Available online www.jsaer.com

Journal of Scientific and Engineering Research, **2016, 3(6):252-261**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Optimization Modeling and Scheduling of Production Control Schemes for Complex JIT Manufacturing Systems

Chukwuedozie N Ezema[1], Eric C Okafor[2], Christiana C Okezie[1]

[1]Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
[2]Department of Computer Engineering, Enugu State University of Science & Technology, Enugu State, Nigeria

Abstract Just in Time systems are kanban-controlled production systems where the flow of material is controlled by the presence or absence of a kanban, and where kanbans travel in the system according to certain rules. Kanban means signal card or token. Kanban cards represent a visual control tool that regulates the flow of materials between cells and aim to respond to demand by delivering parts and products Just-in-Time. Therefore, it is a method of controlling the flow of information between the workstations while eliminating the WIP levels. The essence of kanban-controlled production systems is to use single or multiple closed loops to provide information flow feedback using kanbans. By doing this, the systems keep tight controls over inventory levels, while providing satisfactory production rates. To achieve the goals of this research, stochastic mathematical models and efficient analytical methods for evaluating the performance of systems are required. The actual system must be totally modeled and simulated. Secondly, issues concerning the structure of JIT systems that employ the previously studied Common Frequency Routing (CFR) problems will be explored to understand their impacts on operational costs of the system. Finally, a discrete event simulation model will be developed to study the JIT system by looking at different types of variations in demand and studying their impacts on the stability of inventory levels in the system. The integrated simulation model is tested and validated by analysis of variance. The optimum (most fitted) JIT design is developed and tested by modeling actual system's limitations and its dynamic behavior. The framework is applied and tested for a just-in-time production line (Juhel Drug Process Plant).

Keywords Kanbans, Buffers, Scheduling Rules, Trigger Point, Flow Times

Introduction

JIT manufacturing involves the production of goods based on demand. It contradicts the conventional American manufacturing ideal of producing as much inventory as possible in anticipation of demand. Ideally, JIT eliminates all work-in-progress, and produces only goods that are immediately needed. According to Doll & Vondermbse (2011) [1], JIT attempts to manufacture products from start to finish, the first task in applying JIT production, is to rearrange the factory floor layout away from batch production toward a product layout using flow lines. Additionally, each flow line will normally be U-shaped. This layout allows workers access to more than one machine, and the ability to help other workers if any trouble occurs in the production line. If any problems are encountered during the production flow, the entire line shuts down, and the problem is resolved immediately. Since parts are produced based on demand, there is a constant flow of components rather than batches of work-in-progress (WIP). Under this environment, defective parts must be eliminated. When only minimal levels of inventories are maintained, any hold up in the production process may cause delays in customers' deliveries. Doing the job right the first time is one of the main emphases of JIT production [2].

Just-in-time (JIT) manufacturing is a philosophy that has been successfully implemented in many manufacturing organizations. It is an optimal system that reduces inventory whilst being increasingly responsive to customer needs; this is not to say that it is not without its pitfalls. However, these disadvantages can be overcome with a little forethought and a lot of commitment at all levels of the organization [3].

JIT is likely to be one of the most suitable management concepts for today's business because it meets the paradigms of new businesses such as rapid changes in demand and more customised products. This system is also based on aspects of continuous improvement such as continually reducing costs, defect, inventory and lead time. Since the system has never-ending objectives, it is suitable for companies that want to survive in tomorrow's business world [4].

The JIT system does not just involve lowering inventory reduction or using Kanbans, but the most necessary elements of implementing a JIT system are empowering people and developing a humanised production system. These elements can be achieved only if a proper environment exists within the JIT company such as effective employee involvement and management commitment. Therefore, the role of management is then crucial for cultivating the environment [5].

According to Mehra & Inman (2011), the simulation of a JIT system can provide better insight into the effects of factors contributing to its successful implementation [6]. Some factors such as the number of Kanbans, trigger points, the scheduling rules and location of the buffers that are difficult to evaluate in practice can be evaluated using the simulation. However, due to the capability of the software that was dedicated to the conventional push system, some figures generated from the simulation may need some interpretation before being applied in actual situations. Another problem in using simulations is the complexity of the model and the more accurate the system, the more complex the model. Unfortunately, the more complex model is usually difficult to interpret and it requires more time to develop and verify the model [7].

System Implementation and Simulation

Models can give useful insights into the behaviour of the system [8]. By using the model developed in fig. 2, there are four experiments being conducted to identify the effects of four factors i.e. trigger point levels, the scheduling rules, the number of Kanbans, and location of the buffers. These factors were selected because they are under management control at the Drug Process Plant and they can be manipulated easily in the model. By analysing the simulation outputs, three major performance measures used to determine the effects of these factors were flow time (customer lead time), Work-in-Process (WIP) and shortage. Although the two last measures cannot be obtained directly from the simulation results, they can be calculated from variables available in the simulation results.

In the simulation, the analysis cannot rely on observations from a single replication since the simulation outputs are usually fluctuating due to the variation of variables in the model. Therefore, the use of statistical procedures is unavoidable to overcome the fluctuating data obtained from multiple replications. Since the use of the statistical tools is not a main concern in the paper, a simple statistical procedure is used to investigate the results *i.e.* the procedure for comparing two or three systems.

In the simulation, the replication length was set at four weeks (40320 minutes) which represents the maximum time that the model is able to run. The replication number was set into 10 and later 60 for the same reason. Basically, a sufficient number of replications was determined by using a statistical procedure that specifies a confidence level. However, the replications were assumed to be a sufficient figure for analysing the results.

Model for Increasing the Number of Buffers and Throughput

With the help of "WITNESS" Simulation Software, the model was created. This software was used to conduct simulation experiments to achieve the objectives of the study. The WITNESS is VISM (Visual Interactive Simulation) system developed by Lanner Group. It gives beneficial approach to the users not only to work on creating and using witness models but also to build and test the models on small incremental stage. The input parameters are setup time, machine alteration and shift alteration and output parameter is throughput as shown in fig 1.

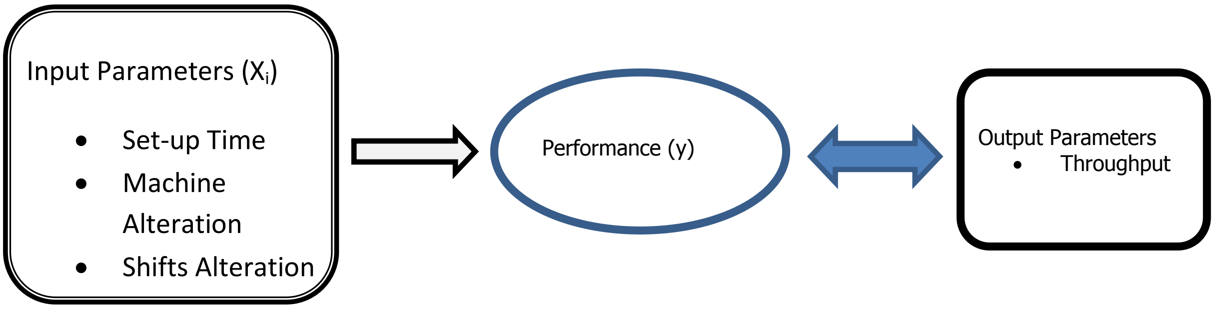

Figure 1: Conceptual Model

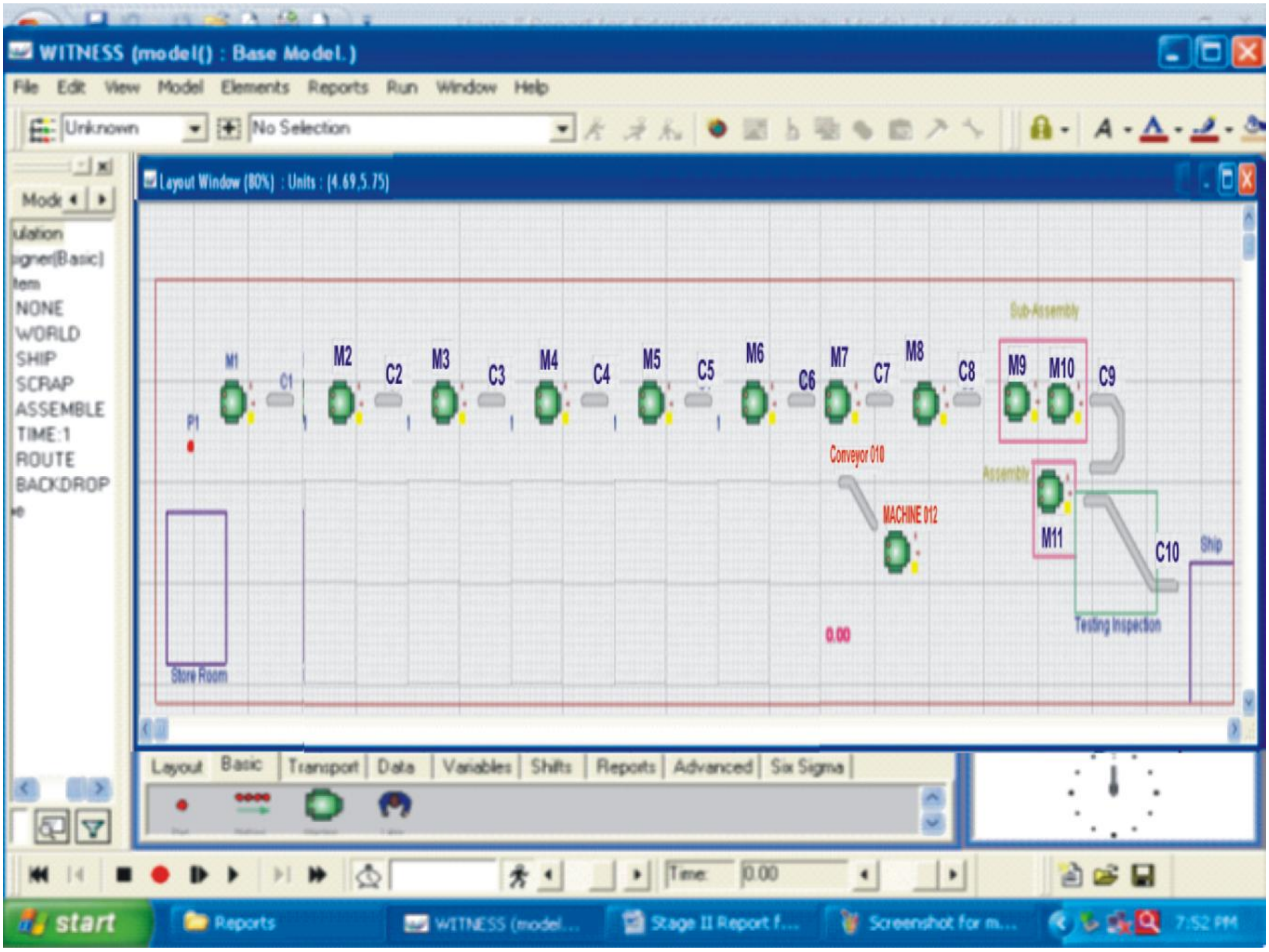

Figure 2: Development of Model using WITNESS Simulation Software

The appropriate JIT practices (process variables) and the performance measures (response variables) are selected. The Input parameters will be used such as Set-up Time, by altering machines, using shifts alteration. The Output Parameters will be used such as Lead Time, Throughput.

Assumptions

i. Parts are always available at the Sore-Room.
ii. The Model is flexible and new elements can be easily add or removed.
iii. No stoppage occurs during the production in the model.

iv. For parts, First-In-First-Out (FIFO) rule is applied.
v. The model works under ideal JIT Conditions.

The screenshot of the model created using WITNESS Simulation Software is shown in figure 2. It contains different notifications which explain different entities. Machines are denoted by M1, M2, M3, M4, M5, M6, M7, M8, M9, M10 and M11.

Conveyors are denoted by C1, C2, C3, C4, C5, C6, C7, C8,C9 and C10. The part which is used for different operations and assembly, sub-assembly is denoted by P1. In this model, when part P1 moves towards the machine M1 then after setup time then its machining done and P1 forwarded to conveyor C1. Similarly done up to C10,then P1 is forwarded to Ship. The normal flow of part P1 is: M1- C1- M2- C2- M3- C3- M4- C4- M5- C5- M6- C6- M7- C7- M8- C8- M9- M10- C9- M11- C10. The Conveyor “Conveyor011” and machine “Machine012” is used for addition of machine in further Design of Experiments (DOE).

Design of Experiments

DOE is used to determine best set of factors for the model optimization [9]. For this purpose, the study of Taguchi design is done. The three factor two level Taguchi design is designed. For that L16 orthogonal array is used. It is shown in the Table 1.

Table 1: Design of Experiment

Run	Setup Time	Machine Alteration	Shift Alteration
1	5	Removing 1 m/c	8
2	5	Removing 1 m/c	8
3	5	Removing 1 m/c	12
4	5	Removing 1 m/c	12
5	5	Adding 1 m/c	8
6	5	Adding 1 m/c	8
7	5	Adding 1 m/c	12
8	5	Adding 1 m/c	12
9	10	Removing 1 m/c	8
10	10	Removing 1 m/c	8
11	10	Removing 1 m/c	12
12	10	Removing 1 m/c	12
13	10	Adding 1 m/c	8
14	10	Adding 1 m/c	8
15	10	Adding 1 m/c	12
16	10	Adding 1 m/c	12

This is the design of experiment drawn with the help of WITNESS software. Here, in this design, the 1 indicates Low and 2 indicates high. The three input parameters Setup time, Machine Alteration and Shift Alteration. The low and high level for the DOE is explained in Table 2.

Table 2: Low and High levels of parameters

S/No.	Input Parameters	Units	Low	High
1	Setup Time	min.	5	10
2	Machine Alteration	-	Removing 1 m/c	Adding 1 m/c
3	Shift Alteration	Hrs.	8 (Current shift)	12 (current shift with overtime)

The Setup Time explains the time required for the machine to be ready for the any function or operation. So, the time 5 min is low level and 10 min is high level. The Machine Alteration means adding and removing the machine from the developed model. In this factor at low level, the Machine M2 is not considered so the line has ten machines and ten conveyors; at high level, the Machine "Machine012" and Conveyor "Conveyor011" is connected to the main line of developed model. The third factor is Shift Alteration explains the shift hours at the low level, the shift hrs are 8 hrs similar to current shift and at high level, extra 4 hrs are added to the current shift becomes 12 hrs.

Results and Discussion

The Effects of the Trigger Point

The purpose of this experiment was to determine the optimal level of the trigger point that can reduce the WIP as well as the customer lead time and the lower the WIP, the higher the risk of the shortage. In this experiment, the effects of the trigger point on shortage were also investigated.

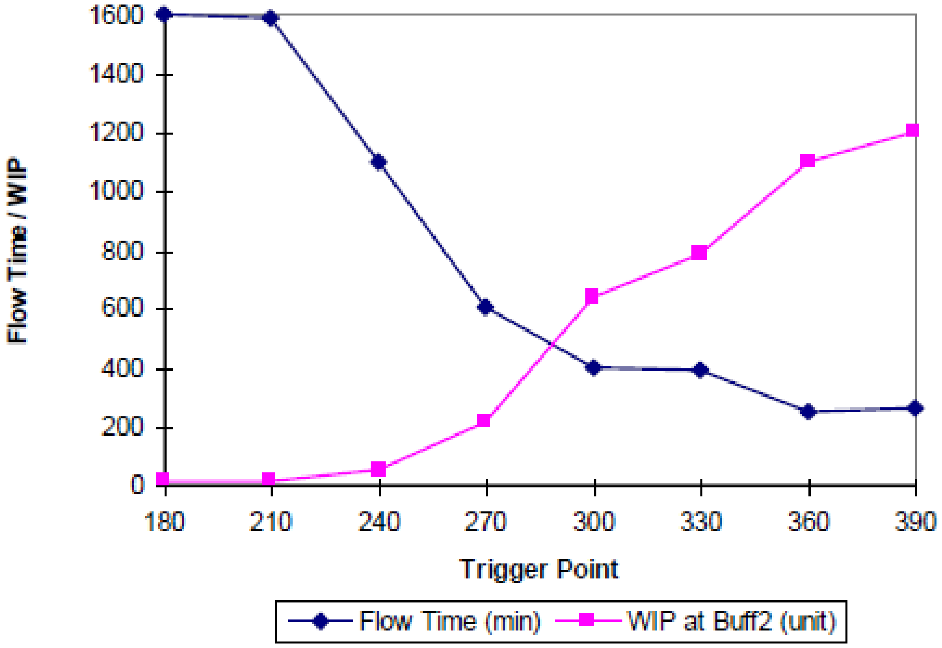

Figure 3: The effects of trigger points in Flow Time and WIP

By changing the values of the trigger points, the results of the simulation can be shown in Figure 3. From this chart, by running the four-week simulations as the trigger point increases, the average flow time representing the customer lead time decreases and the average WIP at buffer 2 increases. This is not surprising because an increase of the trigger point is the same as an increase of the safety buffer at buffer 2. The high buffer level is highly likely to reduce the waiting time since the orders can be accomplished immediately. The number of satisfied orders also increases as a result of decreasing the customer lead time. Unfortunately, this also means creating extra WIP. Therefore, the trade-off between the WIP and the lead time should be attained. Another interesting result from Figure 3 is that an increase of the trigger point after the point of 360 does not give significant reduction of flow time while the increase of the WIP remains high. Therefore, the trigger point is effective for reducing the customer lead time up until a certain level, after that, there is no benefit in increasing the trigger point. Since the Drug Process Plant wishes to reduce the customer lead time and inventory simultaneously, based on Figure 3, a trigger point of 270 or 300 (the existing trigger point) is the best compromise between both objectives.

Another factor affected by trigger point is shortage. The shortage is obtained by subtracting the total Kanban quantity arriving by the order satisfied. Ideally, in the JIT system, there is no shortage since the Kanban arrival is always accomplished. However, if the arrival of orders is probabilistic and the Kanban quantity is fluctuating, shortages are unavoidable. Therefore, shortage must be minimised since it can affect the customer lead time. As an increase in the trigger point is the same as an increase in the safety buffer at buffer 2, the high buffer level is highly likely to reduce the risk of shortage experienced by the customer. However, this results in an increase of the WIP as shown in Figure 4.

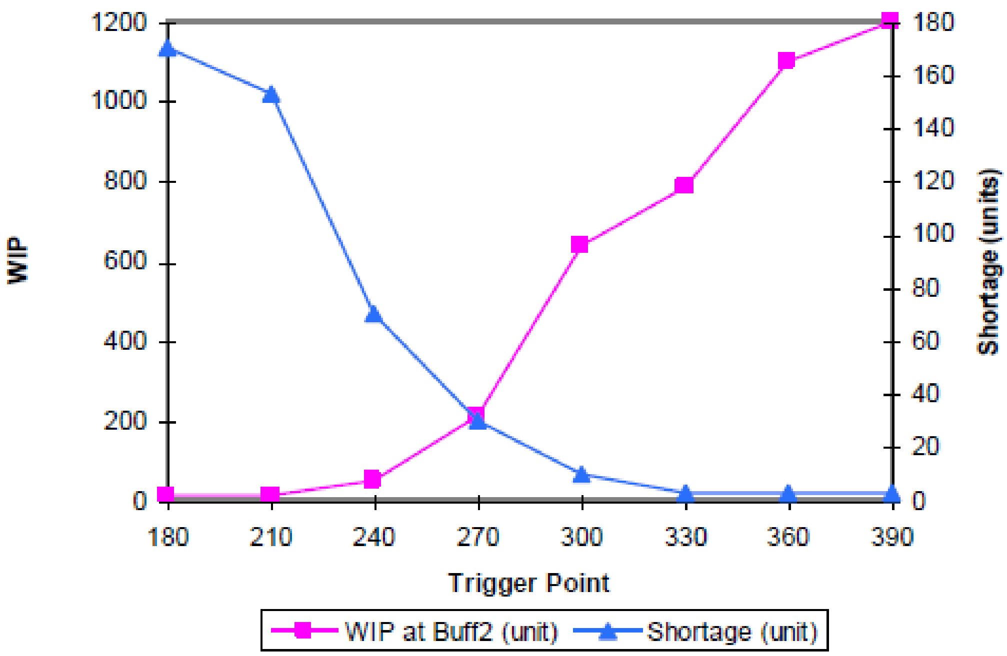

Figure 4: The effects of trigger points on WIP and Shortage of parts

As the Drug Process Plant also wishes to reduce WIP as well as shortages, the trigger point must be set to satisfy both objectives. Based on the simulation results as shown in Figure 4, a trigger point of 270 provides the best trade-off between both objectives.

Scheduling Rules

The purpose of this experiment is to investigate the effects of the scheduling rules on the performance of the system. There are two performance measures selected i.e. utilisation and the trial items produced. Utilisation was selected since in practice JIT implementation is usually accomplished with other push items, therefore, it is essential to optimise the production facilities where two different methods perform together. Since block 2 is the longest process, the utilisation of this block is used in the experiment as an indicator of the overall system. Another measure, the trial item produced, is also used to investigate which scheduling rules are more favourable for the production output of trial items.

In the simulation, there are four rules used i.e Lowest Value First (LVF), First Come First Serve (FCFS), Highest Value First (HVF) and Last In First Out (LIFO). The value is determined by setting Juroxicam tablets (Piroxicam 20mg) as the highest priority, high-volume Kanban items as the second priority and the non-Kanban items as the last priority.

By changing the scheduling rules, the results of the simulation can be shown in Figure 5. From this chart, by running four-week simulations, FCFS provide the highest utilisation of the facilities. However, basically, there are no significant differences amongst the results (all figures around 85%). These results may be affected by the type of production flow employed at the Drug Process Plant. As the manufacturing process forms a single flow, the scheduling rules may not affect the utilisation of facilities very much because all items move to the same production route.

The Effects of Scheduling Rules on the Utilisation and the Output of the Trial Item

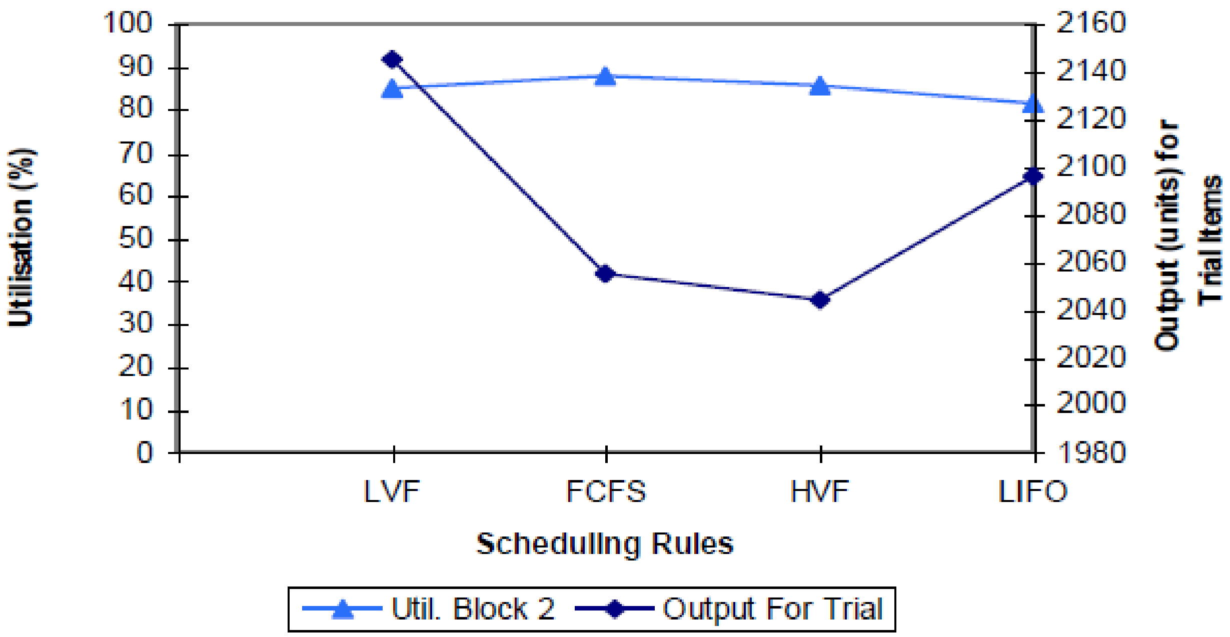

Figure 5: The effects of the scheduling rules on the utilisation and the trial produced

In terms of the output of the trial, LVF provides the highest output. This is not surprising since this rule places the trial item as a priority. Therefore, the flow time required to replenish the orders will be shorter than other rules so the items produced will be higher.

Other interesting results include the fact that that the difference of an increase in output is basically not much different compared to other rules. For example, in a four-week simulation, LVF produces 2150 items or only 100 units (or 25 a week) higher than HVF. This result may not be quite significant compared to the unexpected effects that may occur such as increasing bottle necks due to a change of the scheduling rule. This may happen because the number of items representing high-volume and non-Kanban items is not sufficient to show the differences i.e. only four items each. The use of a small number of items as a representation of a high number of items may not be able to show the effect of waiting or queuing dramatically. For further research, by using the new version of the software, it may be possible to construct a model that involves more representative items for identifying the effects more clearly.

The Number of Kanbans

The purpose of this experiment was to find the optimal number of Kanbans that minimise the flow time as well as maximise the orders satisfied. By changing the number of Kanbans available in the model file, the effects can be observed as shown in Figure 6. Based on this figure the effects of increasing the number of Kanbans for Piroxicam 20mg on both the customer lead time and orders satisfied are minor especially after the number of Kanbans reaches four. However, a decrease of the number of Kanbans drastically affects the customer lead time and the number of satisfied orders. This may happen since the main proportion of arrival orders is 90-unit Kanbans so three Kanbans with the quantity of 30 units are the most reasonable figures to satisfy the orders in terms of both flow time and orders satisfied.

In addition, since the proportion of Kanban arrivals remains the same during the simulation, an increase of the number of Kanbans does not produce drastic effects on the number of parts satisfied. In conclusion, the number of Kanbans must be determined on the basis of the average periodical orders.

The Effects of the Number of Kanbans on Flow Times and Orders Satisfied

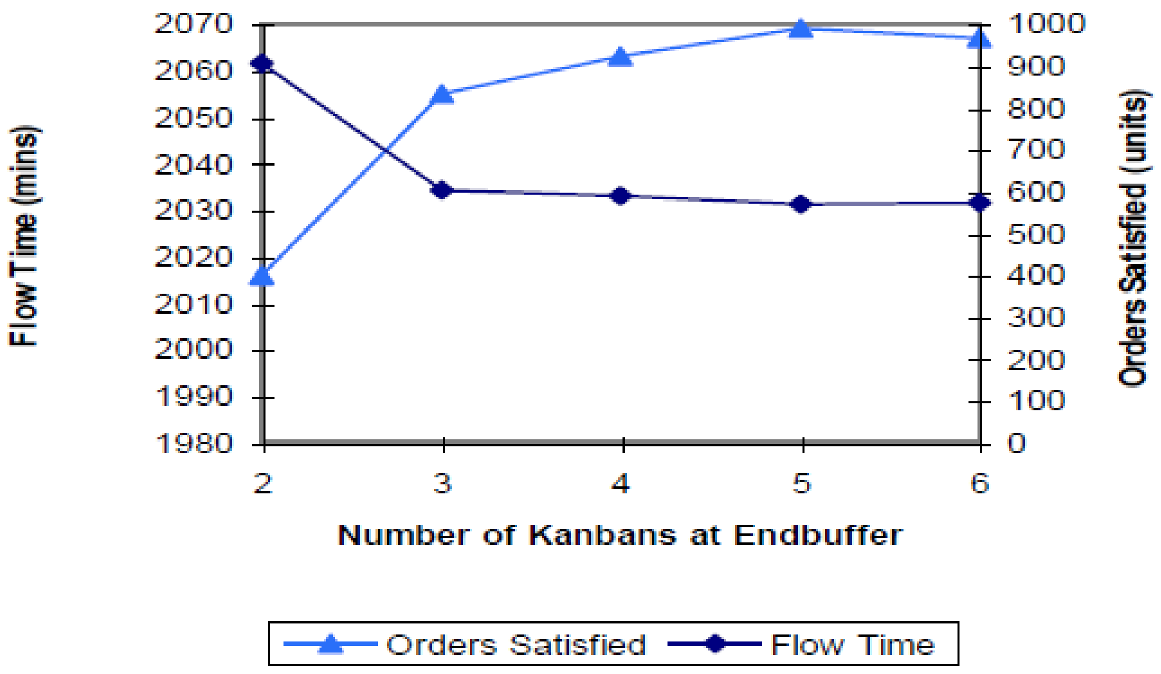

Figure 6: The effects of the number of Kanbans

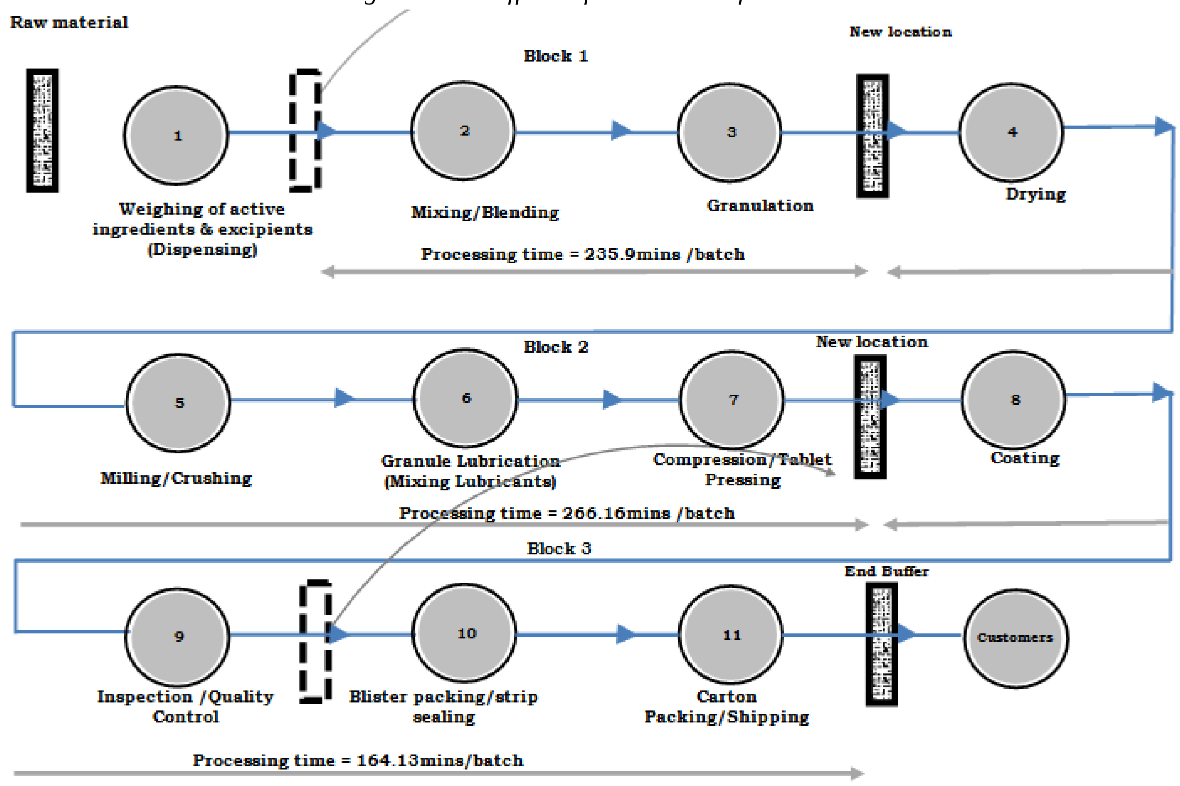

Figure 7: The new locations of the buffers

The orders should be stabilised especially for avoiding shortage since shortage can drastically affect the performance of the JIT system as shown in the chart. The role of supervisors is therefore crucial especially for observing the incoming orders. If the orders are fluctuating, they must add or reduce the number of Kanbans so this keeps the system running smoothly.

3.4 The New Locations of Buffers

In this experiment, the new buffer locations were investigated since the existing locations were determined based on practical reasons and it is essential to understand the effects to the overall performance of the system. By considering the type of processes and the balance of the processing time at each block, buffer 1 was moved from the existing location (between the automated dispensaries and mixing/blending area) to a new place between the granulation and drying area.

Similarly, buffer 2 was moved from the existing place between the inspection/quality control and blister packing/strip sealing area to a new process between compression/tablet pressing and coating. The new locations of the buffers can be shown as in Figure 7.

In the simulation, there are six criteria that were investigated i.e. flow time Kanban items, the flow time of high-volume Kanban items, the flow time of non-Kanban items, WIP, orders satisfied and shortage. Since the processing time at block 2 becomes shorter than the existing design, the batch size can be reduced into 240 units. Consequently, the processing time at block 3 becomes longer so in the experiment the number of Kanbans was increased to six to avoid regular shortage.

Conclusion

This research represents a first step towards integrating industrial automation and operations management research. Based on the results, the following conclusion can be drawn.

1. The number of Kanbans should be as close as possible to the average of the periodical orders since the effects of increasing the number of Kanbans on the flow time and the Work in Process (WIP) were minor. On the contrary, a shortage as an effect of reducing Kanbans produces a significant effect on the performance of the system in terms of the buffer levels and the lead times. Therefore, supervisors should ensure that the number of Kanbans is sufficient to run the system.
2. Trigger points can be used to reduce the customer lead times up until a certain level. However, after the threshold, the effect of increasing the trigger point is not significant.
3. The effect of a change of scheduling rules in improving the lead time and the utilisation of facilities is minor. This may be caused by the type of manufacturing processes employed i.e. process flow since all items move to the same production route.
4. In terms of buffer locations, statistically we cannot prove that the proposed locations which tried to balance the lead time for each block are better than the existing design. The investigation should be continued for other locations and criteria in order to search the best location of buffers. However, this could not be conducted because of software limitations.

References

[1]. Doll, W. J. & Vondermbse, M. A. (2011). The evolution of manufacturing systems: towards the post-industrial enterprise. OMEGA: International Journal of Management Science, 19, 401-411.

[2]. Agrawal, N. N. (2010). Review on just in time techniques in manufacturing systems. *Advances in Production Engineering & Management,* 5 (2), 101-110. Retrieved from EBSCO*host*.

[3]. Blackburn, J. & Millen, R. (2012).The impact of a rolling schedule in a multi-level MRP system. Journal of Operations Management, 2(2), 125-135.

[4]. Anderson, S. W. (2011). Measuring the impact of product mix heterogeneity on manufacturing overhead cost. The Accounting Review, (70)3, 363-387.

[5]. Apte, M.U., Beath, M.S., & Goh, C.H. (1999). An Analysis of the Production Line versus the Case Manager Approach to Information Intensive Services. Decision Sciences, 30(4).

[6]. Mehra, S. & Inman, R.A. (2011). JIT Implementation within a Service Industry: A Case Study. *International Journal of Service Industry Management*, 1(3).

[7]. Berkley, B. J. (2013). Setting Minimum Performance Levels for Two-Card Kanban-Controlled Lines. *International Journal of Production Research*, 31(15).

[8]. Wu, C.Y. (2003). Lean Manufacturing: a perspective of lean suppliers. *International Journal of Operations and Production Management*, 23(11), 1349-1376.

[9]. Ali, S. A., Seifoddini, H., & Sun, H. (2012).Intelligent modeling and simulation of flexible assembly systems. Proceedings of the Winter Simulation Conference, 1350-58.