January 01, 1995

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Bibliographic Information

Gupta, S. M., "The Effect of Machine Breakdown on the Performance of a JIT System", ***Proceedings of the 26th Annual Meeting of Decision Sciences Institute***, 1135-1137, 1995.

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THE EFFECT OF MACHINE BREAKDOWN ON THE PERFORMANCE OF A JIT SYSTEM

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ABSTRACT

In this paper, we present the results of a newly developed Kanban system that systematically manipulates the number of Kanbans to cope with the interruptions introduced by machine breakdowns. We illustrate that the performance of this new system is superior to the traditional Kanban system in such an environment.

INTRODUCTION

Just-In-Time (JIT) is a production methodology that encompasses economically designed product, efficient plant layout to reduce lead-time, worker involvement and motivation, improved data accuracy, reduced scrap, continuos improvement in all areas and implementation of the Kanban system. Advantages of the Kanban system include its ability to control production, its simplicity in production scheduling, reduced burden on operators, ease of identification of parts by the Kanban attached to the container and substantial reduction in paper work.

Even though JIT is designed for a perfect environment (e.g., smooth and stable demand, constant and balanced processing time among stations and no breakdowns), in most realistic cases, it is very rare to achieve. JIT is fraught with numerous types of problems such as processing time variation, line imbalance and machine breakdown. The effect of processing time variation has been addressed by many researchers such as Chaturvedi and Golhar [1], Gupta and Al-Turki [2], Gupta et al [3] and Philipoom et al [7].

Line imbalance can be caused by differences in set-up times and/or processing times at different stations. Line imbalance has been addressed by several researchers including Meral and Erkip [5], Philipoom et al [8], and Sarker and Harris [9] .

The machine breakdown was addressed by Hillier and So [4] and Xie [10]. They use analytical techniques and make unrealistic assumptions or assume constant variables to avoid intractability. Any attempt to expand the model to a realistic situation leads to state space problems. For this reason, we use simulation to study the machine breakdown aspect of JIT. Simulation is capable of handling the dynamics that occur in manufacturing systems and providing the appropriate experimental statistics.

In almost all of the studies reported in the literature, the number of Kanbans are always held fixed during an experiment. We show that it is beneficial to manipulate the number of Kanbans to reduce the effect of machine breakdown. We refer to the system that manipulates the number of Kanbans as the Flexible Kanban System (FKS).

The general objective of this paper is to explore the impact of sudden machine breakdown on the performance of the Traditional Kanban System (TKS) and the FKS. We discuss the performance of JIT systems in which the station where the machine breakdown occurs and its subsequent stations are unbalanced compared to the rest of the stations. We look at the TKS with no machine breakdown, and compare the performances of various cases of TKS and FKS with machine breakdown.

MODEL DESCRIPTION

We consider a JIT system composed of 7 stations in series. Each station has one processing machine, an input buffer and an output buffer. The raw-material is always available at station 1. No special device is needed to move the containers through station 5. However, an AGV (Automated Guided Vehicle) is needed to move a container from the output buffer of station 5 to the input buffer of station 6 and from the output buffer of station 6 to the input buffer of station 7. There is only one AGV available in the JIT system. No special device is needed to move a container from the input buffer to the processing machine or from the processing machine to the output buffer at any station.

When a demand occurs, a container is retrieved from the output buffer of station 7 (finished units buffer). The item in the container is used to fulfill the demand and the production Kanban (which is attached to the container) is detached from the container and sent to the input buffer. (If the output buffer is empty, the demand request waits in a queue at the finished units buffer till a container becomes available). At the input buffer the production Kanban is exchanged with the withdrawal Kanban which is 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 7 starts processing the part provided the machine at that station is idle, 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 station 6. This "pulling" action continues throughout the manufacturing system. It starts at station 7 and continues till it reaches station 1.

The withdrawal Kanbans of a station always circulate between the input buffer of that station and the output buffer of its preceding station, controlling the movement of containers to a station from its preceding station. If there are no withdrawal Kanbans of a station available at the output buffer of its preceding station, then full containers are not allowed to transfer to the station. The production Kanban of a station always circulates within that station, controlling the production at that station. If all the production Kanbans are attached to full containers at the output buffer, the machine at the station will be idle.

SPECIFIC EXAMPLE

We present a specific example of the model considered in this paper. The relevant data is as follows:

- Both TKS and FKS stations were allocated two production and two withdrawal base Kanbans.
- The demand for finished units is 80 units per day.
- A production day is composed of two shifts. The first shift is considered a regular production shift and the second shift is overtime. Each shift is composed of 480 minutes. The demand for a given day must be satisfied during that day even if it takes both shifts to produce it.
- It takes 0.5 minute to transfer the withdrawal Kanbans from a station to its preceding station.
- Similarly, it takes 0.5 minute to transfer parts and the withdrawal Kanban from a station to its succeeding station.
- The processing times at stations 1 and 2 were normally distributed with a mean of 5 minutes and a standard deviation of 0.5 minute per part while the processing times at stations 3 through 7 were also normally distributed but with a mean of 2 minutes and a standard deviation of 0.2 minute per part. We consider a case involving no breakdown of machines and several cases involving machine breakdown. The machine breakdown was uniformly distributed between 0 and 480 minutes (i.e. between the start and the end of the shift). Five machine repair time scenarios were considered, viz., normally distributed duration with mean of 120 minutes and standard deviation of 30 minutes, constant duration of 80 minutes, constant duration of 100 minutes, constant duration of 120 minutes and constant duration of 140 minutes.
- The speed of the AGV is 160 feet per minute. The distance from station 5 output buffer to station 6 input buffer is 40 feet. Similarly, the distance between station 6 output buffer and station 7 input buffer is also 40 feet. The distance from station 7 input buffer to station 5 output buffer is 100 feet. It takes 0.25 minute to load a container on the AGV and 0.25 minute to unload the container from the AGV. The station with the minimum number of parts receives the highest transportation priority. First-Come-First-Serve priority is used to break the tie. The AGV has a capacity of one container.

SOLUTION METHODOLOGY

A simulation model using the PC version of SIMAN (version 4.12) [6] incorporating several modules was developed to study the model example. The following assumptions have been incorporated in the simulation model:

- The raw-material is always available at station 1.
- There is only one part in each container.
- Neither any scrap is created nor the AGV breaks down.
- One unit of raw-material must be sequentially processed by all 7 stations in order to fulfill one unit of demand.
- First-Come-First Serve discipline is used to process the parts.
- To maintain equivalence in processing times at each station, machine breakdown and repair times, TKS and FKS were assigned identical seed numbers.

EXPERIMENTATION

We assumed that the breakdown of the machine only occurred at station 3. This assumption was made so as to keep the study manageable and still gain insight into the machine breakdown phenomenon. Four measures were used to compare the performances of TKS and FKS, viz. average time in the system, order completion time, number of units that must be produced in overtime to satisfy the demand and resource utilization in the regular production shift. The resource utilization measure consisted of: AGV utilization, station 1 utilization, station 5 utilization and station 7 utilization.

OBSERVATIONS

Some of the observations made from the results obtained by simulating the model example were as follows:

- TKS and FKS had identical time in system when the machine broke down towards the end of the production day. This was because either the demand had already been satisfied (at the time of the machine breakdown) or the parts that were available at the subsequent stations were sufficient to satisfy it.

- FKS had slightly larger time in system when the machine broke down at the beginning of the production day. This was caused due to the residual demand at the beginning of the day which resulted in pulling of more parts into the system while the machine was undergoing repairs. The number of parts started to increase at the input buffer of station 3 until either all the production Kanbans were attached to full containers or the machine started operating.
- FKS always had lower order completion time than TKS. This could be explained as follows. If there were a residual demand and the machine were being repaired, the subsequent stations in both FKS and TKS would starve. In addition, in TKS, stations 1 and 2 would experience blocking due to the limited number of production and withdrawal Kanbans. This was not true in FKS. The increase in the number of the production Kanbans at station 3 released its withdrawal Kanbans which created pulling and production at stations 2 and 1. This resulted in accumulation of the needed parts at the input buffer of station 3. Later on, when the machine was repaired, stations 3 through 7 in TKS would continue to suffer from starvation due to the imbalance in processing times. On the other hand, stations 3 through 7 in FKS were not affected as severely by the imbalance problem because of the increase in the number of parts at the input buffer of station 3.
- Both TKS and FKS met the demand during the regular production shift. This is attributed to low demand, sufficient number of base Kanbans allocated at each station to absorb the effect of machine breakdown at station 3, and low parts processing times at stations 3 through 7.
- FKS had higher resource utilization than TKS. This is attributed to the increase in the number of Kanbans when the machine breaks down. FKS reduced blocking at the preceding stations while the machine was being repaired. After the machine started operating, FKS, reduced the subsequent stations starvation by processing the parts that were accumulated in the input buffer of station 3 while the machine was being repaired.

CONCLUSIONS

We examined the effect of machine breakdown on the performance of TKS and FKS. We conclude that FKS is very promising when the processing times at the station that has the machine breakdown and its subsequent stations are lower than all other stations. For the specific example considered, we presented the solution methodology, experimentation and observations.

REFERENCES

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

[2] Gupta, S. M. and Al-Turki, Y. A. Y., 1995, An algorithm to dynamically adjust the number of Kanbans in stochastic processing times and variable demand environment, *Production Planning and Control*, (Forthcoming).

[3] Gupta, S. M., Al-Turki, Y. A. Y. and Perry, R. F., 1995, Coping with processing time variation in a JIT environment, *Proceedings of the 1995 Northeast Decision Sciences Institute Conference*, Providence, Rhode Island, March 1995, 419-421.

[4] Hillier, F. S., and So, K. C., 1991, The effect of machine breakdowns and inter-stage storage on the performance of production line systems. *International Journal of Production Research*, 29 (10), 2043-2055.

[5] Meral, S. and Erkip, N., 1991, Simulation analysis of a JIT production Line. *International Journal of Production Economics*, 24, 147-156.

[6] Pegden, C. D., Shannon, R. E. and Sadowski, R. P., 1990, *Introduction to Simulation Using SIMAN*, McGraw Hill, New York.

[7] Philipoom, P. R., Rees, L. P., Taylor III, B. W. and Huang, P. W., 1987, 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), 457-472.

[8] Philipoom, P. R., Rees, L. P., Taylor III, B. W. and Huang, P. W.,1990, A mathematical programming approach for determining work center lot sizes in a just-in-time system with signal Kanbans, *International Journal of Production Research*, 28 (1), 1-15.

[9] Sarker, B. R. and Harris, R. D., 1988, The effect of imbalance in a just-in-time production system: A simulation study, *International Journal of Production Research*, 26 (1), 1-18.

[10] Xie, X., 1993, Performance analysis of a transfer line with unreliable machines and finite buffers, *IIE Transactions*, 25 (1), 99-108.