push and pull systems on the performance criteria of output and inventory during construction in the job shop production system. This production system has three products and five workstations. The results show that in the proposed system, the performance criteria of the push system are more favorable than the pull system.

2. Literature review

In pull systems, the stations start working according to the signals received from the next station, while in the push systems, the stations work until they have parts to produce and do not wait for the signals from the next stations. Güçdemir and Selim (2018) compared two types of pull and push systems and considered the level of available inventory and output as performance criteria to make the two systems comparable. They first simulated the pull system and the output obtained from it, and they considered it an input to the push system. In other words, in the pull system, they controlled the inventory during construction, and in the push system, they did the opposite, and in both cases, they compared the output and the inventory level as performance criteria. They performed the simulation on different lines and with different numbers of machines, from three to fifteen. In order to get more reliable answers, the way of entering the material into the line was selected as deterministic, probable, or with different distributions. They concluded that for lines with seven or greater cars, the push system and for lines with less than seven cars, the traction system performs better according to the criteria considered. Silva et al. (2022) considered the impact of the push-pull system on the basic pests and natural enemies in brassica crops. They resulted that the plants applied to compose the diversification method are better for composing the pull-push policy in brassica crops. The buffers in the line also affect the system's performance; Determining the size of buffers in the system is difficult. Radovilski (1998) defined the buffer as the number of products waiting in the queue and determined the size of the buffer in a system that has one product. To solve the problem, he took help from queuing theory, and since his chosen production line produced a single product, he considered the system as a single server. To determine the size of the buffer, the balance between the amounts of income obtained from determining a certain amount for the buffer and the operational and inventory costs resulting from it was considered. He defined the system as M/M/1/K and considered K as the number of input pieces, the same as the buffer size. His goal was to determine the buffer behind the bottleneck in the simulation. He assumed the output rate to be lower than the input rate to have a stable system. He tested the answers obtained on different systems and finally concluded that determining the right value for the buffer affects the system's profit. Liu et al. (2020) applied a two-stage push-pull system in a make-to-order production environment. They considered a decision model to define the optimal stock of the work-in-process product and the best lead time for the completed products. The study result is useful for managers to choose the best inventory and lead time to cope with production variability.

Rammer and Rennings (2012) examined the role of simulation in different production systems. They stated that a simulation is an important tool for analyzing and designing production systems. Smith performed simulations for various discrete or continuous production. He concluded that in the design of a production system, the simulation execution time is not very important because this operation is done only once, but the production processes must be examined in the analysis of a system. This operation is repeated during the simulation execution time. Construction is important. Also, Lin et al. (2022) evaluated the dynamic treatment of a hybrid system in which manufacturing elements occur simultaneously to generate the same serviceable inventory for customer orders. They considered the bullwhip effect and evaluated it under push-and-pull remanufacturing systems. The nonlinear control theory was applied in their model with discrete-time simulation, and the result showed the bullwhip efficiency of pull and pushed controlled hybrid systems. Lin et al. (2022) simulated a job shop production system that had ten production stations and ten products to produce. The purpose of the study was to divide the production process of products into similar production processes with the aid of the simulation technique, so that joint processes can be carried out consecutively and without interruption. The result showed that less time is needed for production, and the system is improved. The simulation was repeated for seven different types of queuing systems for fifty weeks and ten times, and one of the main performance criteria of this simulation was to calculate the maximum time for making each piece. The results showed that in the investigated system, the first-in, first-out queuing system was the minimum manufacturing time for parts.

3. The problem modeling

In push systems, products are produced by a pre-prepared program, so the buffer in these systems is assumed to be infinite. Each station that completes its piece pushes it to the next station. In this system, blocking does not happen, although starvation may occur due to the products not arriving from the previous station. In the pull system, where the buffer is limited, production occurs when each station's buffer allows the product's production. In this way, if the nth station's buffer is full, the n-1st station will not generate until it receives a signal from the nth station that the buffer is empty. Therefore, in this system, in addition to starvation, blocking also occurs due to the limited buffer. Since the buffer in the pull system is limited, the work in the construction process is less in this system. While in the push system, the output is more because the production takes place continuously and regardless of the buffer. Although the inventory costs in this system increase.

3.1. Simulation

Table 1 demonstrates some general information and the input data of processing time and precedence of the tasks. The proposed system consists of 5 workstations: parts cutting, turning, CNC with high flexibility to perform various operations, hardening operations. Finally, the assembly station. It is assumed that the machines of each station are completely identical. The parts that the system can produce are of two models, each of which accounts for a certain percentage of the total demand, and each has a specific production sequence that is defined using the sequence module. Each piece's preparation time and process time at each station are defined as an attribute in its sequence. Each workstation with any number of machines has an operator who places the part before the machine starts working, and because of the short time of placing, it can support several machines.

Table 1. The input data of processing time and precedence of the tasks

Task no.	Model 1	Model 2	precedence
1	4	2	-
2	3	-	-
3	-	-	2
4	2	3	3
5	-	6	3,4
6	1	4	5
7	6	5	6
8	5	3	7

The operator of the cutting station works on the piece at the same time as the machine. Each part entered into the system also includes ready parts that must be assembled. After entering the parts into the system, the part is copied using a separate module. The original part goes through its production process; they are permanently batched using the internal software attribute and finally exit the system after assembly process.

A transporter with a capacity of one is used to transfer the parts between the stations. The loading time and imagination in the system are variable with a constant value. The parts are batched before being transferred to the next station, the size of which is assumed to be constant with all stations, considering that it is assumed that the parts of a batch are processed one after the other. After the parts arrive at each station, the preparation time for all the batch parts is done, and the parts are separated and enter into the process (Figure 1).

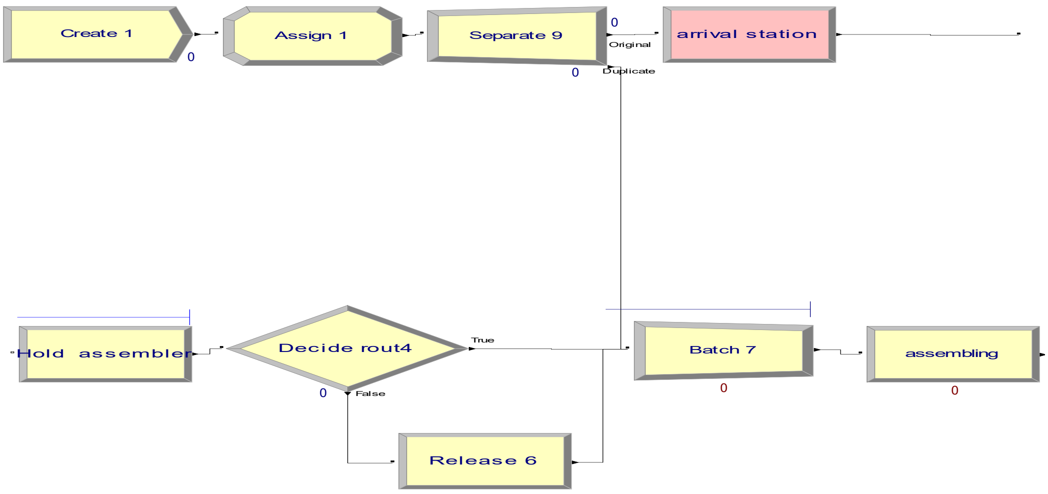

Figure 1. Using the separate module to separate the main part and parts ready for assembly

In the traction system, the buffer size is limited, and the part is allowed to leave the current station if the buffer of the next station has an empty capacity. In this system, the buffer size in the whole model is a variable with a fixed value. For further explanation, let's assume that part one is at the cutting station, and the destination station is turning (Figure 2).

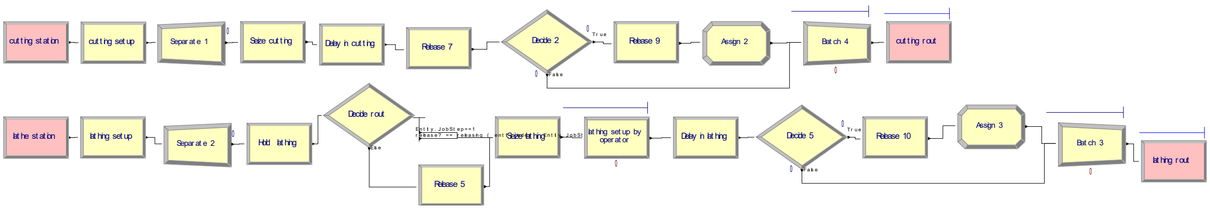

Figure 2. Cutting and turning station

In the initial modeling of the system, we assumed that the part entered the turning machine before leaving the cutting machine. In the Hold module, it remains in the queue related to this part until the turning machine queue has an empty capacity for this part (waiting queue according to the type of part as a set is defined). The problem, in this case, was that the parts that entered the cutting station could not catch the machine, and the queue was extremely long. To solve the problem of checking the buffer of the next station and releasing the machine, every station is performed at the same station. First, the buffer of the turning station is done at the current station (cutting), and if the buffer has an empty capacity, the turning machine is abandoned, and the attribute value of Entity.JobStep is assigned in its sequence (Figure 3).

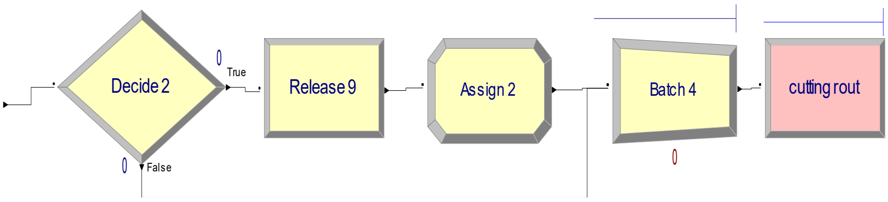

Figure 3. Checking whether the car will be left at the current station or not?

Otherwise, this machine is kept at the lathe station in the Hold module. Of course, until the queue of this part in the lathe has the capacity and if the cutting machine has not been abandoned at the origin station. (Figure 4).

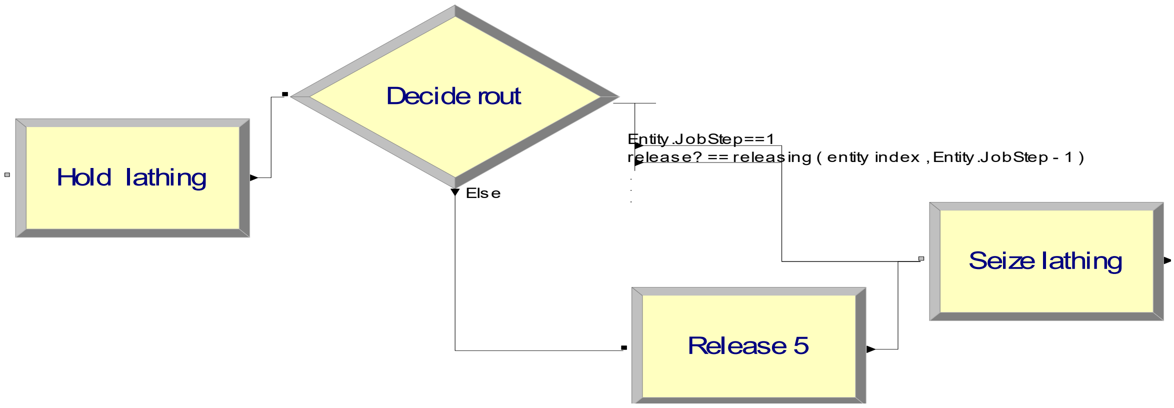

Figure 4. Checking whether the car of the previous station was left at the same station or not?

In this system, it is assumed that each system applies a fee proportional to the time of its presence in the system, and the selling price of the piece is already known. Therefore, the profit obtained from the sale of parts is equal to: sales profit = {number of parts leaving the system * (selling price of the part * time the part is in the system - the cost of the part being in the system per unit of time)}

To compare this system with the push system, there is no need to have limited buffers in the system. We released the buffers we had defined in the queue and set them to infinity. The hold and decide modules related to receiving signals to release resources from the system. To make the two systems comparable, we defined the process times, costs, and related issues in the two systems.

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4. The simulation results

Considering that the basis of the comparisons is based on the traction system. We first determined the model repetitions for this system. For this purpose, we ran the system for 20 repetitions and examined two evaluation criteria of waiting time and work in process. The value of these results was recorded for 20 repetitions, and the average and standard deviation of the results were calculated. The results are shown in Table 2.

Table 2. The results of running the pull model for 20 iterations

No. replication	Waiting time(min)	WIP
1	206.5	58.9137
2	209.36	48.0289
3	201.89	52.5545
4	226.33	55.5182
5	239.29	63.361
6	215.68	55.2005
7	240.47	53.6088
8	216.86	46.2414
9	204.91	52.1742
10	217.48	53.4045
11	214.67	46.1574
12	221.7	50.3895
13	219.73	52.9149
14	193.01	52.4658
15	229.41	54.5159
16	211.25	45.3365
17	221.23	40.324
18	202.67	52.2584
19	223.96	49.6284
20	202	54.2195
m	**215.92**	**51.8608**
s	**12.46203498**	**5.070019**

The value of half-width was calculated using the formula 1,2, 3, and the result is as follows:

HW calculation for waiting time:

$$HW=2.093\frac{12.462}{\sqrt{20}}=5.832 \tag{1}$$

Calculate HW for work in process:

$$HW=2.093\frac{5.07}{\sqrt{20}}=2.372 \tag{2}$$

The optimal number of repetitions according to work-in-process:

$$n=20\ \frac{2.3728^2}{2^2}=28.151\approx 29 \tag{3}$$

The maximum calculated values were selected for the number of iterations to perform calculations in both pull and push systems. In the pull system, two variables, batch size and buffer size, affect the work in the construction process. To choose the best value for these variables according to the least work in the construction process, 10 scenarios were defined, and the best answer for the work in the construction process per batch size And the buffer size was equal to 5 and 6, respectively. Three modes were considered for the batch size value in all the scenarios defined for the pull system. In the push system, because the buffer is infinite, only three scenarios were defined for these batch size values, and in this case, the batch size of 5 was the best answer. The scenarios defined for these two systems can be seen in Figures 5 and 6.

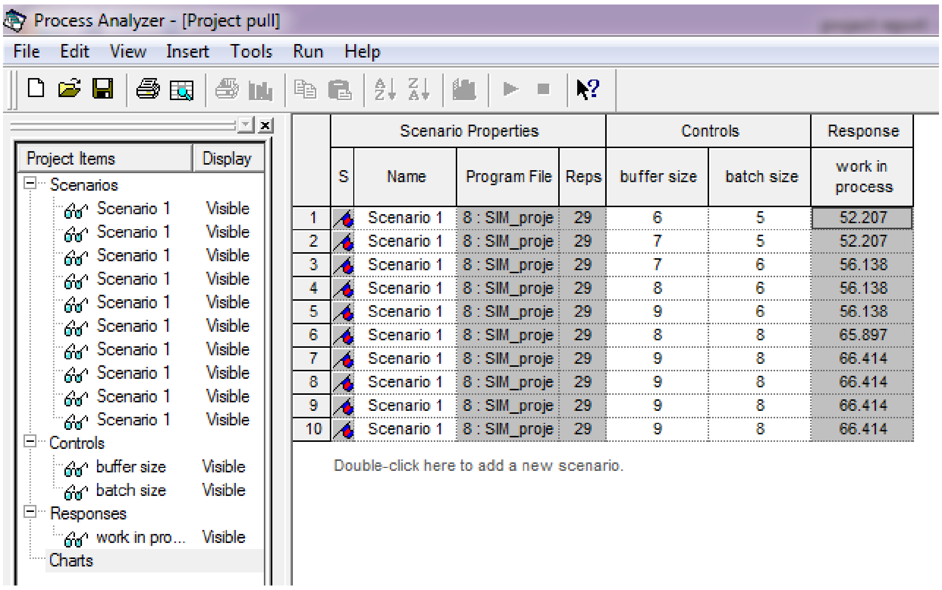

Figure 5. Defined scenarios for the pull system

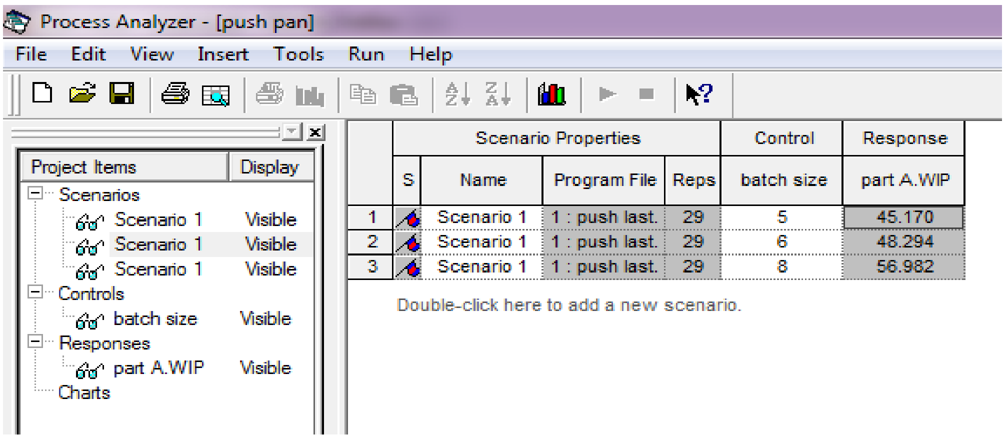

Figure 6. Defined scenarios for the push system

Therefore, for the batch size equal to 5 for both systems and buffer size = 6 for the push system, and the number of repetitions equal to 29, the results table of the important criteria for comparing the two systems is shown in Table 3:

Table 3. The results of running the model for two pull and push systems

	Total Time	WIP	throughput	Cost	Income	Profit
Push system	117.84	45.1697	75	176760	375000	198240
Pull system	136.41	50.9458	70	190974	350000	159026

In order to check the ability of the two proposed simulation models, an experiment is conducted using some self-made test problems, and comparing the pull solution with the push solution indicates that the push system performs well in problems. As seen in the table, the output in the push system is more than the pull system and the total time in the model is less for the push system. The cost applied to the system is also less, and as a result, the profit of the push system is more than the pull system.

For managers in production systems that supply a family of products for customers, the key issue is to find the best lead time to satisfy customer demands and also to maximize the throughput. We proposed a decision model for the pull and push systems with similar elements and evaluated the buffer effect in manufacturing systems. According to the results obtained from models and simulation, the push system proved to be the suitable method for this problem. The pull system also appears more general in its applicability than traditional pull systems. So the study result is useful for managers to choose the best production policy and lead time to cope with production variability with attention to the manufacturing situation.

5. Conclusion

In this paper, according to the way of defining the systems and the desired criteria in evaluating the efficiency, the push system is a better option. Of course, this result is true in this system, and if the conditions change, including the number of machines in each station, the sequence of product operations in each station, the processing time, as well as the desired criteria for evaluating efficiency, the pull system can be more suitable than the push system.

There is some suggestion for this study that could be useful for future investigation. Applying a mixed pull push simulation model with a similar element is fantastic and comparing it with only a pull or push system. Furthermore, pricing and setup time are key factors for managing production lines that can be considered in future studies. In future research, except for the buffer discussion mentioned in this paper, we can also pay attention to issues such as customer orders and customer orientation in the model. It is also possible to use other comparative evaluation factors, such as product delivery time to compare the two systems.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

Betterton, C. and Cox, J., 2009. Espoused drum-buffer-rope flow control in serial lines: A comparative study of simulation models. *International Journal of Production Economics*, *117*(1), pp.66-79. https://doi.org/10.1016/j.ijpe.2008.08.050.

Silva, V., dos Santos, A., Silveira, L., Tomazella, V. and Ferraz, R., 2022. Push-pull cropping system reduces pests and promotes the abundance and richness of natural enemies in brassica vegetable crops. *Biological Control*, 166. https://doi.org/10.1016/j.biocontrol.2021.104832.

Grosfeld-Nir, A. and Magazine, M., 2002. Gated MaxWIP: A strategy for controlling multistage production systems. *International Journal of Production Research*, *40*(11), pp.2557-2567. https://doi.org/10.1080/00207540210128251.

Güçdemir, H. and Selim, H., 2018. Integrating simulation modelling and multi criteria decision making for customer focused scheduling in job shops. *Simulation Modelling Practice and Theory*, *88*, pp.17-31. https://doi.org/10.1016/j.simpat.2018.08.001.

Hirakawa, Y., 1996. Performance of a multistage hybrid push/pull production control system. *International Journal of Production Economics*, *44*(1-2), pp.129-135. https://doi.org/10.1016/0925-5273(95)00098-4.

Horbach, J., Rammer, C. and Rennings, K., 2012. Determinants of eco-innovations by type of environmental impact -The role of regulatory push/pull, technology push and market pull. *Ecological Economics*, *78*, pp.112-122. https://doi.org/10.1016/j.ecolecon.2012.04.005.

Lin, J., Zhou, L., Spiegler, V., Naim, M. and Syntetos, A., 2022. Push or Pull? The impact of ordering policy choice on the dynamics of a hybrid closed-loop supply chain. *European Journal of Operational Research*, *300*(1), pp.282-295. https://doi.org/10.1016/j.ejor.2021.10.031.

Liu, L., Xu, H. and Zhu, S., 2020. Push verse pull: Inventory-leadtime tradeoff for managing system variability. *European Journal of Operational Research*, *287*(1), pp.119-132. https://doi.org/10.1016/j.ejor.2020.04.033.

Ndayisaba, P., Kuyah, S., Midega, C., Mwangi, P. and Khan, Z., 2020. Push-pull technology improves maize grain yield and total aboveground biomass in maize-based systems in Western Kenya. *Field Crops Research*, *256*, pp.1–12. https://doi.org/10.1016/j.fcr.2020.107911.

Puchkova, A., Le Romancer, J. and McFarlane, D., 2016. Balancing Push and Pull Strategies within the Production System. *IFAC-PapersOnLine*, *49*(2), pp.66-71. https://doi.org/10.1016/j.ifacol.2016.03.012.

Radovilsky, Z., 1998. A quantitative approach to estimate the size of the time buffer in the theory of constraints. *International Journal of Production Economics*, *55*(2), pp.113-119. https://doi.org/10.1016/S0925-5273(97)00131-X.

Yeboah, S., Ennin, S., Ibrahim, A., Oteng-Darko, P., Mutyambai, D., Khan, Z., Mochiah, M., Ekesi, S. and Niassy, S., 2021. Effect of spatial arrangement of push-pull companion plants on fall armyworm control and agronomic performance of two maize varieties in Ghana. *Crop Protection*, *145*. https://doi.org/10.1016/j.cropro.2021.105612.