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Multi-Objective Flexible Job-Shop Scheduling and Control of JIT Systems

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ABSTRACT

Just in Time (JIT) concepts are believed to overcome the problems, particularly those concerned with inventory. Since there are three main factors that affects inventory i.e. lead time, batch size and volatility of demand, JIT implementation reduce these factors by reducing lead times and batch size as well as stabilizing demand. Shorter lead time results in quicker response to rapid changing demand as well as lower inventory. Smaller batch sizes can cause smoother production flow, resulting in shorter lead time as well as lower inventory. Finally, more stable demand requires less buffer stocks as well as providing smoother production flow. In this work, a tablet drug item (blend) was selected as a trial or a pilot project. This research equally developed a discrete event simulation model to study Just-In-Time Supply Delivery System (JSS). The connections between JSS and manufacturing system under real time operations are studied. The study identifies interesting inventory dynamics and factors that contribute to this behaviour. Results from the work reveal that although the overall defective rate in each item is around 5%, the Drug Process Plant is still expected to improve its quality performance because in the JIT system, reducing variability of the defects is also far more important rather than just reducing the percentage of defects.

Keywords: Product Variety, Lead Time, Batch Size Reduction, JIT Flow, Demand- Pull

INTRODUCTION

Just-in-time (JIT) manufacturing keeps stock holding costs to a bare minimum. The release of storage space results in better utilization of space and thereby bears a favorable impact on the rent paid and on any insurance premiums that would otherwise need to be made. Just-in-time manufacturing eliminates waste, as out-of-date or expired products, do not enter into this equation at all. As under this technique, only essential stocks are obtained, less working capital is required to finance procurement. Here, a minimum re-order level is set, and only once that mark is reached, fresh stocks are ordered making this a boon to inventory management too. Due to the aforementioned low level of stocks held, the organizations return on investment (referred to as ROI, in management parlance) would generally be high.

As just-in-time production works on a demand-pull basis, all goods made would be sold, and thus it incorporates changes in demand with surprising ease. This makes it especially appealing today, where the market demand is volatile and somewhat unpredictable. Just-in-time manufacturing encourages the 'right first time' concept, so that inspection costs and cost of rework is minimized. High quality products and greater efficiency can be derived from following a just-in-time production system. Close relationships are fostered along the production chain under a just-in-time manufacturing system. Constant communication with the customer results in high customer satisfaction. Overproduction is eliminated when just-in-time manufacturing is adopted.

JIT concepts are believed to overcome the problems, particularly those concerned with inventory. Since there are three main factors that affects inventory i.e. lead time, batch size and volatility of demand, JIT implementation should be able to reduce those factors by reducing lead times and batch size as well as stabilizing demand. Shorter lead time results in quicker response to rapid changing demand as well as lower inventory. Smaller batch sizes can cause smoother production flow, resulting in shorter lead time as well as lower inventory. Finally, more stable demand requires less buffer stocks as well as providing smoother production flow.

As [1] puts it 'capital and output growth depends on the entrepreneur, the quality of performance of the entrepreneur determines whether capital would grow rapidly or slowly and whether the growth involves innovation where new products and production techniques and in extension costing techniques are developed. The implication of the above statement is that the difference in the growth rates and profitability of manufacturing firms (or companies) of the world is largely due to the quality of manufacturing system and costing tool of companies [2].

Origins of JIT

JIT is a manufacturing philosophy, which seeks to eliminate the ultimate source of waste, in all of its forms throughout the producing processes, from purchasing through distribution. By eliminating waste, JIT targets production with the minimum lead-time and at the lowest total cost.The JIT philosophy has its roots after World War II when the Japanese were striving to compete with the U.S. manufacturing system (also known as Mass Production). TaichiOhno was the founder of this philosophy in the 1940s when he began developing a system that would enable Toyota to compete with U.S. automakers. Note that the environment dominating manufacturing over the last five decades has been based on the Material Requirements Planning (MRP) formalized by Joseph Orlicky, Oliver Wight, and George Plossl. In an MRP environment, planning is performed based on the independent (customers') demand, in an almost JIT basis.

However, shop floor control is performed based on a push philosophy in which manufacturing orders are introduced in the system and pushed through production. This is the fundamental difference between JIT and MRP.

According to Ohno JIT rests on two pillars:
1. Just-in-timeas it is described in the following chapters and
2. Autonomation or automation with human touch. This term refers i) to the installation of one-touch automation so an operator will be able to place a part in a machine, initiate the machine cycle, and move on and ii) 'fool proofing' or 'poke yoke' which is the incorporation of sensors in the machines to signal abnormal conditions and even automatically stop machines if necessary, so operators don't need to watch machines during their cycle [3].

Ohno formulated the whole idea based on two concepts he encountered during visits in the U.S.: An American supermarket and the cable cars in San Francisco. First, he was impressed by the way American supermarkets supplied merchandise in a simple, productive and, timely manner and attempted to develop a similar concept in manufacturing. Each workstation would become the internal customer for the preceding workstation. The former would simply pick up the required parts from the latter, a supermarket shelf. The second concept was analogous to a simple cable car operation. Ohno observed that the cable car riders were pulling an overhead cord when they wanted to disembark. This cord produced a similar sound signalling the cable car to stop the car. Ohno applied a similar system using machine sensors.

An operator will stop the operation of a machine using a cord whenever he/she found a problem (autonomation) (Black and Hunter, 2003). Another contributor to JIT was Shigeo Shingo, who developed a new methodology for the reduction of setup time. This new method, called Single-Minute-Exchange-of- Dies (SMED) system, seeks to simplify and minimize the time required for the process of changeovers, so setups become simple and fast [4].

The success of the JIT also rests on the principle of 'respect for humanity'. According to [5], the Toyota Production System (TPS) makes full use of the workers' capabilities and relies fully on them for the running and continuous improvement of the plant.

JIT Objectives

The goal of JIT is to create a production environment that enables the customer to purchase products needed at the required time and quantity needed, in a predefined quality, at the lowest cost. This is accomplished by reducing variability in all of its forms.

Thus, JIT focuses on reducing seven commonly accepted wastes as follows:
Overproduction, is prevented by a) synchronizing all processing steps by using the Pull philosophy and the kanban technique and b) by reducing set-up times.
Waiting, is prevented by a) synchronizing all processing steps by using the Pull philosophy and the kanban technique and b) organizing production in Cells
Transport of materials, is prevented by organizing production in Cells
Rework processing, is prevented by a) applying quality at the source and b) redesigning processes
Unnecessary inventory is prevented by a) synchronizing all processing steps by using the Pull philosophy and the kanban technique and b) by reducing setup times
Unnecessary movement of employees is prevented by organizing production in Cells
Production of defective parts is prevented by a) applying quality at the source and b) redesigning processes

Central themes of JIT are *Flow in Production* and *Pull of Production. Flow* is the idea of processing one single item at a time in a continuous way from raw material to finished product without interruptions, delays, defects or breakdowns. *Pull* as the concept of responding to customer demand by delivering parts to assembly, and finished products to customers in a 'Just-in-Time' fashion. The number of orders that are provided to the system is strictly determined by the system's capacity. In this manner, the levels of WIP between the workstations are explicitly limited and as a result, the system overloads are avoided [6-8]. This is the key difference with MRP, in which work orders are provided to the system without considering explicitly the state of the system.

JIT constitutes a strategic weapon for a company because it results in a more efficient and less wasteful manufacturing system. By following the methodology of JIT, setup times are minimized successfully and frequent changeovers are feasible. Direct results include considerable reductions of lot sizes and Work in Process (WIP) and total system's inventory. The end result is the significant reduction of the total manufacturing cost. Implementation of the Flow and Pull concepts is based on a number of significant methods. For example, the implementation of techniques such as Total Quality Management (TQM), Total Productive Maintenance (TPM) help in minimizing costly (both in terms of time and costs) rework or loop-backs [9].

Furthermore, in a JIT environment, a) workers should be trained to obtain multifunctional skills and b) machines should be allocated properly to the re-designed manufacturing cells to cope with unexpected fluctuations in demand. Thus, manufacturing cannot reap the benefits of JIT unless the above preconditions exist, i.e. multiskilling and problem solving by workers, elimination of rework etc. In addition, supplier networks must support long-term and mutually beneficial relationships in order to achieve synchronization between supplies and production [10]. The above steps interact with one another and thus, must be achieved following an iterative process that continuously reveals waste and ensures continuous improvement or Kaizen in the system.

METHODOLOGY

In this research work, simulation is used to investigate the effects of dominant factors in the implementation. Several factors such as the number of buffers, the location of the buffers and scheduling rules will be investigated in this stage. The implementation is related to the execution of the new system including the preparation. The evaluation assesses how successfully the new system achieves the objectives. This stage includes formulating recommendations for further improvement. In this work, simulation is also used as a means to evaluate technical aspects contributing to improving the performance of the new system after the implementation stage. ARENA/ SIMAN and WITNESS simulation software packages were used for this.

This research equally developed a discrete event simulation model for Just-In-Time Supply Delivery System (JSS). Successful JIT implementation requires improvements in various areas including setup time reduction, vendor relationship and levelling production. These are beyond the scope of this research.

It is important to remember that every research methodology has its own unique set of strengths and corresponding limitations, and simulation modeling is no exception to this rule. Probably the greatest strength of simulation modeling is the model itself is virtually endlessly reconfigurable and therefore may be relatively easily extended and improved to incorporate more detail. The principal limitation is that no simulation model can possibly capture the infinite number of extraneous variables that exist within any real system.

Thus, the results of any simulation study are greatly impacted by the assumptions built into the model and must be interpreted with caution. However, the benefit of being able to observe the behaviour of the performance measures under the same environmental settings is the major benefit of simulation modeling, and may provide insight and guidance for future research. The software package used ensures the simulation represents the system accurately. However, the developed model is useful to get insight into the behavior of the system modeled.

The Ordering System

The ordering system at the Drug Process Plant is conducted using a MRPII system. Generally, this system works as in the following steps. When a customer requires particular items, the customer's planning section firstly checks the inventory file at the computer screen that contains the list of the inventory status of the items. If the items are available, the customer takes the items directly to the storage area of the Drug Process Plant. Otherwise, an order is placed to the Drug Process Plant. The order is then processed by the planning section at the Drug Process Plant to produce an updated Master Production Schedule (MPS). In this step, rough-cut capacity planning is used to optimize the utilization of the resources by changing the date of production. This information and other MPS modifications are used as inputs to update the MPS. By incorporating the bill of material, the MRP system then generates a planned order schedule as a primary output as well as inventory transaction and performance reports as secondary outputs. When the order reaches the production date according to the schedule, the planning section issues both a traveler and a traveler insert to the shop floor. Both of these documents give authority to the shop floor to begin production of the order.

Travellers and traveller inserts are issued for executing the production of an item. There is no production of the item until both documents are received at the shop floor. The traveller is a form containing information for executing the steps in production such as the process routing, the quantity, the Ericam number and material specifications. A traveller moves following the materials of the item. In relation to the traveller, a traveller insert is a form that must be filled out by operators. The traveller insert provides information such as the production start and finish at each stage of operation, operator names, the quantity and the scrap produced at each stage of operations.

Order Quantity
The order quantity of most items at the shop floor is set based on the capacity of the tablet press (machines) since tableting/compression is the most critical process to determine batch sizes and order quantity. The machines are critical because they require significant setup time, which can cause bottle necks. The production capacity of the machine is 20 pallets or 120 sub-pallets (one pallet is later separated into six sub-pallets). The batch size of the item processed through the machines must be a multiple of 120. For example, if the average weekly order of the item is 370 units (sub pallets), 360 units is selected.

Problem Formulation
Based on an investigation of the plant, problems encountered by the Drug Process Plant can be classified into three major problems:

Long Lead Time to Customers
The Drug Process Plant produces various items. This results in more time being required for waiting and queuing at the production facilities as well as more efforts for scheduling and resource allocation. Based on the calculation of the total process, using the standard times as shown in Fig. 1, around 76% of the throughput time for most items is spent on non-productive time such as waiting and queuing.

No Visual Method to Observe the Process
As a result of space limitation, the WIP of items is located on conveyors. This makes it difficult to check the status and the amount of particular items. In addition, there is no fixed location for the conveyors so this also results in less consciousness of the importance of reducing inventory. Therefore, a more visual system should be established to increase the timeliness of the status and the location of the inventory.

Extra Storage Held to Anticipate Rapid Changes of Demand
The production process in the Drug Process Plant was conducted by the MRP system. This led to extra inventory of finished items stored at the Drug Process Plant. Therefore, the introduction of the JIT system at the Drug Process Plant is crucial to eliminate this problem. Since JIT implementation at the Drug Process Plant is a management requirement, the design of the JIT system must be able to meet the objectives as well as the problems encountered as previously formulated.

DESIGN OF THE NEW SYSTEM

In this work, a tablet drug item (blend) was selected as a trial or a pilot project. The reason for this was the pilot project could be easily monitored so the problems which appeared could be identified quickly. The successful implementation of the pilot project would motivate people to develop the same system for other items.

JPBF 113155 was selected as a trial. The three reasons for selecting this item included:
1. Juhel Pharmaceutical Nigeria Ltd is a market leader in the production of this tablet so the successful improvement of the JIT system would help improve the performance of this plant.
2. Manufacturing processes of drug tablets are relatively simple so this item was considered as a good trial.
3. This item has a weekly order that covers 20% of total order of the drug tablets so the effects of introducing the new system would be more visible than lower volume items.

By considering the objectives and problems encountered at the Drug Process Plant, there are five characteristics of the JIT system that need to be designed and to be determined i.e.:
1. The number of buffers to determine how many group of JIT workstation would be required. In this thesis, a group of JIT workstations is called block.
2. The parameters of the pull system designed such as batch size, Kanban quantity and frequency of picking.
3. Mechanisms or operating procedures for running the system.
4. Visual control systems.
5. JIT devices for running the system such as information boards and shelves.
All the characteristics will be discussed in depth in the following sections.

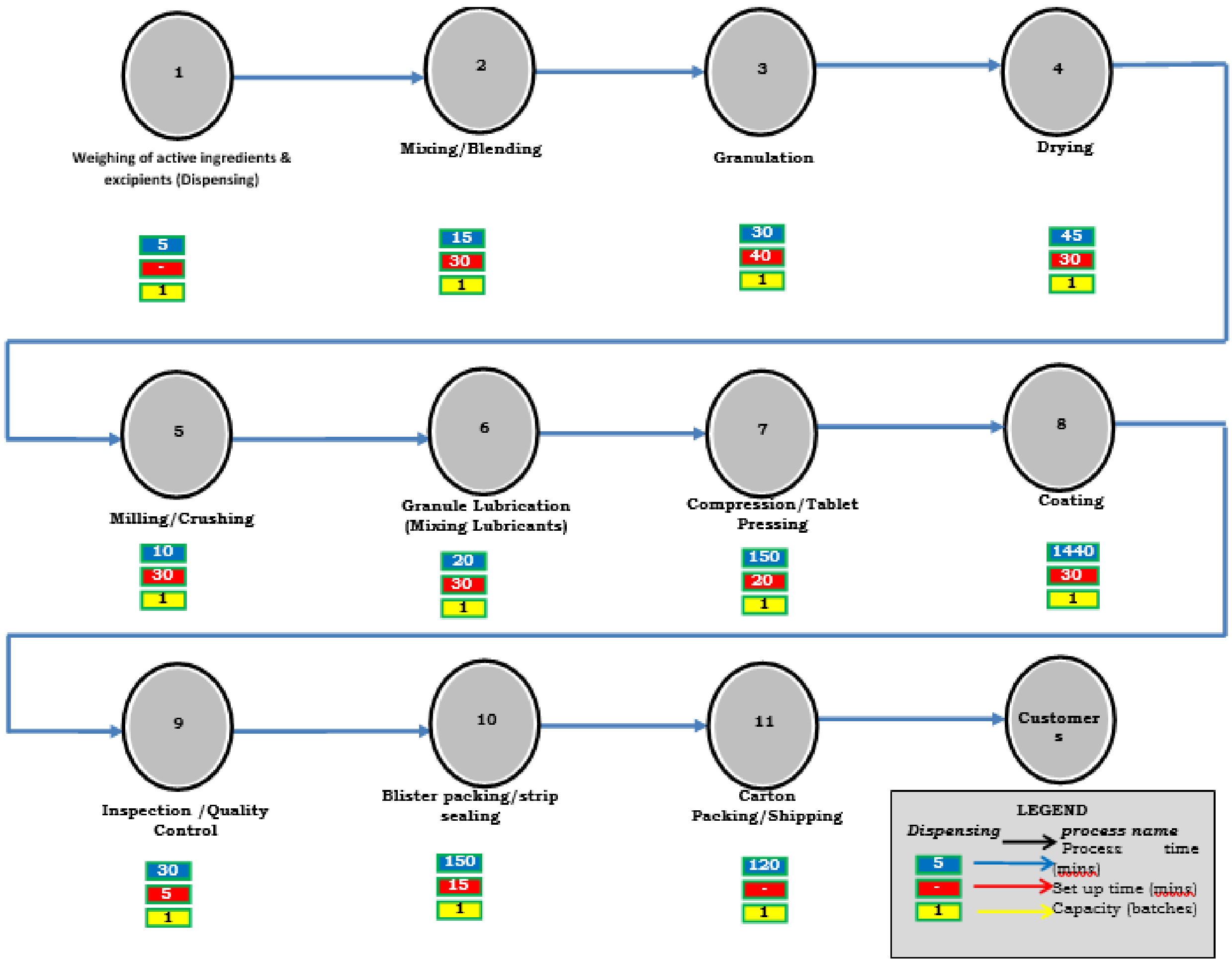

Fig. 1 The processing time and the capacity of processes at the Drug Process Plant

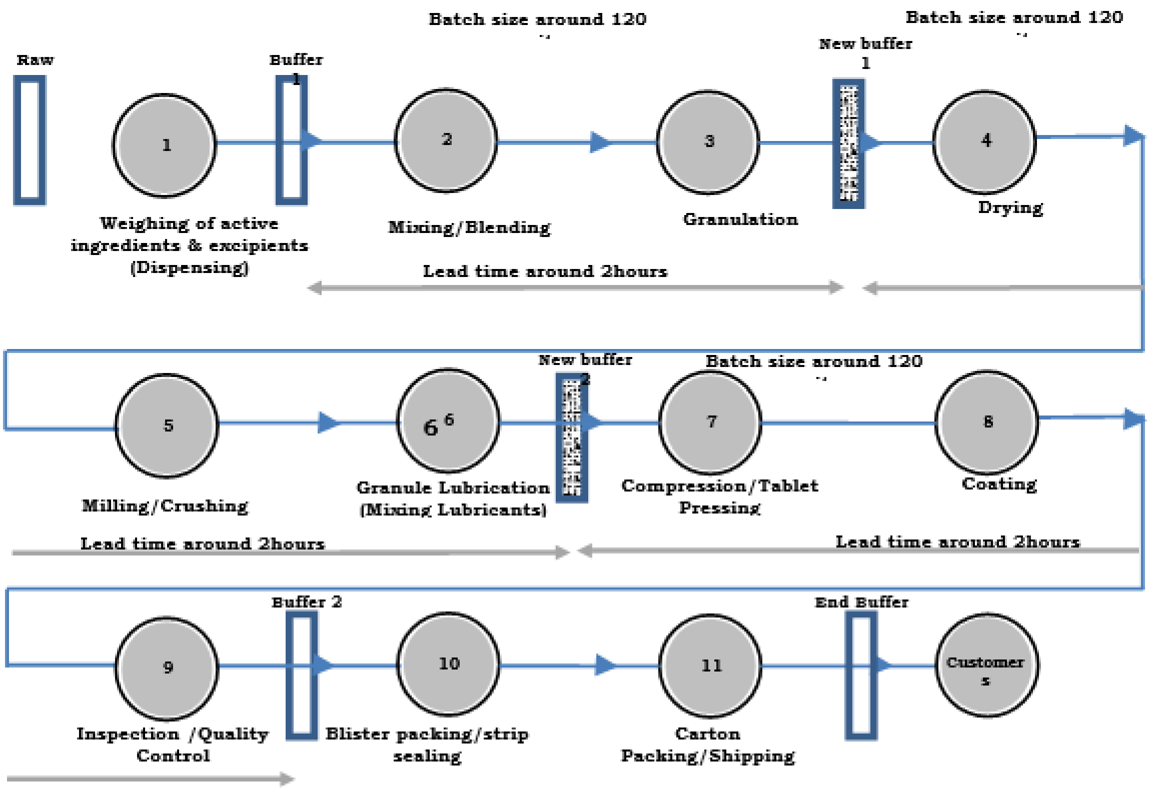

Fig. 2 The effects of additional buffers on lead time and batch size

RESULTS AND DISCUSSION

Batch Size Reduction

To achieve a true JIT system that reduces the inventory, batch sizes must be reduced to the minimum level. Since block 2 runs with a batch size of 360 units, which is the same as the previous system, this system actually does not provide significant improvement in terms of inventory reduction at the Drug Process Plant. The inventory moved only from the end storage to buffer 2. To achieve a true JIT system, block 2 must be divided into two or three new blocks so all the new blocks can run in smaller batch sizes. Most processes in block 2 require setup time (see Figure 3.1), the batch size of each new block can be calculated directly. For example, if two new blocks are inserted so block 2 consists of three new blocks, the batch size of each new block is 120 units (360/3) and each new block will require a lead time of around two days (6.5/3 days).

Diagrammatically, this can be shown in Figure 3.2. The batch size of 120 is more preferable since it is equal to the minimum batch size of mixing/blending machines, a group of facilities that determines the quantity batch size of each order. By running the production using this batch size, the Drug Process Plant will also become more responsive by anticipating the fluctuating orders.

Improving Visibility

The other benefit of dividing block 2 into the smaller blocks is that WIP becomes more visible than before. Block 2 is actually too long and hard to manage since it comprises 8 different processes that take around 6.5 days in all to finish. In addition, the accumulation of WIP within this block is difficult to detect. Therefore, more blocks in the system can provide a better visible indicator of WIP. This will motivate operators to detect the problems as they occur.

Setup Time Reduction

Basically, successful JIT implementation cannot be conducted without setup time reduction. Production of small batches, a characteristic of the JIT system, always requires reduction of setup time. Batch sizes can be reduced without reducing setup but the productivity of the machine becomes lower, so this is contrary to JIT principles. Setup time reduction is crucial especially when many items will be processed in the same production facilities. Since in the future, the Drug Process Plant will apply the pull system for most major items, setup time reduction must become the first priority. According to [6], in practice, there are two common approaches in reducing setup times:

Physical Configuration

This approach is conducted by grouping products into families that are placed into dedicated cells. Reduced setup times can be attained because not many tasks are required to load or unload similar parts. Unfortunately, this approach is hard to implement in the Drug Process Plant because of the type of manufacturing processes and the space limitation.

Engineering Methods

This approach is conducted by standardizing tools, removing unnecessary adjustment, modifying fixtures and improving operators' skills. By considering the availability of resources in the Drug Process Plant, all of those techniques are suitable to apply.

Product Variety Reduction

Almost 73% of the throughput time to process the items is spent for waiting and queuing, therefore, the Drug Process Plant, if necessary, must reduce the variety of the items. Various approaches can be applied such as stabilised demands, standardizing products, avoiding special orders and machine variation reduction. To accomplish these approaches, application of new management methods or technologies may be required.

Matching with the Existing System

Continuing to use the MRP system in the JIT environment without any modification commonly results in an overwhelming increase of paperwork. Although, both MRP and JIT have benefits, both of them have different objectives and conflicting purposes.

In the JIT environment, the MRP should be solely developed to manage demands and to create a Master Production Schedule (MPS), often also to order raw materials. As a result, MRP just deals with the report of finished products. Therefore, the rest of the operations at the shop floor are under the control of the JIT system.

The traditional measurement system reported from MRP must be changed because it is not suitable for measuring the JIT performance. The use of a traditional measurement system such as labor efficiency and utilization tends to emphasize standardization and encourage overproduction. The new measures must be focused on detecting improvements such as higher product quality, lower inventory levels, faster throughput time and flexibility. In the trial, the MRP is still applied, not just to create MPS, but also for tracking and calculating capacity planning as well as reporting status/progress represented by the use of traveler inserts. In the future, this will not be required since the Kanbans can inform and estimate the requirement of the resources. This modification then requires a change of other systems such as performance measurement, incentive systems and quality control.

In the Drug Process Plant, the pull system can result in an overwhelming increase in paperwork for the MRP. Since the pull system works in the smaller lot sizes from 360 units into 90 units, completion reports on the Kanban items required becomes fourfold. To avoid this problem in the future, the reporting period for Kanban items must be changed from daily to longer periods of time.

Quality Improvement

Although the overall defective rate in each item is around 5%, the Drug Process Plant is still expected to improve its quality performance because in the JIT system, reducing variability of the defects is also far more important rather than just reducing the percentage of defects. The lower the variability of the processes, the smaller the quantity of each buffer required between two stations. Therefore, this will improve production flow as well. To achieve better quality performance, responsibility for quality control must shift from inspectors to everyone involved in production. Currently, the responsibility for quality control in Juhel Nigeria ltd is carried out by inspectors because operators do not have sufficient skills to do this job. Therefore, in the future, training for operators is required to handle this.

CONCLUSIONS

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. 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.

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