JEAS

JOURNAL OF ENGINEERING AND APPLIED SCIENCES

Journal of Engineering and Applied Sciences 12 (2018), 35-43

Visual Control and Manufacturing System Performance Enhancement Using ARENA Modular Simulation and TECNOMATIX Modeling

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

[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

ecnaxel@gmail.com

Abstract

Just- In - Time (JIT) 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. Furthermore, the manufacturing operations face considerable uncertainty and were considered stochastic due to uncertainty in timing customer orders, variability in the processing time, rework, and scrap rate, inaccuracy of demand forecasting and uncertainty of equipment failure. This study investigated effect of trigger point on cycle time and Work in Process (WIP), effect of number of kanbans on flow time and orders satisfied. Several factors such as number of buffers, location of buffers and scheduling rules are investigated. This study utilized TECHNOMATIX software and a modified version of ARENA's existing "Electronic Assembly and Test System with Part Transfers" as a baseline model. Results also indicate that Net Operating Income (NOI) differs significantly for manufacturing system ($F(2, 1593)=1704.381$, $p=.000$, $ήp^2=.682$), manufacturing overhead level ($F(2, 1593)= 31768.716$, $p=.000$, $ήp^2=.976$), and product mix complexity ($F(2, 1593)=20449.024$, $p=.000$, $ήp^2=.963$). Manufacturing overhead level did not have a significant impact on Demand Fulfillment Rate (DFR) [$F(2, 1593)=.038$, $p=.962$, $ήp^2 =.000$] or average cycle-time [$F(2, 1593)=.014$, $p=.986$, $ήp^2 =.000$], nor do any of its interactions significantly affect DFR or average cycle-time. The enhancement of trigger points, Kanban number and scheduling rules should be further explored to improve WIP, lead time and the utilisation of facilities.

Keywords: TECNOMATIX, ARENA, WIP, Lead Time, DFR, Visual Control

1. Introduction

Just-in-time manufacturing keeps stock holding costs to a bare minimum (Suzaki, 2014). 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 reduces waste, as outdated or terminated items; don't go into this system by any means. As under this technique, only essential stocks are obtained, less working capital is required to finance procurement (Fullerton & McWatters, 2014). Here, a lowest re-order point is set, and just once that stamp is achieved, crisp stocks are requested making this a safe haven to inventory administration as well. 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 (Hayes, Wheelwright & Clark, 2008).

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 particularly appealing today, where the market request is unstable and to some degree variable. 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 (Karplus, 2013). 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 (Law & David 2012).

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 (Papadopoulus, Heavey &

Browne, 2013). 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 (Sugimori, Kusunoki & Uchikawa, 2014).

As Abegglen & Stalk (2015) 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 (Evans, 2011).

JIT implementation for Juhel Pharmaceutical Drug Process Plant is considered in order to reduce inventory and lead time. Therefore, this concept was proposed for 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.

The research work will be beneficial to all manufacturing organizations. It will equally be useful to small scale business, large corporations, and the government. Finally, it will be of great value to students, researchers as a point of reference and will equally form the basis for further research study.

2.0 Methodology

The purpose of the problem identification is to define the main issues in the manufacturing Plant by collecting relevant information and understanding the actual operating system. The range of information required includes material on manufacturing processes, operating procedures for executing orders, plant layout and items produced by the Plant.

2.1 Design of the New System

This step sets characteristics and mechanisms of the proposed JIT system according to information obtained in the first step. The characteristics considered in the design cover:

a. The number and location of buffers

b. The batch size

c. Operating procedures or mechanisms for running the system/ information flow of the orders

2.2 Implementation

The implementation involves activities to achieve model design specification. This step includes training since training is considered the dominant factor for successful implementation of the system. Therefore, it includes:

a. Preparing training materials

b. Delivering training materials

c. Running the system.

2.3 Evaluation

This stage consists of two separate approaches as follows:

a. Practical Review

The purpose of this step is to review the results obtained from the implementation and to provide the practical recommendations for further improvement. This step discusses practical issues encountered in the implementation. All these issues should become main concern if the manufacturing plant wants to get maximum benefits from the JIT implementation.

b. Simulation of the New System

In this research, simulation was 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. This step covers:

1). Construction and operation of simulation models.

2). Analysing and evaluating the results.

There are different simulation software packages available in the market. These include "ARENA", "ProModel", "FlexSim", "TECNOMATIX", etc. In this research, ARENA / SIMAN and TECNOMATIX simulation software packages were used to construct the models. These softwares are used to conduct simulation experiments to achieve the objectives of the study. ARENA / SIMAN is one of the most popular simulation packages available and it is user-friendly and easy to operate. ARENA is the interface to the SIMAN language. The TECNOMATIX is a VISM (Visual Interactive Simulation) system developed by SIEMENS. It gives beneficial approach to the users not only to work on creating and using TECNOMATIX models but also to build and test the models on small incremental stage.

2.4 JIT System Evaluation

The JIT system was evaluated using simulation to determine factors contributing to improved performance of the new system. The effects of factors such as number of buffers, location of buffers, kanban quantities and scheduling rule on inventory, visual control and flow time/ customer lead time were evaluated.

Also, the effects of trigger points on flow time, shortage of parts and WIP were evaluated based on the simulation results**.** The experiment further investigated the effects of the scheduling rules on performance measures such as utilisation and output of the trial items produced. Experiments were equally performed to find the optimal number of Kanbans that minimise the flow time as well as maximise the orders satisfied.

With the help of Design of Experiment (DOE), a total of 16 runs were taken to determine the 'main effect plot of throughput for signal - to - noise ratio.' This also led to the determination of the optimum solution for throughput. Behavior analysis of the production control was evaluated by plotting production rate and total inventory level on the 'I_1 - I_2' plane. Sensitivity analysis was also conducted to determine the effects of making changes in the model parameters (total demand of finished product, finished product demand changing rate, ordering cost, holding cost, etc) over a given optimum solution.

This research went further to determine the effect of the new JIT system on key manufacturing performance measures such as demand fulfillment rate, cycle-time, and net operating income by presenting the results and statistical analyses of the data collected from the ARENA simulation experiment. The initial data were downloaded into Excel and then uploaded into Statistical Package for Social Sciences (SPSS) for statistical analysis.

2.5 Experimental Design

To achieve the objective of this study, first, the existing system was totally modeled and simulated. Secondly, the simulated model was tested and validated by analysis of variance. Thirdly, the optimum or most fitted JIT design was developed and tested to overcome existing system's limitations and its dynamic behavior. This solution was implemented and tested in a just-in-time production line.

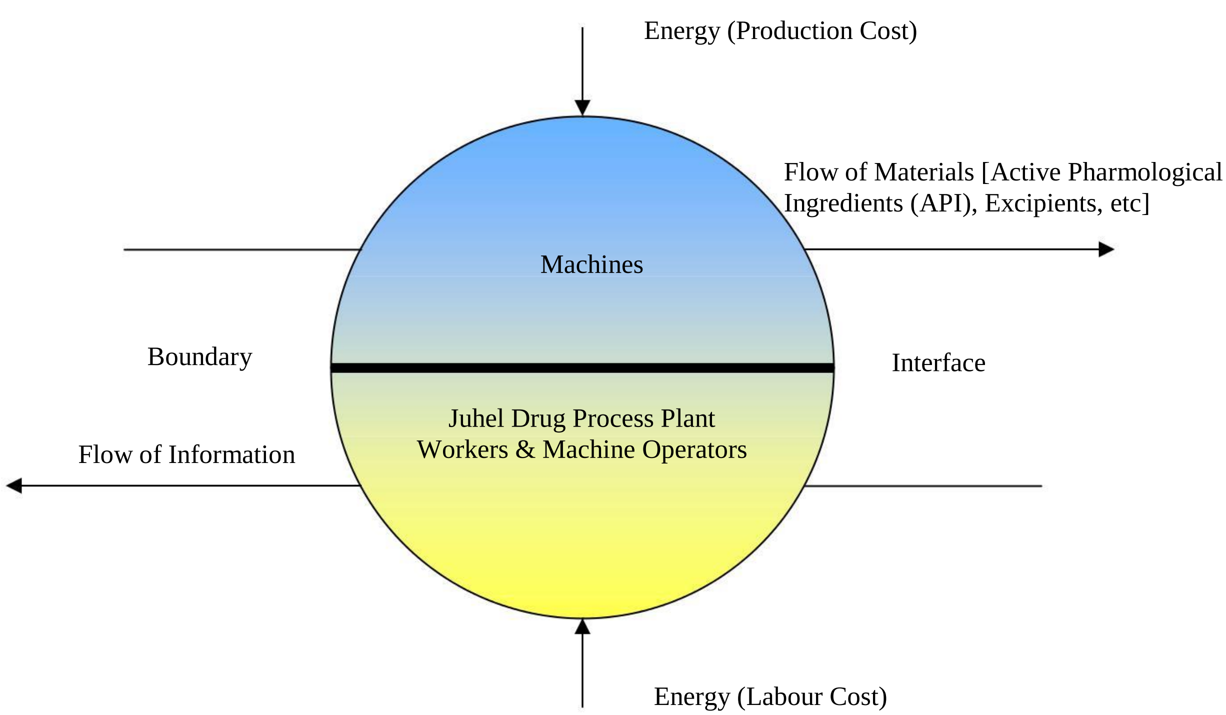

Figure 1: Enhanced JIT Manufacturing System Model

This work developed an enhanced discrete event simulation JIT manufacturing system model described in Figure 1. The system consists of components, workers/machine operators 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. 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. Conveyors regulate 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 plant workers /machine operators become organizations.

In the enhanced JIT Manufacturing System Model, the parts represent the materials, while the kanban represent the information mechanism. In this way, we can analyze the efficiency of these flows. Related with every mechanism that handles the parts or kanban, a cost is connected to the operation of the machine. Therefore a buildup of parts and kanban implies an increasing cost.

The experimental research design used to address the research problem in this work includes three experimental factors; the various levels of manufacturing system alternatives (MAS), three levels of product mix complexity (MIX), and three levels of manufacturing overhead (MOH). Most simulation analysts apply an inferior design of experiments, changing one input at a time as opposed to factorial (2^{K-P}) designs, which controls estimated effects of input changes and shows the importance of interaction effects. For each performance measure used in this research work, the experimental design is a 3 X 3 full factorial with 60 replications, thus resulting in a total of 1620 (3x3x3x6) observations.

The experimental design is then:

$$Y_{aom} = \mu + MAS_a + MOH_o + MIX_m \quad \text{(Main Effect)}$$

$$+ MAS_a * MOH_o + MAS_a * MIX_m + MOH_o * MIX_m \quad \text{(Two-Way Interaction)}$$

$$+ MAS_a * MOH_o * MIX_m \quad \text{(Three-Way Interaction)}$$

$$+ eaom \quad (1)$$

Where: Y_{aom} = Performance Measurements

μ = Mean Effect

MAS_a = Manufacturing System Effect, a = 1, 2, 3

MAS_1 = MPS

MAS_2 = MRP

MAS_3 = JIT

MOH_o = Manufacturing Overhead Level Effect, o = 1, 2, 3

MOH_1 = Low

MOH_2 = Medium

MOH_3 = High

MIX_m = Product Mix Complexity Effect, m = 1, 2, 3

MIX_1 = Narrow

MIX_2 = Medium

MIX_3 = Wide

eaom = Random Effect

2.6 Design Model

The decision logic model will utilize the following formulation, which includes all constraints for the resources and market demand, in order to determine optimal performance for the master production schedule:

$$\rho = \sum_{j=1}^{n} \mu_{ij}\xi_i\sigma_i\beta \quad i = 1, 2, 3, \ldots, m \text{ (Resource/ Capacity Constraint)} \qquad (2)$$

$$x_j \leq d_j \quad \text{For every j, j = 1, 2, 3, . . . , n (Market Demand Constraint)}$$

$$x_j \geq 0$$

Where:

ρ = System performance in terms of Net Operating Income (NOI), Inventory at the end Buffer, Work in Progress (WIP), Demand Fulfillment Rate (DFR) and Cycle Time (CT)

μ = machine alteration,

ξ = shift alteration

σ = number of parts per kanban card

β = setup time.

With m + n constraints for this model

The model input parameters are Setup Time, Machine Alteration and Shift Alteration and output parameter is Throughput as shown in Figure 2.

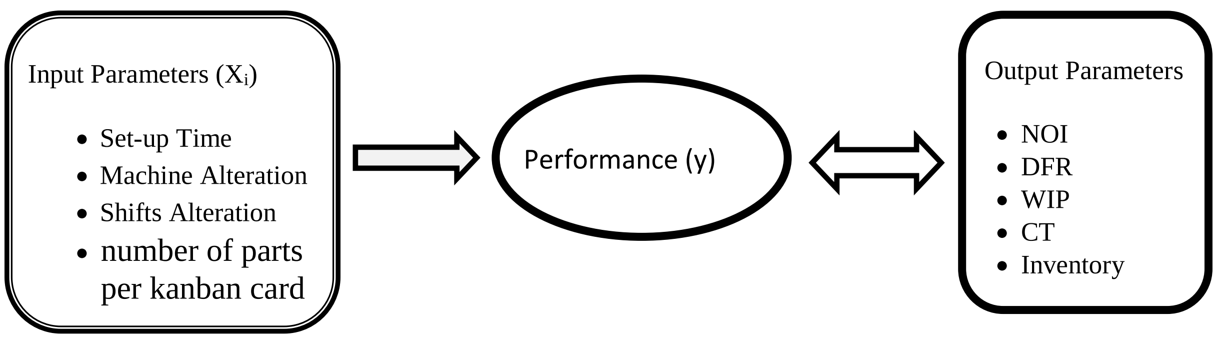

Figure 2: Conceptual Model

The appropriate JIT practices (process variables) and the performance measures (response variables) are selected.

Assumptions

i. Parts are always available at the Store-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 for some of the Runs using TECNOMATIX Simulation Software is shown in figure 3 and figure 4. It contains different notifications which explain different entities. This model shows Juhel Drug Process Plant with pallet-based transport.

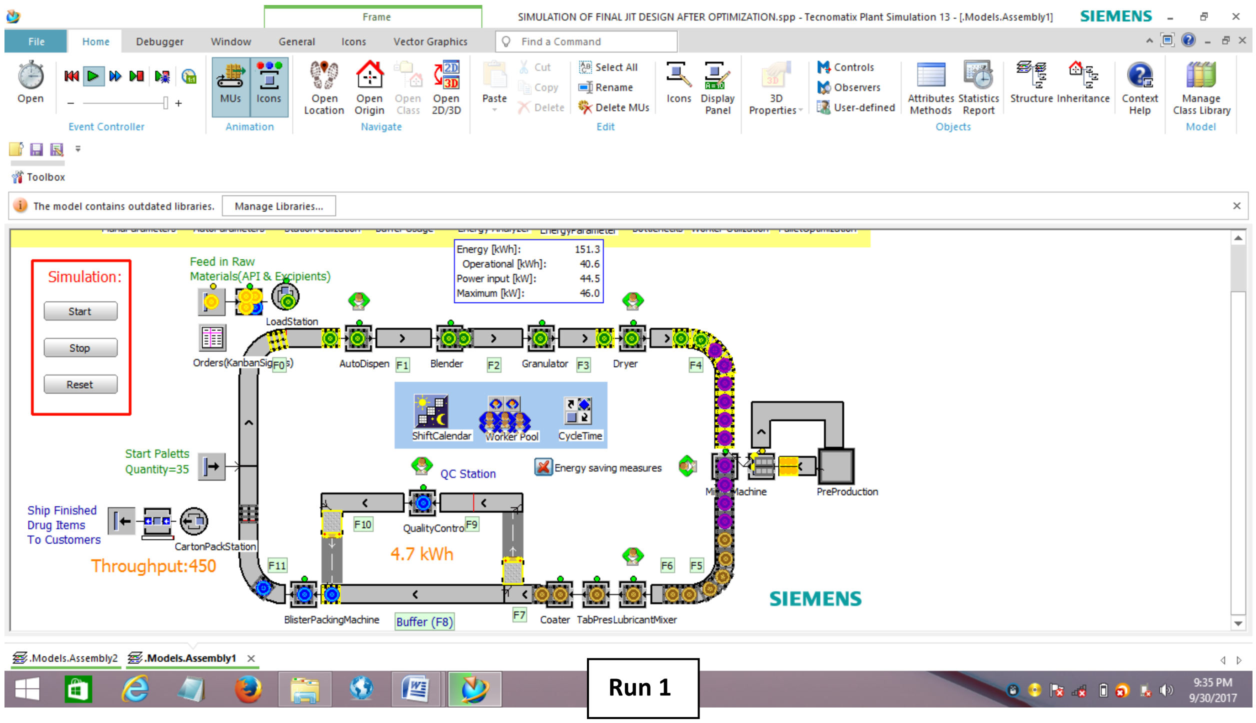

Figure 3: Screenshot for Runs **1 using TECNOMATIX Plant Simulation Software**

Pallets enter the system at the left hand side. The Load Station at the upper left corner of the production line loads one part onto a pallet. Then, the pallets move along passing several manual and automated workstations. The sub-parts arrive from the station preproduction. At the Unload Station, the main part is unloaded from the pallet and leaves the system. The pallet moves on to the Load Station to be loaded with the next part.

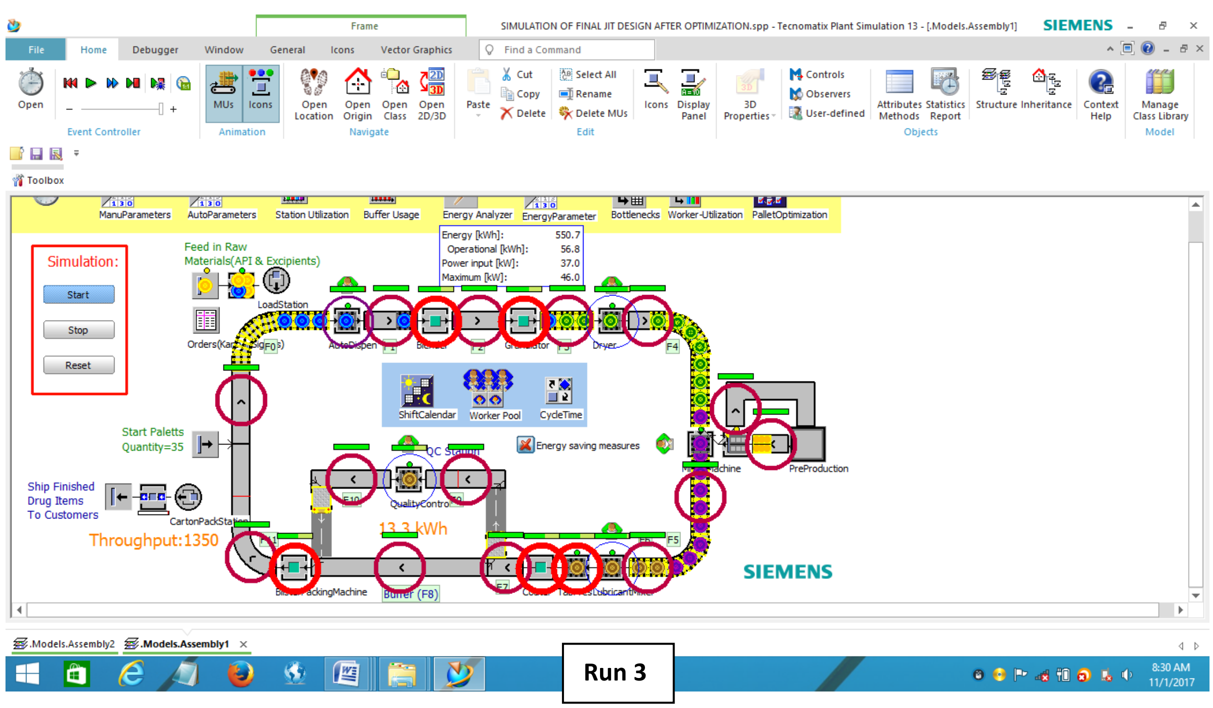

Figure 4: Screenshot for Run **3 using TECNOMATIX Plant Simulation Software**

3.0 Results and Discussions

Based on this evaluation, the differences between using the previous system and the new system are summarised in Table 1.

Table 1: The Results of the Implementation

RESULTS	BEFORE JIT	AFTER JIT	IMPROVEMENT
NOI	67.34	75.21	11.69%
Lead Time	10 days	5 days	2 times
Inventory at the end Buffer	1080 units (2 x360 +360)	540 units (90 + 360)	50%
Visual Control	None	Self-Driven	Better
WIP	Normal	Higher	Better
DFR	53.2%	99.7%	46.5%

Table 1 reveals that NOI in the old system was 67.34 but after JIT implementation in the pilot phase, NOI recorded 11.69% improvement. Lead Time before JIT implementation was 10 days but after JIT implementation it became 2 times better (5 days). Also, Inventory at the end buffer before was 1080 units but recorded 50% improvement after JIT implementation.

Table 2: Multiple Comparisons of System Performance

Scheffe

Dependent Variable	(I) MIX	(J) MIX	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DFR_2	1	2	.15082359*	.000245697	.000	.15022161	.15142556
		3	.41631103*	.000245697	.000	.41570906	.41691300
	2	1	-.15082359*	.000245697	.000	-.15142556	-.15022161
		3	.26548745*	.000245697	.000	.26488548	.26608942
	3	1	-.41631103*	.000245697	.000	-.41691300	-.41570906
		2	-.26548745*	.000245697	.000	-.26608942	-.26488548
CT_2	1	2	-352.30321*	1.9131977	.000	-356.990639	-347.615779
		3	-320.63793*	1.9131977	.000	-325.325364	-315.950503
	2	1	352.30321*	1.9131977	.000	347.6157787	356.9906393
		3	31.665276*	1.9131977	.000	26.97784547	36.35270605
	3	1	320.63793*	1.9131977	.000	315.9505030	325.3253636
		2	-31.665276*	1.9131977	.000	-36.35270605	-26.97784547
NOI_2	1	2	-18.783746*	.124743740	.000	-19.08937396	-18.47811711
		3	-23.975737*	.124743740	.000	-24.28136503	-23.67010817
	2	1	18.783746*	.124743740	.000	18.47811711	19.08937396
		3	-5.1919911*	.124743740	.000	-5.49761949	-4.88636264
	3	1	23.975737*	.124743740	.000	23.67010817	24.28136503
		2	5.19199106*	.124743740	.000	4.88636264	5.49761949

Based on observed means.

*. The mean difference is significant at the .05 level.

Furthermore, the drug process plant originally had no visual system but the implementation of the JIT system brought in a visual control system that was self-driven and better than the existing old system. However, DFR recorded 46.5% improvement over the previous old system while WIP was higher and better in the new system unlike in the old system.

As presented in Table 2, product mix complexity has a significant effect on the demand fulfillment rate measure. Average demand fulfillment rate was 99.5% under a love level of product mix complexity and drops to 84.5% under medium level and 57.9% under a high level of product mix complexity.

The Partial Eta Squared ($ήp^2$) presented in the results clearly show high effect size for the two-way interaction of manufacturing system and product mix complexity and a significant, albeit it rather low, effect size for manufacturing overhead level and product mix complexity. The amount of variance in the dependent variable combination explained by these interactions was 73% and 7% respectively. The two-way combination of manufacturing system and manufacturing overhead level as well as the three way interaction of manufacturing system, manufacturing overhead level, and product mix complexity was insignificant with less than 1% in effect size. Manufacturing overhead level had an amplification effect and only significantly affected the performance measure of net operating income.

Manufacturing overhead level did not have a significant impact on demand fulfillment rate (F(2, 1593)=.038, p=.962, $ήp^2$ =.000) or average cycle-time (F(2, 1593)=.014, p=.986, $ήp^2$ =.000), nor do any of its interactions significantly affect demand fulfillment rate or average cycle-time. The two-way interactions of manufacturing System and manufacturing overhead level have an insignificant impact on demand fulfillment rate (F(2, 1593)=.056, p=.994, $ήp^2$ =.000) and average cycle-time (F(2, 1593)=.006, p=1.000, $ήp^2$ =.000). The interactions of manufacturing overhead level and product mix complexity also have an insignificant effect on demand fulfillment rate (F(2, 1593)=.012, p=1.00, $ήp^2$ =.000) and average cycle-time (F(2, 1593)=.005, p=1.000, $ήp^2$ =.000). Finally, the three-way interactions of manufacturing system, manufacturing overhead level, and product mix complexity had an insignificant affect on demand fulfillment rate (F(2, 1593)=.057, p=1.00, $ήp^2$ =.000) and average cycle-time (F(2, 1593)=.008, p=1.000, $ήp^2$=.000).

4.0. Conclusion

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.

References

Abegglen, J. C. & Stalk, G. (2015). Kaisha: The Japanese Corporation. New York, NY: Basic Books, Inc.

Evans, D. (2011). *Production Supervisory Management: Principles and Practice.* Casell, Wellington House, Fourth ed.

Fullerton, R. R. & McWatters, C. S. (2014).The role of performance measures and incentives in relation to the degree of JIT implementation.Accounting, Organizations and Society, 27.

Hayes, R., Wheelwright, S., & Clark, K. (2008).Dynamic Manufacturing. New York, NY: The Free Press.

Karplus, W. J. (2013). The spectrum of mathematical models. Perspectives in Computing, 3(2), 4-13.

Law, A.M., & David W. K. (2012).*Simulation Modeling and Analysis*.Second Ed., McGraw-Hill.

Mejabi, Olugbenga.,& Gary, S. Wasserman, (2012). Simulation Constructs for JIT Modelling. *International Journal of Production Research*, 30(5).

Papadopoulus, H. T., Heavey, C., & Browne, J. (2013).*Queueing Theory in Manufacturing Systems Analysis and Design.*Chapman and Hall.

Sugimori, Y. K., Kusunoki, K., & Uchikawa, S. (2014). Toyota production System and Kanban system:

materialisation of just-in-time and respect-for-human system. *International Journal of Production and Research*, 15(6), 553– 564.

Suzaki, K. (2014). *The New Manufacturing Challenge: Techniques for Continuous Improvement*. New York: Free Press.