January 01, 1995

Coping with processing time variation in a JIT environment

Surendra M. Gupta
Northeastern University

Yousef A. Y. Al-Turki
Northeastern University

Ronald F. Perry
Northeastern University

Bibliographic Information

Gupta, S. M., Al-Turki, Y. A. Y. and Perry, R. F., "Coping with Processing Time Variation in a JIT Environment", ***Proceedings of the 1995 Northeast Decision Sciences Institute Conference***, 419-421, 1995.

Copyright Information

Contact Information

Dr. Surendra M. Gupta, P.E.
Professor of Mechanical and Industrial Engineering and
Director of Laboratory for Responsible Manufacturing
334 SN, Department of MIE
Northeastern University
360 Huntington Avenue
Boston, MA 02115, U.S.A.

(617)-373-4846 ***Phone***
(617)-373-2921 ***Fax***
gupta@neu.edu ***e-mail address***

http://www.coe.neu.edu/~smgupta/ ***Home Page***

COPING WITH PROCESSING TIME VARIATION IN A JIT ENVIRONMENT

Surendra M. Gupta, Northeastern University, Boston, MA 02115, (617)-373-4846
Yousef A. Y. Al-Turki, King Abdulaziz City for Sc. and Tech., P.O.Box 53726, Riyadh 11593, Saudi Arabia.
Ronald F. Perry, Northeastern University, Boston, MA 02115, (617)-373-4844

ABSTRACT

It is well known that the performance of the JIT production system is optimum in a deterministic environment. However, real-world situations contain uncertainties in processing times, with which traditional JIT does not deal well. In this paper, we present a newly developed Kanban system that systematically manipulates the number of Kanbans to cope with the discrepancies introduced by the uncertainty in processing times. We illustrate that the performance of this new system is superior to the traditional JIT system in such an environment.

INTRODUCTION

Over the past decade, the JIT technique has proved to be very successful. The JIT principles include: elimination of waste, reduction of production cost, total quality control and recognition of employees' abilities. JIT seeks to produce defect free goods in the required amounts at the right time. The Kanban system is an element of the JIT system that has several advantages including its ability to control production, its simplicity in production scheduling, reduced burden on operators, substantial reduction in paper work and ease in identifying parts by the Kanbans attached to the containers.

Among the researchers who have addressed processing time variation are: Berkley [2], Chaturvedi and Golhar [4], Huang et al [5], Jordan [6], Lee [7], Lee and Seah [8], Meral and Erkip [9], Muralidhar et al [11], Philipoom et al [13], Sarker and Fitzsimmons [14], Schroer et al [15], Swinehart and Blackstone [16] and Villeda et al [17].

The analytical techniques used to date in the modeling of the JIT system make unrealistic assumptions or use constant variables to avoid intractability (see for example, Bard and Golany [1], Bitran and Chang [3], Moeeni and Chang [10], Wang and Wang [18]). Any attempt to expand these models to realistic situations leads to state space problems. For this reason, simulation is the methodology of choice in a majority of studies reported in the literature. Simulation can model just about all of the dynamics that occur in manufacturing systems and provide the appropriate experimental statistics.

Traditionally, the number of Kanbans are always held fixed during the production cycle. However, in an uncertain processing time environment, it is beneficial to vary the number of Kanbans during the production cycle to compensate for the discrepancies introduced by the unpredictability in processing times. We investigate this issue and demonstrate that, indeed, a new system allowing systematic fluctuations in the number of Kanbans, which we term the Flexible Kanban System (FKS), provides us with promising results. For comparison purposes, a Traditional Kanban System (TKS) is also studied.

MODEL DESCRIPTION

Consider a JIT system composed of N stations in series. Each station has one processing machine, an input and an output buffer. When demand occurs, a container is retrieved from the output buffer of station N (finished goods buffer) and the production Kanban is detached from that container and sent to the input buffer (assuming that there is a container available in that buffer). If the output buffer is empty, then the demand request waits in a queue at the finished goods buffer until a container becomes available. Once the container is available, it is retrieved to fulfill the demand and the production Kanban is detached from it and sent to the input buffer. At the input buffer this production Kanban is exchanged with the withdrawal Kanban attached to the container waiting there. (If no container is waiting in the input buffer, the production Kanban waits there in a queue till one becomes available). At this time, station N starts processing the part in the container provided the machine at that station is not busy, otherwise it waits in a queue at the input buffer. The withdrawal Kanban which was detached from the container acts as a demand request for the preceding station. This "pulling" action continues throughout the manufacturing system. It starts at station N and continues till it reaches station 1.

Because the number of Kanbans in the TKS is fixed, there are times when the intermediate stations can either be blocked or starved. One of the main reasons for blocking and starving of stations is the variability, and hence inequality created thereof, in processing times. This, in turn, retards the flow of production which can have an adverse effect on many performance measures. FKS is designed to overcome some of these deficiencies.

JIT does not maintain a large amount of finished goods inventory. If a big demand occurs, it can only fulfill it partially with the finished goods available at station *N*'s output buffer. Since the processing times are probabilistic, the time it takes to fulfill the demand could vary widely. In order to fulfill the demand in the shortest possible time, the probability of blocking and starving needs to be reduced. The FKS achieves this by immediately increasing the number of withdrawal Kanbans at every station. The amount of increase in the number of withdrawal Kanbans influences the amount of production flow by controlling the degree of blocking and starving. The more the increase, the less the blocking and starving. However, the increase in the number of withdrawal Kanbans should not exceed what is necessary to fulfill the demand. Once the demand is fulfilled or within sight of being fulfilled, it is time to start decreasing the number of withdrawal Kanbans (otherwise their continuous presence will have a detrimental effect on the amount of work in process). A decrease in the number of withdrawal Kanbans before the appropriate time may not result in any beneficial effect because of the untimely return of blocking and starving.

METHODOLOGY

A simulation model using the PC version of SIMAN (version 3.5) [12] incorporating several modules (viz., raw material, Kanban, production, demand and flexible Kanban) was developed to study the performances of the two systems. The overall control of the simulation is carried out by the Kanban module. A brief description of each module is given below.

The raw material module ensures an unlimited supply of raw material and provides raw material units to the first station by interacting with the Kanban module and the production module. The Kanban module keeps track of both the withdrawal and the production Kanbans at every station. This module interacts with the flexible Kanban module (if necessary), the demand module, the production module and the raw material module. By interacting with the flexible Kanban module and the demand module, it controls the processing and flow of parts through the manufacturing system. The production module controls the processing of the parts at different stations. It interacts with the raw material and demand modules in conjunction with the Kanban module to achieve this control. The demand module creates orders for finished units and keeps track of the time needed to complete them. Finally, the flexible Kanban module (used for the FKS case only) controls the variations in the number of Kanbans.

In developing the simulation model, the following assumptions were made:

- The raw-material is always available at station 1.
- A production day is composed of 480 minutes.
- There is only one part in each container.
- The demand is constant.
- Neither any scrap is produced nor any machine breakdown occurs.
- One unit of raw-material must be sequentially processed by all *N* stations in order to fulfill one unit of demand.
- All transfer times are considered to be negligible.
- First-Come-First-Serve discipline is used to process the parts.

EXPERIMENTATION

TKS and FKS, were compared under various conditions. In order to see if FKS is as sensitive to the number of stations as TKS, we looked at systems with five and nine stations. To evaluate the effect of mean processing time under the same load factors (the load factor is the ratio of mean processing time of total demand to the total available production time), we looked at systems with mean processing times of one and ten minutes respectively. The systems were examined under constant as well as exponential processing times. The choice of exponential distribution was made because of its high coefficient of variation. The rationale being that if FKS can cope with such extreme situation, it should certainly be able to handle most real life cases. In addition, several combinations of the number of withdrawal and production Kanbans were considered (for the FKS case, these combinations represented the base number of Kanbans).

Four measures were used to compare the performances of TKS and FKS, viz. the average Time In System (TIS), the average Order Completion Time (OCT), the average Work-In-Process at the end of the production day (WIP) and the average number of units backlogged over 50 days (in unit-days).

CONCLUSIONS

- In a constant processing time and synchronized stations environment, the FKS offers no advantage over the TKS because the production capacities in both systems remain identical. This is true because until the demand is completely satisfied, all the stations commence and cease processing of parts at exactly the same times regardless of the system.

- The onset of stochastic processing times, leads to a reduction in the production capacity. The stochastic processing times cause asynchronization in the system which leads to starvation of some stations and blocking of others. This results in an increase in the OCT and an increase in the probability of backlog. The system that has stations with limited number of base Kanbans are more severely affected by the blocking and starvation phenomena.

- FKS is a better choice, if the objective is to minimize the WIP while reducing the OTC and minimizing the backlog. FKS accelerates the "pulling" mechanism which minimizes station blocking and station starvation. This results in faster service and less backlog. The FKS with a base of one production and one withdrawal Kanban at each station has an almost identical OTC, less WIP and less backlog than the TKS with a base of four production and four withdrawal Kanbans!

- While in the TKS, OTC and backlog are affected by the number of stations, these measures are not significantly affected when FKS is adopted. This is because FKS enhances the supply reliability and reduces station blocking and station starvation.

- At identical base number of Kanbans in a stochastic processing time environment, FKS always has better OTC and backlog performance than TKS, but has slightly higher TIS and WIP.

REFERENCES

[1] Bard, J. and Golany, B., "Determining the number of Kanbans in a multiproduct, multistage production system", *International Journal of Production Research*, 29 (5), 1991, 881-895.

[2] Berkley, B., "Analysis and approximation of a JIT production line: A comment", *Decision Sciences*, 22, 1990, 660-669.

[3] Bitran, G. R. and Chang, L., "A mathematical programming approach to deterministic Kanban system", *Management Science*, 33 (4), 1987, 427-441.

[4] Chaturvedi, M. and Golhar, D. Y., "Simulation modeling and analysis of a JIT production system", *Production Planning and Control*, 3 (1), 1992, 81-92.

[5] Huang, P. Y., Rees, L. P. and Taylor III, B. W., "A simulation analysis of the Japanese just-in-time technique (with Kanbans) for a multiline, multistage production system", *Decision sciences*, 14 (3), 1983, 326-343.

[6] Jordan, S., "Analysis and approximation of a JIT production line", *Decision Sciences*, 19 (3), 1988, 672-681.

[7] Lee, L. C., "Parametric appraisal of JIT system", *International Journal of Production Research*, 25 (10), 1987, 1415-1429.

[8] Lee, L. C. and Seah, K. H. W., "JIT and the effects of varying process and set-up times", *International Journal of operations and Production Management*, 8(1), 1988, 19-35.

[9] Meral, S. and Erkip, N., "Simulation analysis of JIT production line", *International Journal of Production Research*, 24, 1991, 147-156.

[10] Moeeni F. and Chang, Y-L., "An approximate solution to deterministic Kanban system", *Decision Sciences*, 21 (3), 1990, 596-606.

[11] Muralidhar, K., Swenseth S. and Wilson R., "Describing processing time when simulating JIT environments", *International Journal of Production Research*, 30 (1), 1992, 1-11.

[12] Pegden, C. D., Shannon, R. E. and Sadowski, R. P., *Introduction to simulation using SIMAN*, McGraw Hill, New York, 1990.

[13] Philipoom, P. R., Rees, L. P., Taylor III, B. W. and Huang, P. W., "An investigation of the factors influencing the number of Kanbans required in the implementation of the JIT technique with Kanban", *International Journal of Production Research*, 25 (3), 1987, 457-472.

[14] Sarker, B. R. and Fitzsimmons, J. A., "The performance of push and pull systems: A simulation and comparative study", *International Journal of Production Research*, 27 (10), 1989, 1715-1731.

[15] Schroer, B. J., Black, J. T. and Zhang, S. X., "Just-in-time (JIT), with Kanban manufacturing system simulation on a microcomputer", *Simulation*, 45 (2), 1985, 62-70.

[16] Swinehart, K. D. and Blackstone, J. H., "Simulating a JIT/Kanban production system using GEMS", *Simulation*, Oct., 1991, 262-269.

[17] Villeda, R., Dudek, R. and Smith, M. L., "Increasing the production rate of a just-in-time production system with variable operations times", *International Journal of Production Research*, 26, 1988, 1749-1768.

[18] Wang, H. and Wang, Ben, "Optimum number of Kanbans between two adjacent workstations in a JIT system", *International Journal of Production Economics*, 22, 1991, 179-188.