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Optimum Common Frequency Routing (CFR) of JIT Systems with Time-Varying Demand and Flexible Production Capacities

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ABSTRACT

This study introduces a framework for optimum Common Frequency Routing (CFR) of a JIT system with time-varying demand and flexible production capacities. The system consists of components, people and machines that make useful products. The system is managed across boundaries and interfaces. The boundaries define the scope of the system or subsystem, while the interfaces control the flows through transactions. There are three flows in the JIT manufacturing system model: the flow of materials, the flow of information, and the flow of cost. These flows establish the value streams. Components of the value stream can be value-add or waste, depending on the operating conditions. In this research work, re-design of manufacturing systems into practical optimum Just-In-Time systems will be achieved by integration of computer simulation and analysis of variance. The conventional JIT approach is mostly applicable to static production systems and the dynamic production systems require a more practical integrated JIT approach. However, the re-design of existing dynamic systems into just-in-time systems must follow a practical path, which can be a cumbersome task. This means, a unique practical optimum Just-In-Time system that considers system's limitations and its dynamic behavior must be designed.

Keywords: Common Frequency Routing, Manufacturing System Model, Drug Process Line, Information Exchange, JIT Devices

INTRODUCTION

Since the beginning of the 80's, much attention has been focused on a Japanese manufacturing system which becomes known in the western world as Just-In-Time (JIT). JIT concepts have focused on improvement of manufacturing processes, reducing setup times and lot sizes, developing mistake-proof operations and using simple scheduling techniques. This may be seen as eliminating waste, where waste is anything other than the minimum amount of resources. Successful JIT implementation usually results in reduced costs, improved quality and smoother production flow.

JIT has been credited for the economic success that has transformed Japanese firms into world class companies. However, some observers point out that there are other factors that contribute to the success including government support for industry, the Japanese management culture and the characteristics of Japanese workers. In addition, the Japanese workers are also characterized as multi-skilled workers who are able to handle various jobs without being restricted by rigid demarcation so this achieves high flexibility [1]. The JIT production concepts were firstly pioneered at the Toyota Motor Company (TMC) by Taiichi Ohno, and later adopted by other Japanese companies. The idea of JIT was derived from the mechanisms used in American supermarkets to replenish shelves as customers withdraw goods from them [2]. This idea was then applied by Ohno at the TMC. Today many companies in the world have employed the JIT concepts.

JIT in various modified forms, as a production management concept, has been adapted by western companies with considerable success. Authorities in this area are [3-5] by introducing the concepts of zero inventory, [6] by coining the 14 points for management and [7] by proposing the quality management grid. Today, many companies in the world regard JIT or its modified forms as a major component of competitive strategy.

Optimal common frequency routing of a JIT-Kanban manufacturing system replenishes raw materials from outside suppliers, converts them into finished products and sells finished products to customers. The total demand of the finished products is assumed to be a known quantity that resulted from a forecast. A linear demand of final products in a fixed interval of time is considered in this research to roughly capture the life cycle pattern of the demand of a product. Raw materials are supplied to the production system and their ordering policy is dependent on the shipping plan of the finished products. Therefore, according to the known shipping strategy of the finished products, it is necessary to determine the ordering policy of the associated raw materials.

In a production line operating under a JIT production policy, the production rate of each work-stage is generally dictated by the demand of the following stage or final products [8]. Therefore, the production rates of each work-stage should be treated as the decision variables. The problem can be addressed as: minimizing the integrated inventory cost of the system as well as determining the production system operation policy about raw material procurement rate, finished product delivery rate, and the associated Kanban system configuration under flexible production capacities. Intense competition in today's economy, the shrinking life cycles of products, and the heightening expectations of customers have forced business enterprises to focus their attention on correctly arranging and controlling their production and supply chain systems [9]. The production and supply chain system presented in this research is a serial multi-stage JIT- Kanban controlled manufacturing system which is one of the most popular systems among contemporary manufacturing companies because they can minimize the inventory build-up, increase flexibility, and minimize waste of material resources, human resources and facilities.

Kanban means signal card or token. A kanban-controlled production system is one 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.

In this research, a serial multi-stage manufacturing system controlled by Kanbans is considered which procures raw materials from outside suppliers and processes them through multiple work-stages to deliver a varying quantity of finished products to customers at a fixed-interval of time (Figure1). Also, the raw materials are replenished instantaneously to the manufacturing system to meet the JIT operation and time-varying finished product demand pattern, and the production capacity of the system is flexible.

METHODOLOGY AND SYSTEM ANALYSIS

The pharmaceutical industry is one of several industries that are experiencing fierce competition as a result of global competition, rapid technological changes and rapid changes of consumer requirements. Juhel Pharmaceutical Drug Process Plant, Enugu, a division of Juhel Nigeria Ltd, manufactures pharmaceutical blends and products to supply both the Nigerian and West African markets.

Juhel Nigeria Ltd is located at 35 Nkwubor Road, Emene, Enugu, capital of Enugu State, Nigeria. It is a 100% indigenous company incorporated in 1987 with RC No. 104648 as a wholesale Pharmaceutical Company. In answer to calls for local provision of cost-effective generic products to fill the gap left by Multinational companies operating in the country; the factory was commissioned in 1989 as the first pharmaceutical drug manufacturing company in old Anambra state.

Their brand and product range have since grown in strength and include virtually all therapeutic classes, such as, Antibiotics and Anti-infective, Cardiovascular, Anti-diabetics, Anti-malarial, Cough and Cold, Vitamins and Minerals, Anxiolytics, Antihistamines, Analgesics, Antacids and Anti-flatulent, etc. To cope with these challenges Juhel Pharmaceutical Nigeria Ltd applies new technology and management techniques.

JIT Manufacturing System Model

A general manufacturing model is described, as shown in Figure 2 below. The system consists of components, people and machines that make useful products. The system is managed across boundaries and interfaces. The boundaries define the scope of the system or subsystem, while the interfaces control the flows through transactions.

There are three flows in the manufacturing model: the flow of materials, the flow of information, and the flow of cost. These flows establish the value streams. Components of the value stream can be value-add or waste, depending on the operating conditions. For example, excess material flows become a stream of inventories, while excess information leads to confusion in process execution. By managing the flows, we can control the streams. An effective control of these streams is required for lean production.

As mentioned earlier, the interfaces control the flow. For example, a conveyor regulates the flow of materials and a visual control regulates the flow of information between two stations. The interfaces arise from disconnected points in the system, e.g., the physical distances between two machines, the communication barriers between two people, or the control panels between a machine and an operator. It is often a good location for cost transactions. As the number of components and interfaces grows, the machines become factories and the people become organizations.

In the JSS model, the parts represent the materials, while the kanban represent the information mechanism. In this way, we can analyze the efficiency of these flows. Associated with each device that handles the parts or kanban, a cost is applied to the operation of the device. Therefore, a build-up of parts and kanban implies an increasing cost.

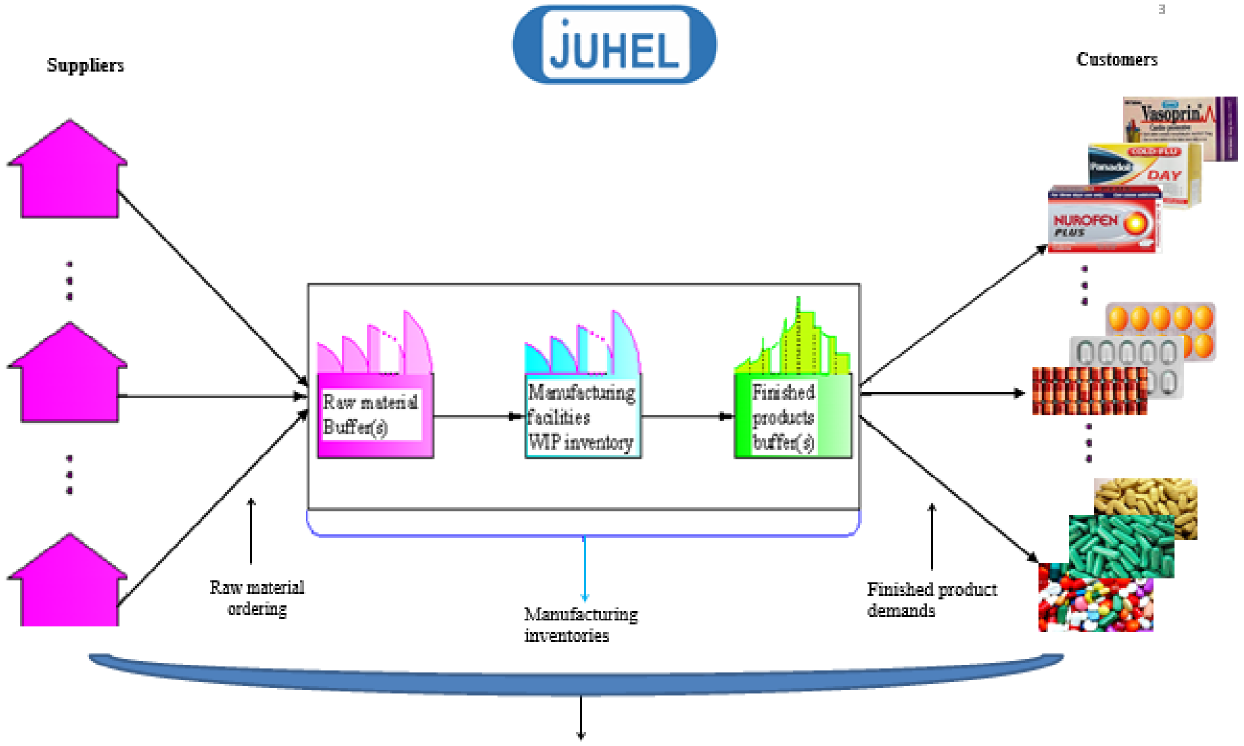

Fig. 1 Juhel Nig. Ltd Drug Process Plant and the JIT System

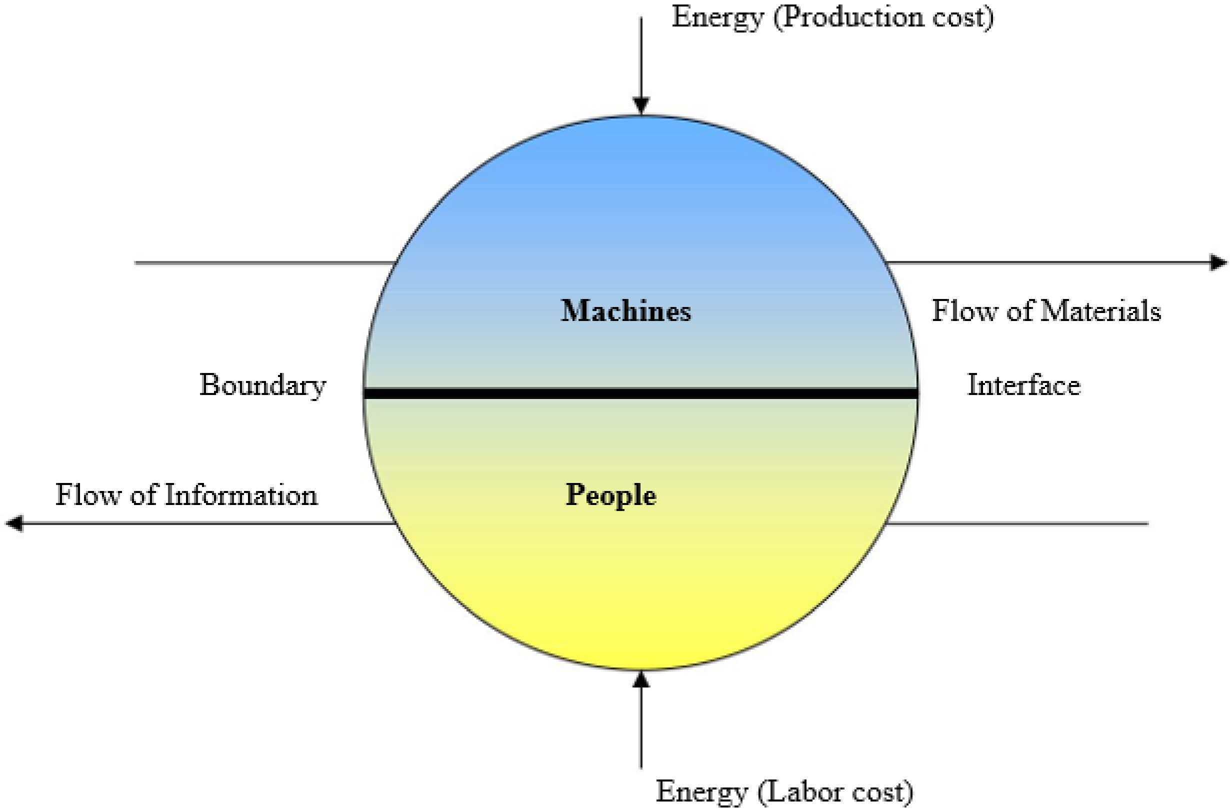

Fig. 2 A Manufacturing System Model

The Purpose of Just-In-Time (JIT) Implementation

JIT implementation for Juhel Pharmaceutical Drug Process Plant is considered in order to reduce inventory and lead time. Therefore, this concept was then introduced to the Juhel Pharmaceutical Drug Process Plant situated in Enugu, Nigeria. The first trial was conducted in the company's Drug Process Plant and demonstrated a significant reduction of inventory.

Pharmaceutical blends may be compressed by slugging (dry granulation), wet granulation or direct compaction (direct compression) as shown in figure 3 above to obtain the desired physical properties, before their formulation as a finished product. In wet granulation, the active ingredients and excipients are wetted with aqueous or solvent solutions to produce coarse granules with enlarged particle sizes. The granules are dried, mixed with lubricants (e.g., magnesium stearate), disintegrates or binders, then compressed into tablets, capsules and pills. During direct compression, a metal die holds a measured amount of the drug blend while a punch compresses the tablet. Drugs that are not sufficiently stable for wet granulation or cannot be directly compressed are slugged. Slugging or dry granulation blends and compresses relatively large tablets which are ground and screened to a desired mesh size, then recompressed into the final tablet. Blended and granulated materials may also be produced in capsule form. Hard gelatin capsules are dried, trimmed, filled and joined on capsule-filling machines.

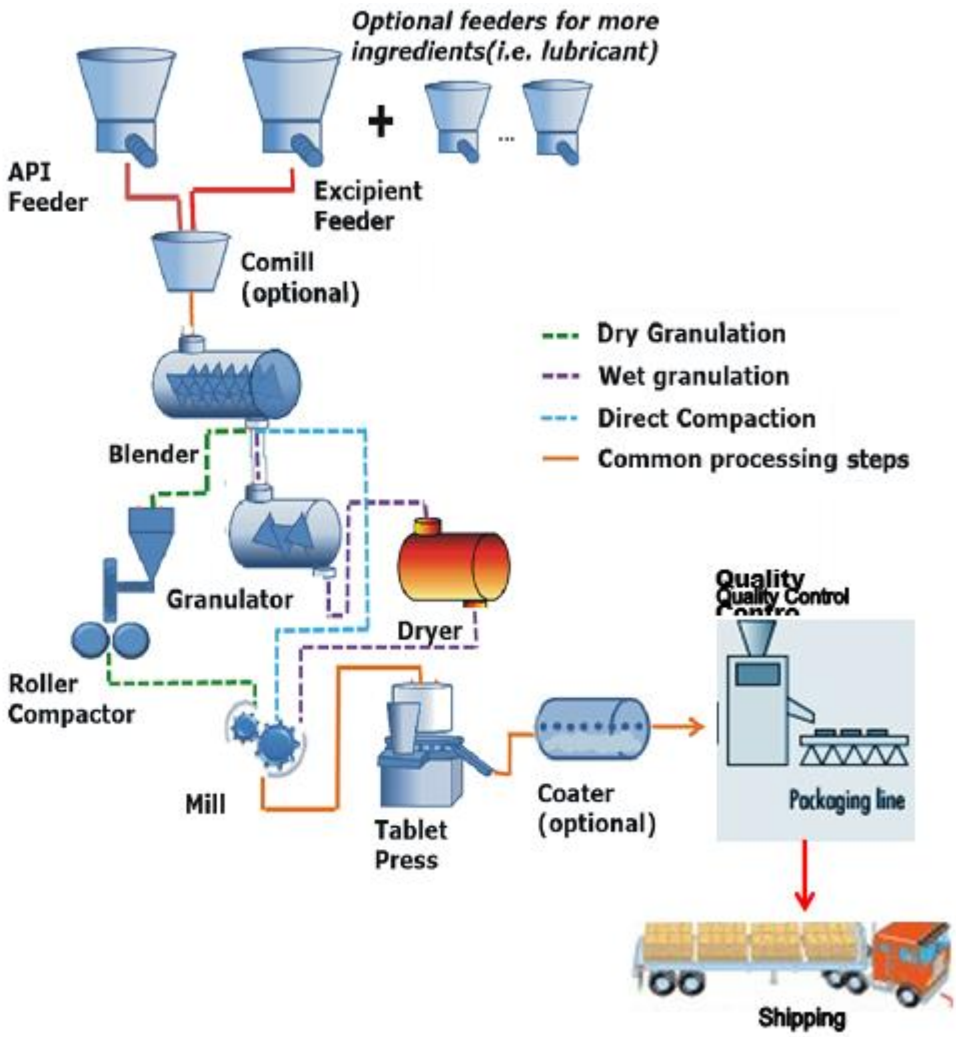

Fig. 3 Overview of the Drug Process Line

Designing the Means for Information Exchange

In this system, the Kanban is applied as a means of accelerating a transfer of information between two adjacent workstations. Basically, the Kanban is not always in the form of cards and it can be any means such as verbal, floor square, golf ball or electronic ordering signals.

However, in this research, a card is used since there is a lot of information that must be included that cannot be conveyed by other means i.e. the process routing, the quantity, the destination of the Kanban, the Ericam number and the material specification.

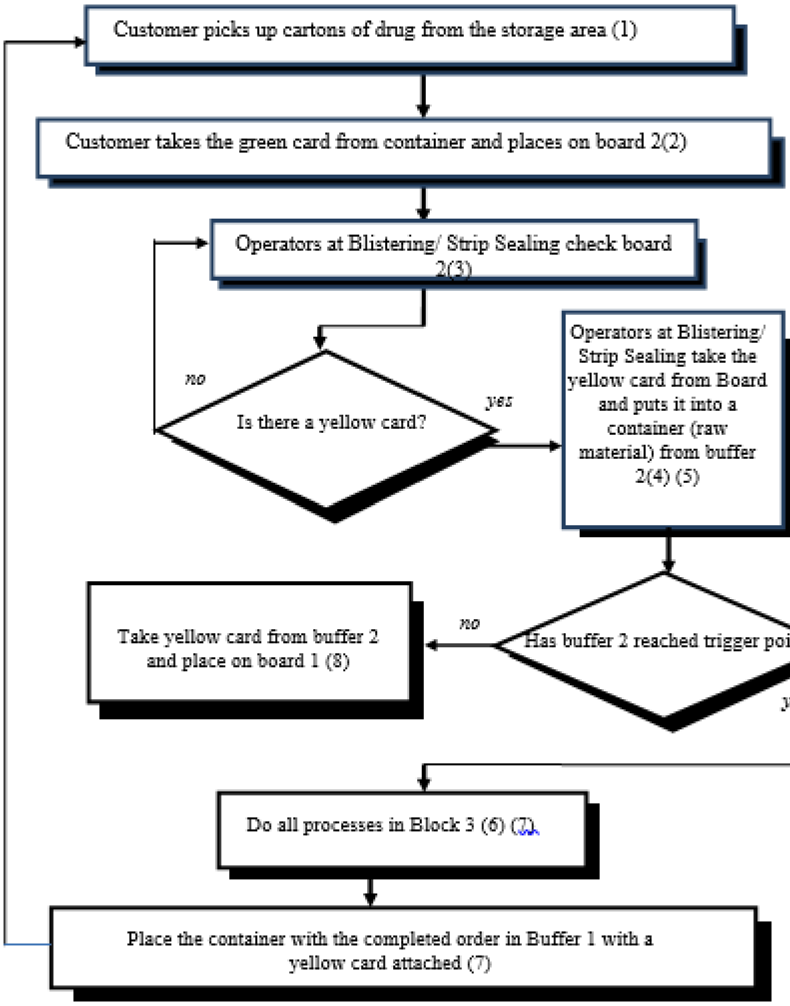

Fig. 4 The operating procedure of the pull system (the number referring to the mechanisms in of the JIT System)

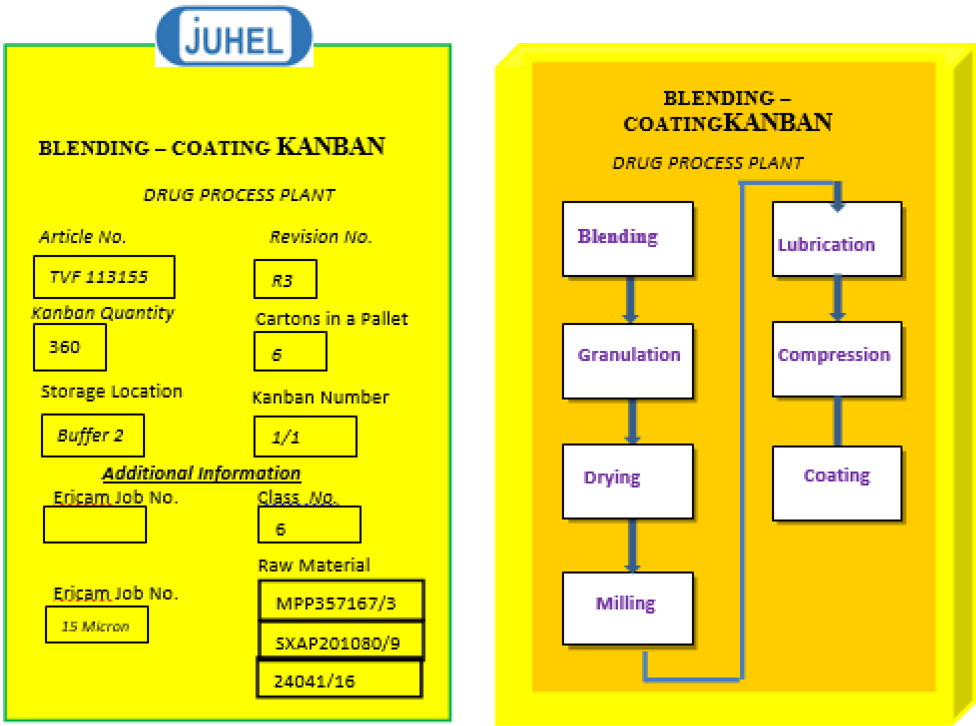

Fig. 5 The design of a yellow Kanban (both sides) for block 2

By considering the purpose of Kanbans, the role of travellers and the traveller insert must be evaluated. Since the role of travellers is almost similar to Kanbans that is to authorise the production, travellers can be replaced by Kanbans. Therefore, the Kanban card must contain the same information as written on the traveller. A sample of Kanbans used at the Drug Process Plant is shown in Figure 5. Although Kanbans can replace the role of travellers, the traveller insert cannot be replaced by a more visual system because the main purpose of this form is to provide information about the production activities that are required for the Drug Process Plant.

Designing JIT Devices for Running the System

Visual boards are used to attach Kanban cards so operators working in the first operation in each block can check whether there are cards or not on the boards. If there is a card, they must start processing the item with the quantity as written on the card. The location of the board should be close enough to the first operation of each block so operators working in this process can easily observe arrival of the cards.

In a pull system, the production runs in a fixed but smaller batch size for each item based on the Kanban quantity, therefore, the operators need to count the exact number of the items represented by the Kanban quantity before starting production. This job is very tedious, so to make this job easier, shelves and racks are specifically designed for holding a certain amount of items so operators will not be required to count the items. In the Drug Process Plant, both shelves and racks are designed to store product item JPBF 113155. By using the racks and shelves that are designed to store the fixed quantity of product item JPBF 113155, the operators only need to fill the empty shelves or racks without counting the product items.

RESULTS AND DISCUSSION

Evaluation

When the system was introduced for the first time, there were no significant problems in the implementation. Most operators did not have any difficulties when working with the new system. This may have happened because the system only employed one Kanban item so the process become simple and the operators could easily understand it. The use of flow charts was also helpful to guide the operators. In the implementation, the role of the supervisors was important specially to guide operators as well as to observe how the system worked. After the system had been operating for three weeks, which was regarded as a sufficient time to evaluate the system there were several significant improvements compared to the previous system. The comparison between the previous and new system (Table 1 - Table 3) was derived from three criteria as specified in the project proposal i.e (customer) lead time, inventory and visual control.

Customer Lead Time

Customer lead time is considered as the first concern since the objective of the system is to satisfy the customer. Simply stated, customer lead time is the time required for customers from placing to receiving the orders. In the new system, customers can take the finished products away immediately because the products are already available at the end buffer. In the previous system, the customer must place an order first and it took around 10 days to get the items ordered. Unfortunately, although there was significant improvement in terms of the customer lead time, the manufacturing lead time in the new system did not really change much. Therefore, some improvements must be conducted to reduce this lead time including reduced setup time, reduced process variability, improved production scheduling and reduced machine break down.

Inventory

The amount of inventory is measured by using a practical approach as in the following step. To overcome the variability of orders and manufacturing lead time i.e around 360 units at each buffer, since block 2 and block 1 work in the batch sizes of 360 units, the average WIP at the shop floor can be estimated at around 360 units. Therefore, the total inventory for the previous system is (2 x 360 + 360) or 1080 units. In the new system, the Drug Process Plant holds the inventory of the finished items i.e. around 90 units reflected in the maximum amount of inventory available in the end buffer (three Kanbans). The average WIP remains the same as in the previous system i.e. 360 units. Therefore, the total inventory in the new system is (90 + 360) or 450 units.

Visual Control

Visual control is measured by comparing the degree of visibility and the availability of the visual devices in both systems. In the previous system, neither supervisors nor operators could check the amount of inventory in the buffer because there was no specified place for particular items and the WIP was not stored in fixed locations. On the other hand, in the new system, the inventory in each buffer is stored in an orderly way at the fixed location, thereby; it will motivate everyone to observe the amount of inventory properly. If the amount of inventory exceeds the normal quantity, the operators or supervisors can take immediate action or find solutions for example by reducing the number of Kanbans. In addition, the visual board, gives information about the status and number of Kanbans (normal, emergency and waiting), motivates the operators to solve the problem immediately. The more Kanbans at the emergency or waiting status, the more problems appear in the production. In conclusion, the new system provides better visual control than the previous system.

Statistical Analysis for Comparing Systems

Table -1The Existing Location of Buffers

		Observation	1	2	3	4	5	6	7	8	9	10	MEANS	STD
TP=	*10*	**Flowtime1**	345.61	456.27	314.90	2354.70	400.72	606.75	432.13	355.66	375.12	374.30	**604.65**	**620.04**
FCFS		**Flowtime2**	620.40	612.92	660.60	1204.30	574.84	1012.50	640.95	1053.50	681.84	542.60	761.15	235.28
K=	*3*	**Flowtime3**	2025.00	2301.00	2447.10	2740.00	2260.20	2866.60	1899.10	3019.80	1759.90	3021.80	2445.10	452.88
T=	*40320*													
Block 1=	*123.00*	**NQ(CustQ)**	0.02	0.12	0.01	1.59	0.03	0.07	0.01	0.01	0.02	0.01	0.19	0.49
Block 2=	*210.17*	**NQ(EndB)**	2.38	2.08	2.48	0.84	2.37	1.99	2.32	2.37	2.30	2.42	2.15	0.49
Block 3=	*20.00*	**NQ(Buff2)**	6.02	5.84	6.74	0.94	5.02	6.22	6.85	6.68	8.32	6.36	5.90	1.94
		NQ(Buff1)	0.89	0.73	0.75	0.71	0.72	0.72	0.85	0.85	0.82	0.73	0.78	0.07
		30	4.00	0.00	4.00	4.00	2.00	1.00	3.00	2.00	2.00	6.00		
		60	7.00	7.00	8.00	9.00	13.00	9.00	11.00	7.00	4.00	8.00		
The trial item		**90**	14.00	15.00	13.00	13.00	9.00	15.00	12.00	16.00	17.00	11.00		
		120	2.00	5.00	2.00	1.00	3.00	2.00	1.00	2.00	4.00	2.00		
		OUTPUT	68.00	73.00	67.00	61.00	67.00	72.00	65.00	72.00	77.00	63.00	68.50	4.95
		OUT 2	6.00	7.00	6.00	5.00	6.00	7.00	6.00	7.00	7.00	6.00		
		OUT 1	6.00	6.00	6.00	5.00	6.00	7.00	6.00	7.00	7.00	6.00		
		SHORTAGE	**0.00**	**-6.00**	**0.00**	**-4.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-1.00**	**2.16**
		INVENT	4.00	11.00	5.00	-1.00	5.00	12.00	7.00	12.00	7.00	9.00	7.10	4.09

Table -2 The New Location of Buffers

		Observation	1	2	3	4	5	6	7	8	9	10	MEANS	STD
TP=	*6*	**Flowtime1**	389.45	445.38	306.44	374.61	540.06	466.98	2501.30	3235.70	315.09	483.59	**905.86**	**1051.33**
FCFS		**Flowtime2**	626.13	636.87	509.11	694.92	691.27	855.25	566.34	685.19	515.04	1105.00	688.51	177.98
K=	*9*	**Flowtime3**	2122.20	2289.30	1913.80	3270.50	2243.00	1892.80	2334.50	1566.90	1912.90	3255.10	2280.10	566.52
T=	*40320*													
Block 1=	*235.90*	**NQ(CustQ)**	0.12	0.17	0.07	0.09	0.18	0.12	2.21	3.45	0.07	0.18	0.67	1.18
Block 2=	*266.16*	**NQ(EndB)**	1.46	1.37	1.54	1.43	1.23	1.35	0.49	0.00	1.57	1.37	1.18	0.52
Block 3=	*164.13*	**NQ(Buff2)**	6.11	6.23	7.37	7.06	5.18	7.06	2.05	1.43	9.54	6.91	5.89	2.46
Batch Siz	*240*	**NQ(Buff1)**	0.83	0.72	0.81	0.72	0.81	0.86	0.81	0.89	0.81	0.65	0.79	0.07
		30	4.00	0.00	0.00	1.00	1.00	3.00	6.00	4.00	2.00	3.00		
		60	7.00	11.00	13.00	11.00	10.00	10.00	11.00	9.00	13.00	10.00		
		90	14.00	14.00	13.00	12.00	14.00	12.00	8.00	12.00	11.00	11.00		
The trial item		**120**	2.00	2.00	1.00	3.00	2.00	2.00	2.00	2.00	1.00	3.00		
		OUTPUT	68.00	72.00	69.00	71.00	71.00	67.00	60.00	61.00	65.00	68.00	67.20	4.10
		OUT 2	6.00	7.00	7.00	6.00	7.00	6.00	5.00	5.00	6.00	7.00		
		OUT 1	6.00	7.00	7.00	6.00	7.00	6.00	5.00	5.00	6.00	7.00		
		SHORTAGE	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-5.00**	**0.00**	**0.00**	**-0.50**	**1.58**
		INVENT	4.00	12.00	15.00	1.00	13.00	5.00	0.00	-1.00	7.00	16.00	7.20	6.39

Table -3 Comparison of the Old and New Systems

1. Comparison of flow time 1

Observation	1	2	3	4	5	6	7	8	9	10	MEANS	STD
OLD	345.61	456.27	314.90	2354.70	400.72	606.75	432.13	355.66	375.12	374.30	**604.65**	**620.04**
NEW	389.45	445.38	306.44	374.61	540.06	466.98	2501.30	3235.70	315.09	483.59	**905.86**	**1051.33**
difference	-13.54	10.89	8.46	1980.09	-139.34	139.77	-2069.17	-2880.04	60.03	-109.29	**-301.21**	**1318.43**

t9,.975=	2.26216	sd-bar=	416.92559
H= t9,.975*sd-bar=	943.151	Interv1=	-1244.37
Interval=difference-bar	+/- H	Interv2=	641.94

2. Comparison of Flow Time 2

Observation	1	2	3	4	5	6	7	8	9	10	MEANS	STD
OLD	620.40	612.92	660.60	1204.30	574.84	1012.50	640.95	1053.50	681.84	542.60	**761.15**	**235.28**
NEW	626.13	636.87	509.11	694.92	691.27	855.25	566.34	685.19	515.04	1105.00	**688.51**	**177.98**
difference	1.33	-23.95	151.49	509.38	-116.43	157.25	74.61	368.31	166.80	-562.40	**72.64**	**289.41**

t9,.975=	2.26216	sd-bar=	91.520899
H= t9,.975*sd-bar=	207.035	Interv1=	-134.40
Interval=difference-bar	+/- H	Interv2=	279.67

3. Comparison of Flow Time 3

Observation	1	2	3	4	5	6	7	8	9	10	MEANS	STD
OLD	2025.00	2301.00	2447.10	2740.00	2260.20	2866.60	1899.10	3019.80	1759.90	3021.80	**2445.10**	**452.88**
NEW	2122.20	2289.30	1913.80	3270.50	2243.00	1892.80	2334.50	1566.90	1912.90	3255.10	**2280.10**	**566.52**
difference	13.30	11.70	533.30	-530.50	17.20	973.80	-435.40	1452.90	-153.00	-233.30	**165.00**	**634.28**

t9,.975=	2.26216	sd-bar=	200.57735
H= t9,.975*sd-bar=	453.737	Interv1=	-288.74
Interval=difference-bar	+/- H	Interv2=	618.74

Table -3 Comparison of the Old and New Systems (Contd.)

4. Comparison of Inventory

Observation	1	2	3	4	5	6	7	8	9	10	MEANS	VAR
OLD	4.00	11.00	5.00	-1.00	5.00	12.00	7.00	12.00	7.00	9.00	**7.10**	**4.09**
NEW	4.00	12.00	15.00	1.00	13.00	5.00	0.00	-1.00	7.00	16.00	**7.20**	**6.39**
difference	0.00	-1.00	-10.00	-2.00	-8.00	7.00	7.00	13.00	0.00	-7.00	**-0.10**	**7.34**

t9,.975=	2.26216	sd-bar=	2.3211587
H= t9,.975*sd-bar=	5.25083	Interv1=	-5.35
Interval=difference-bar	+/- H	Interv2=	5.15

5. Comparison of Output

Observation	1	2	3	4	5	6	7	8	9	10	MEANS	VAR
OLD	68.00	73.00	67.00	61.00	67.00	72.00	65.00	72.00	77.00	63.00	**68.50**	**4.95**
NEW	68.00	72.00	69.00	71.00	71.00	67.00	60.00	61.00	65.00	68.00	**67.20**	**4.10**
difference	0.00	1.00	-2.00	-10.00	-4.00	5.00	5.00	11.00	12.00	-5.00	**1.30**	**7.02**

t9,.975=	2.26216	sd-bar=	2.2213609
H= t9,.975*sd-bar=	5.02507	Interv1=	-3.73
Interval=difference-bar	+/- H	Interv2=	6.33

6. Comparison of Shortage

Observ.	1	2	3	4	5	6	7	8	9	10	MEANS	VAR
OLD	0.00	-6.00	0.00	-4.00	0.00	0.00	0.00	0.00	0.00	0.00	**-1.00**	**2.16**
NEW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-5.00	0.00	0.00	**-0.50**	**1.58**
difference	0.00	-6.00	0.00	-4.00	0.00	0.00	0.00	5.00	0.00	0.00	**-0.50**	**2.88**

t9,.975=	2.26216	sd-bar=	0.9098229
H= t9,.975*sd-bar=	2.05816	Interv1=	-2.56
Interval=difference-bar	+/- H	Interv2=	1.56

DISCUSSION

JIT can improve worker motivation since the implementation of the system requires more worker involvement and more worker authority. When the JIT system was introduced for the first time, many operators were not motivated to understand this new system. Most of them considered it as a burden because they had to adapt to a new way of working.

JIT system design will improve workers' motivation since they will get more authority to run production as well as more responsibility to find and to solve the problems. Since this system encourages problem solving, most of them were convinced that the system will be able to improve coordination and communication among different working areas. In addition, this system is also considered more flexible and less formal than previous systems since the order comes directly from customers, represented by Kanbans, not from the production planner as in the previous system so they can execute directly the orders without much instruction from other sections.

The other benefit of the JIT system is that problem solving becomes a first concern rather than just achieving production targets. In the previous system, both operators and supervisors were more encouraged to meet the due date rather than to improve the system that achieves less inventory and shorter lead times. Therefore, performance improvement, including inventory reduction tended to be ignored and it did not become the first concern because finding solutions was not a priority. In contrast, in the JIT system, workers are encouraged to make their own decisions on the production line; therefore, they have more responsibility and authority to solve the problems directly.

CONCLUSION

There are many opportunities in various areas that can be conducted by the Drug Process Plant since the JIT system is not just related to material management but also to all activities for eliminating wastes, so the improvement can be related to other areas such as quality control, setup time reduction and maintaining relations with suppliers. If these areas can be improved, more benefits can be obtained by the Drug Process Plant. However, Kanbans do not provide information about due date of production, so workers must put this order as a priority. Based on this problem, another rule for running the pull system at the Drug Process Plant must be included. Kanban items must become the first priority in the production to achieve planned lead time.

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