東海管理評論
民國八十八年七月，第一卷，第一期，35-54

The Estimation of Production Effectiveness of a JIT Manufacturing Workpool in a Unreliable-Reliable Condition

Cheng-Jung, Lin*

Abstract

This paper is intended to employ the continuous time Markov chain (CTMC) model to solve the problem of production effectiveness of a workpool in a kanban "pull" JIT environment. A workpool contains one upstream workstation and one downstream workstation, the upstream one is in an unreliable condition, and the downstream one is in a reliable condition. The study concerns the implementation of withdraw kanban with demand rate and production rate of the downstream and upstream workstations in a workpool, and meanwhile, in the consideration of various combinations of failure rate and repair rate of the upstream workstation to discuss the throughput rate in the workpool, Though the dynamic kanban control and sensitivity analysis of production effectiveness, one can easily manage the flexible production capacity.

Keyword: Production effectiveness; failure rate; repair rate; continuous time; Markov chain(CTMC); workpool.

* Department of Business Administration, Tunghai University

1.Introduction

In a JIT manufacturing system one of the major concerns is to balance material flow to match market demand. In order to estimate the production effectiveness, the following assumptions are made:

•Autonomous maintenance: In promoting TPM, everyone in the organization must believe that it is necessary for the operators to perform autonomous maintenance. Therefore, individuals are to be trained to perform autonomous maintenance and to be responsible for their own equipment.

•Preventive maintenance(PM) schedule: All the PM activities are scheduled to be completed between two regular shifts. In other words, there is no PM work during any shift.

•Flexible workers: well-trained(versatile) and multi-functional operators are ready for emergent needs.

•Flexible equipment: Multi-functional machines capable of producing a range of products that meet the market demand.

•Machine layout: Good design of the GT layout is required for the manufacturing system.

The author proposes a basic unit of a JIT pull system called a "workpool." A workpool contains an upstream workstation and a downstream workstation. In this paper, the upstream workstation is in the unreliable condition and the downstream workstation is in the reliable condition.

This paper is intended to employ the continuous time Markov chain(CTMC) model to solve the problem of production effectiveness of a workpool in a withdraw (single) kanban "pull" JIT environment. The input of this model are upstream production rate, downstream demand rate, upstream failure rate and repair rate. Meanwhile, the output is the throughput of a workpool.

2.Literature Review

JIT has its origin in the Toyota company, Japan. In the 1960s, Toyota worked hard on developing a whole range of new approaches to managing manufacture. The result is the well-known "Toyota Manufacturing System." In 1982, Ohno explained the process for developing JIT at Toyota from his experience with Toyota company. He defined the objectives of JIT as follows:

•To provide possible alternatives for reduction of material stocks, WIP and manufacturing cycle time.

•To increase the speed of information exchange.

•To upgrade system productivity.

Monden(1983) provided a detailed description of pull systems and JIT implementation. He discussed the "Kanban Systems" that smoothed the production at Toyota. He also described the rules reason for this is that the number of kanbans between two adjacent workstations represents the maximum inventory level, therefore should be kept minimum.

Schonberger(1982, 1983) described JIT as a philosophy of producing and delivering products just in time to be sold. He discussed the adoptability of JIT to Western industry and pointed out that JIT is not simply a management concept that can be copied from another firm of country. He(1982) also pointed out the impact of equipment failure and maintenance policy. An equipment failure is a serious matter, with the potential to shut down a production line. To avoid such failures, the Japanese are careful not to overload the machines. Workers are trained to perform a daily regimen of machine checking before starting up in the morning. All equipment, however well designed and maintained, is liable to failure, and such failure often occurs without warning. Therefore, the existence of a buffer stock will ensure that the subsequent stations are not immediately "starved" of work in case the supplying station is temporarily out of service. Japanese plants have increasingly adopted a two eight-hour shift plan, which means two eight-hour production shifts nested with four-hour shifts in which maintenance and tool changes are performed.

Richard(1988) described how the JIT philosophy could be implemented at different levels of management and discussed the requirements for each level of effective implementation of JIT. He also pointed out that just as quality and productivity are optimized, so is equipment usage. In a JIT system, the equipment is never operated at its maximum capacity. Some system effectiveness principles are implemented: (1)derating the equipment extends the useful life of the equipment, (2)allowing the extra time that can be used to program preventive maintenance requirements around the production schedule, (3)and allowing a buffer capacity to meet emergency production needs.

Wang and Wang(1990) employed continuous time Markov Chain(CTMC) model to determining the number of kanbans, but they only discuss about both the upstream and downstream workstations are all reliable. Congdon and Rapone(1995), Muckstadt and Tayur(1995) indicated that in several of the high-volume automative control lines, where semi-automated equipment is used, equipment uptime is crucial in order to maintain a smooth manufacturing system.

3. Methodology

3.1 General Structure of a Workpool

Suppose a workpool which contains both the upstream and downstream workstations(Figure 1). The demand information sent from the downstream workstation to the upstream workstation and then processed by the upstream workstation to produce the output. In a kanban pull system, an upstream workstation will not allow the output flow to pass through unless there is a input (information) pull from the downstream station. The production release rate of the upstream unit is limited by its production capacity and the downstream demand (pull) rate.

If the upstream workstation is assumed unreliable and the downstream workstation is assumed reliable, then we define it as a case of an unreliable-reliable workpool. The author employ the limiting distribution of an unreliable-reliable system in continuous-time Markov chain(CTMC) model to discuss the performance measure of the production effectiveness.

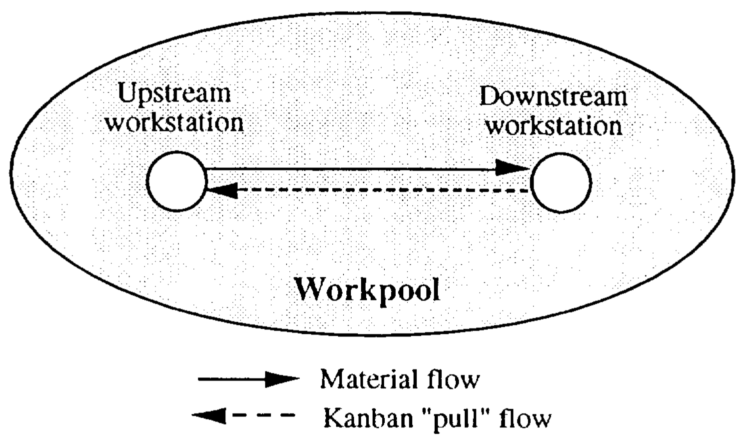


Figure 1 A workpool

3.2 Notation

λ_D: the demand (pull) rate is reliable which follows a Poisson process

μ_u: the production rate of a workpool in reliable condition while K kanban(s) is (are) allocated

$\mu_u^{'K}$: the production rate of a workpool in unreliable condition while K kanbans are allocated

$U_u^{'}$: the base production rate of a workpool in unreliable-reliable condition

μ_u^E: the net production rate of the upstream workstation

λ_u^f: the failure rate of an upstream workstation in a workpool

μ_u^r: the repair rate of an upstream workstation in a workpool

E : the state space of a Markov process

G : the *infinitesimal* generator matrix of a Markov process for a workpool

F_K : the flow balancing index while K kanban(s) is (are) allocated

π_1 : the probability of undersupply in a workpool

π_0 : the probability of oversupply in a workpool

π_1^T : the target probability of undersupply in a workpool

π_0^T : the target probability of oversupply in a workpool

3.3 Limiting Distribution of an Unreliable-Reliable Workpool

This applies to the condition where the upstream workstation is unreliable while the downstream workstation is reliable. Here we assume the mean service (supply) time $1/\mu_u^K$ and mean arrival (demand) time $1/\lambda_D$ to be exponentially distributed.

Define for each $t \geq 0$, as follows:

$$K(t) = \begin{cases} 1 & \text{if a undersupply occurs while } K \text{ kanbans are in the workpool} \\ 0 & \text{otherwise} \end{cases}$$

$$X_u(t) = \begin{cases} 1 & \text{if an upstream workstation of the workpool is in good condition} \\ 0 & \text{otherwise.} \end{cases}$$

The process $\{X(t) = K(t), X_u(t), t \geq 0\}$ is a continuous-time Markov chain with state space $E = \{(j,k) \mid j = 0,1; k = 0,1\}$.

State Space

The state is represented as a two-tuple vector (j,k). The state of the workpool in oversupply or undersupply is denoted as j, while the state of the upstream workstation, whether in good or bad condition, is denoted as k. For the workpool with an initial allocation of K kanban(s), the total number of state is 2^2 and the state space is E ={(0, 0), (0, 1), (1, 0), (1, 1)}.

Transition

Some possible scenarios of transition are described as follows:

State (0, 1), in which the workpool is in oversupply and u is in good condition. The states that can be reached from the current state are (0, 0) with λ_u^f, and (1, 1) with λ_D.

State (0, 0), in which the workpool is in oversupply with u in bad condition. The states can be reached from this state are (0, 1) with μ_u^r, and (1, 0) with λ_D.

State (1, 1), in which the workpool is in undersupply with u in good condition. The states that can be reached from this state are (0, 1) with $\mu_u^{'K}$, and (1, 0) with λ_u^f.

We denote the steady-state probability of the process $\{X(t);t \geq 0\}$ by $\pi_{(j,k)}^K$, where $\pi_{(j,k)}^K$ indicates the probability that the workpool is in oversupply or undersupply with the upstream workstation in good or bad condition, while K kanban(s) is (are) circulating in the workpool.

Using the balance principle "rate out of a state=rate into that state", we obtain the following possible scenarios of balance equations:

- $\left(\mu_u^r + \lambda_D\right) \pi_{(0,0)}^K = \lambda_u^f \pi_{(0,1)}^K$,
- $\left(\lambda_u^f + \lambda_D\right) \pi_{(0,1)}^K = \mu_u^r \pi_{(0,0)}^K + \mu_u^{'K} \pi_{(1,1)}^K$,
- $\mu_u^r \pi_{(1,0)}^K = \lambda_u^f \pi_{(1,1)}^K + \lambda_D \pi_{(0,0)}^K$,
- $\left(\mu_u^{'K} + \lambda_u^f\right) \pi_{(1,1)}^K = \lambda_D \pi_{(0,1)}^K + \mu_u^r \pi_{(1,0)}^K$ (1)

with $\pi_{(-1,k)}^K = \pi_{(2,k)}^K = 0$ by convention. Also, we have the following normalizing equation

$$\sum_{j=0}^{1} \sum_{k=0}^{1} \pi_{(j,k)}^K = 1 \tag{2}$$

The balance equations can be shown as a corresponding transition rate diagram. The generator matrix G_K, which corresponds to the balance equations of this process $\{X(t);t \geq 0\}$ can also be found as follows:

$$G_K = \begin{bmatrix} -(\mu_u^r + \lambda_D) & \mu_u^r & \lambda_D & 0 \\ \lambda_u^f & -(\lambda_u^f + \lambda_D) & 0 & \lambda_D \\ 0 & 0 & -\mu_u^r & \mu_u^r \\ 0 & \mu_u^{'K} & \lambda_u^f & -(\mu_u^{'K} + \lambda_u^f) \end{bmatrix}.$$

Algorithm

Step1: Construct the state space of the Markov process.

Given that K kanbans are circulating in the workpool $(K \geq 1)$, the state space is represented as a two-tuple vector (j,k) defined as above.

Step2: Find the infinitesimal generator matrix G_K of the Markov process.

There are two states of oversupply and undersupply, and two states of machine conditions in the upstream workstation, all of which result in 2^2 balance equations with 2^2 unknowns. Any one of these equations is redundant and must be replaced by the normalizing equation that sets the sum of all of the state probabilities to 1.

Step 3: Calculate the limiting distribution from G_K and the normalizing equation.

$\pi^K = (\pi_0^K, \pi_1^K)$, where π_0^K, π_1^K are the limiting probabilities of oversupply and undersupply for the upstream workstation in unreliable condition.

$$\pi_0^K = \pi_{(0,0)}^K + \pi_{(0,1)}^K,$$

$$\pi_1^K = \pi_{(1,0)}^K + \pi_{(1,1)}^K. \quad (3)$$

Example

The following data is given for a workool: $U_u^{'} = 10$ containers/hour, $\lambda_D = 8$ containers/hour, $\lambda_u^f = 0.005$ failures/hour, and $\mu_u^r = 0.5$ repairs/hour. Suppose the upstream workstation is unreliable. If two kanbans are allocated in the workpool at $2U_u^{'}$, then, the balance equations of the generator matrix G_2 are:

$$-8.5\pi_{(0,0)}^2 + 0.005\pi_{(0,1)}^2 = 0$$

$$0.5\pi_{(0,0)}^2 - 8.005\pi_{(0,1)}^2 + 20\pi_{(1,1)}^2 = 0$$

$$8\pi^2_{(0,0)} + 0.005\pi^2_{(1,1)} - 0.5\pi^2_{(1,0)} = 0$$

$$-10.005\pi^2_{(1,1)} + 0.5\pi^2_{(1,0)} + 8\pi^2_{(0,1)} = 0$$

and $$\sum_{j=0}^{1}\sum_{k=0}^{1}\pi^2_{(j,k)} = 1.$$

Solving the balance equations, we obtain

$$\pi_1^2 = \pi^2_{(1,0)} + \pi^2_{(1,1)}$$

$$=0.009485+0.283004$$

$$=0.292489$$

$$\pi_0^2 = \pi^2_{(0,0)} + \pi^2_{(0,1)}$$

$$=0.000416+0.707095$$

$$=0.707511,$$

where $\pi_1^2 = 0.292489$ is the probability of undersupply and $\pi_0^2 = 0.707511$ is the probability of oversupply. Since $\pi_1^2 < 0.50$, then the workpool is in oversupply.

3.4 Flow-Balancing Index-Dynamic Kanban Control

Once a kanban system in set up in a JIT system, it is expected to operate in an equilibrium status. If there is any variation in the demand pull, the kanban allocation changes accordingly. Groenevelt and Karmarkar (1988) listed the following conditions where a dynamic kanban control was employed.

- The demand has significant seasonal variability. Therefore, the system cannot be operated with a fixed kanban system. The number of kanbans in a workpool should be adjusted accordingly.
- The system runs in a forecast-driven mode. Since it is forecast driven, kanbans are not released solely based on the pull rate from the downstream workstations. Kanbans may be

released in advance based on forecast of demand.

- Extra kanbans may be released if there is an emergency customer order.
- Kanbans can be increased if there is a demand peak which exceeds the current production capacity.

From the standpoint of flexible capacity utilization, it is necessary to establish an index to show what level the current production rate has to be adjusted to. Therefore, the number of kanbans in a workpool will be determined accordingly. This index is called flow-balancing index F_K of a workpool while K kanban(s) is (are) allocated.

Flow-balancing index F_K is devised to be an indicator of the dynamic kanban control of a workpool. It is shown as the ratio of the probability of oversupply π_0^K to the probability of undersupply π_1^K, i.e., $F_K = \frac{\pi_0^K}{\pi_1^K}$. The derivation of flow-balancing index is discussed in the following paragraphs.

If there are K kanbans allocated in a workpool $(K \geq 1)$, then through the enumeration of limiting distribution with the given data of supply and demand, we can obtain that

$$\pi_0^K + \pi_1^K = 1, \tag{4}$$

where π_1^K is the probability of undersupply in a workpool, and

π_0^K is the probability of oversupply in a workpool.

When $\pi_1^K = \pi_0^K$, it means that the "balance" point of supply has been reached:

$$\pi_1^K = \pi_0^K = 0.50.$$

Proposition

In a one-station-to-one-station (one-flow-path) mode, if supply and demand rates are equal, then the material supply reaches a balance point, i.e., $\pi_1^K = \pi_0^K = 0.50$.

Proof:

Through the calculation of the limiting distribution from the generator matrix of a unreliable-reliable workpool, we can find the relationship, while $K \geq 1$,

$$\pi_1^K = \frac{\lambda_D}{\mu_u^K}\pi_0^K \tag{5}$$

i.e.,

$$\frac{\pi_0^1}{\pi_1^1} = \frac{\mu_u^1}{\lambda_D} \quad \text{while} \quad K = 1, \tag{6}$$

and

$$\frac{\pi_0^K}{\pi_1^K} = \frac{\mu_u^E}{\lambda_D} \quad \text{or} \quad \mu_u^E = \mu_u^K = \frac{\pi_0^K}{\pi_1^K}\lambda_D \quad \text{while} \quad K > 1, \tag{7}$$

where μ_u^E is the net production rate of the upstream workstation while $K > 1$. If $\mu_u^K = \lambda_D$, then $\pi_0^K = \pi_1^K = 0.50$ and the flow-balancing index F_K is 1.00 or 100%. We can also extend Proposition 4.1 to include unreliable conditions in a one-station-to-one-station (one-flow-path) mode.

Generally speaking, the production management adjust the production rate to meet target flow-balancing index of the workpool F^T, i.e., $F^T = \frac{\pi_0^T}{\pi_1^T}$ and $\pi_0^T + \pi_1^T = 1$, where π_0^T is the target probability of oversupply and π_1^T is the target probability of undersupply of the workpool.

In an unreliable-reliable workpool we can obtain the net production rate μ_u^E from Equation (8) at $\pi_1^T = \pi_1^K$ while $K \geq 1$, i.e., μ_u^E is the net production quantity of $\mu_u^{'K}$. Where

$$\mu_u^E = \frac{\pi_0^K}{\pi_1^K}\lambda_D \quad \text{where} \quad K \geq 1. \tag{8}$$

Moreover, we can obtain the adjusted production rate from Equation (9):

$$\frac{\pi_0^K}{\pi_1^K} = \frac{\mu_u^{'K}}{\lambda_D}\frac{\mu_u^r\left(\lambda_u^f + \mu_u^r + \lambda_D\right)}{\left(\lambda_u^f + \mu_u^r + \lambda_D\right)\left(\lambda_u^f + \mu_u^r\right) + \mu_u^{'K}\lambda_u^f} \tag{9}$$

For example, given that $U_{u}^{'} = 10$ containers/hour, $\lambda_{D} = 9$ containers/hour, $\lambda_{u}^{f} = 0.005$ pieces/hour, $\mu_{u}^{r} = 0.5$ pieces/hour in a workpool and F^{T} is 120%. From Equation (8) we obtain the net adjusted production rate $\mu_{u}^{E} = 10.8$ containers/hour; meanwhile, from Equation (9) we obtain the adjusted production rate $\mu_{u}^{'2} = 11.03$ containers/hour.

4.Computional Experiences and Discussion -The Sensitivity Analysis for the Throughput Rate

In a JIT manufacturing system, the production system effectiveness will be enhanced through the use of kanbans provided that the flexible capacity policy is implemented. The purpose of implementing kanbans is to supply just in time with the right quality and quantity. The variation of the failure rate and repair rate as well as the fluctuation of the demand rate are the key factors in the determination of the throughput rate and the number of kanbans in a workpool. Therefore, sensitivity analysis of the throughput rate versus failure rate and repair rate in a workpool is employed.

Given that $U_{u}^{'} = 11$ containers/hour, $\lambda_{D} = 10$ containers/hour, $\lambda_{u}^{f} = 0.005$ failures/hour and $\mu_{u}^{r} = 0.5$ repairs/hour in a workpool, the adjusted production rate meets the throughput rate at 10 containers/hour is 10.20 containers/hour, i.e. the flow-balancing index is at 100% (Figure 2). When the production rate is adjusted to 11 containers/hour, it serves the throughput rate at 10.78 containers/hour, which is the upper limit of production rate of one kanban, i.e., the flow-balancing index is 107.8%. When the upper limit of two kanbans are allocated in the workpool, the flow-balancing index is increased to 213.4%, i.e., the production rate of 22 containers/hour meets the throughput rate at 21.34 containers/hour. When three kanbans are allocated, the flow-balancing index is increased to 316.9%, i.e., the production rate of 33 containers/hour meets the throughput rate at 31.69 containers/hour. However, the upper limit of inherent and additional capacity is supposed to be equivalent to 16 containers/hour, and the flow-balancing index can only be increased to 156.1% while two kanbans are allocated. Therefore, the production rate of 16 containers/hour meets the throughput rate at 15.61 containers/hour.

In Figure 3 the production rate and the demand rate are all in reliable condition, given that $U_u = 11$ containers/hour, $\lambda_D = 10$ containers/hour, and the production rate that meets the throughput rate at 10 containers/hour is 10 containers/hour. When the production rate is adjusted to 11 containers/hour, it serves the throughput rate at $U_u^{'} = 11$ containers/hour. When two and three kanbans are allocated in the workpool at $2U_u$ and $3U_u$, the flow-balancing index can be increased to 220% and 330%, respectively. The flow-balancing index at the throughput rate of 16 containers/hour is 160%. In this case the throughput rate is equal to the production rate.

Comparing with Figure 2 and 3, we find that the production rate in unreliable condition should be much higher than the production rate in reliable condition. For example, 10.20 containers/hour should be produced in an unreliable condition and 10 containers/hour should be produced in a reliable condition to meet the throughput rate of 10 containers/hour. The additional portion (10.20-10.00=0.20 containers/hour) is to compensate for the production efficiency loss due to the breakdown and repair time of the equipment.

With the given data: $U_u^{'} = 11$ containers/hour, $\lambda_D = 10$ containers/hour, there are four cases of the throughput rate in unreliable condition (while the demand rate is reliable) to be discussed:

- low failure rate and low repair rate,
- low failure rate and high repair rate,
- high failure rate and low repair rate, and
- high failure rate and high repair rate.

4.1 Production Rate with Low Failure Rate and Low Repair Rate

Given that $U_u^{'} = 11$ containers/hour, $\lambda_D = 10$ containers/hour, $\lambda_u^f = 0.0001$ failures/hour and $\mu_u^r = 0.1$ repairs/hour for a workpool, the throughput rate is affected relatively little by the breakdown and repair time of its equipment(Figure 4). In this case, there is approximately a 0.2% compensation of the production rate due to the loss of production efficiency at $\lambda_D = 10$ containers/hour while flow-balancing index is at 100%, i.e., $\mu_u^{'1} = 10.02$ containers/hour.

A relatively low failure rate means that the equipment is always in good condition. In this case, the change of the repair rate is relatively insensitive to the throughput rate in the workpool.

4.2 Production Rate with Low Failure Rate and High Repair Rate

Given that $U_u^{'} = 11$ containers/hour, $\lambda_D = 10$ containers/hour, $\lambda_d^f = 0.0001$ failures/hour and $\mu_u^r = 10$ repairs/hour for a workpool, the throughput rate of the workpool is affected very little by the breakdown and repair time of its equipment (Figure 5). In this case, there is approximately a 0.0014% compensation of production rate due to the loss of production efficiency at $\lambda_D = 10$ containers/hour while flow-balancing index is at 100%, i.e., the throughput rate is 10.00014 containers/hour.

A very low failure rate means that the equipment is in an almost perfectly-reliable condition. In this case, the variation of the repair rate has almost no affect on the throughput rate in the workpool.

4.3 Production Rate with High Failure Rate and Low Repair Rate

Given that $U_u^{'} = 11$ containers/hour, $\lambda_D = 10$ containers/hour, $\lambda_u^f = 0.1$ failures/hour and $\mu_u^r = 0.1$ repairs/hour for a workpool, the throughput rate of the workpool is affected by the breakdown and repair time of its equipment (Figure 6). In this case, even though the inherent and additional capacity is fully utilized, the production rate of this workpool is only about 4.48 containers/hour to meet the throughput rate, i.e., the flow-balancing index is only at 44.8%. The management and related departments have to improve the reliability and maintainability of the equipment to enhance the throughput rate.

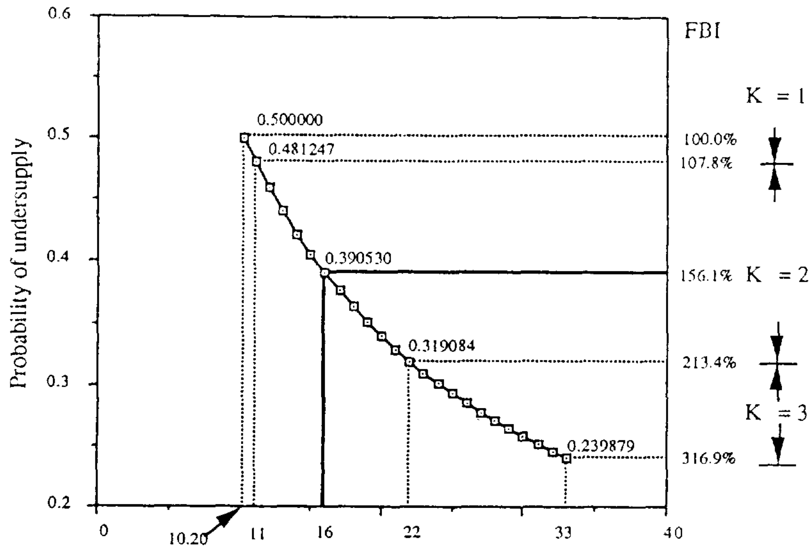
4.4 Production Rate with High Failure Rate and High Repair Rate

Given that $U_u^{'} = 11$ containers/hour, $\lambda_D = 10$ containers/hour, $\lambda_u^f = 0.1$ failures/hour and $\mu_u^r = 10$ repairs/hour for a workpool, the throughput rate is affected relatively little by the breakdown and repair time of its equipment (Figure 7). In this case, there is approximately a 1.5% compensation of production rate due to the loss of production efficiency at $\lambda_D = 10$ containers/hour while the flow-balancing index is at 100%, i.e., the adjusted production rate is 10.15 containers/hour.

5.Conclusion

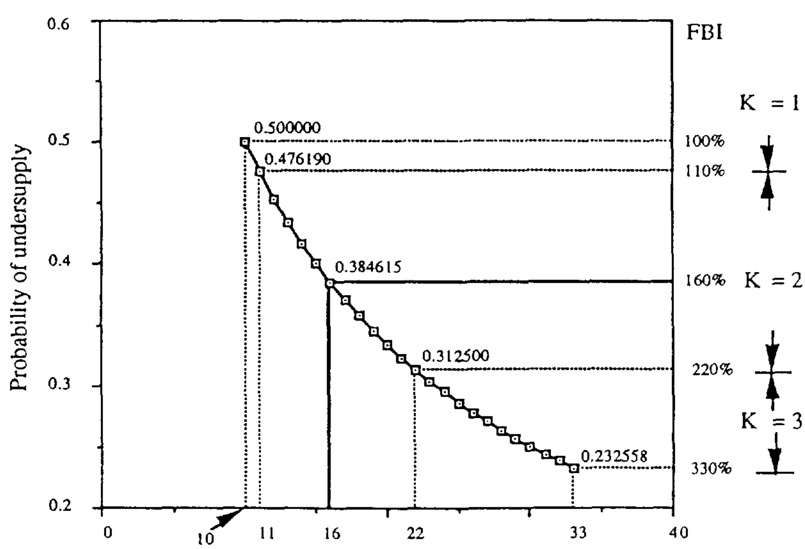
In a JIT manufacturing system, the input of the production effectiveness of a workpool containes downstream demand rate, upstream production rate, failure rate and repair rate, and the output is the throughput. The production effectiveness will be enhanced through the use of kanbans provided that the flexible capacity policy is implemented. The dynamic kanban control to flexibly adjust the capacity of a workpool and through the linkage of a series of workpools, the production effectiveness of the production line is expected to maintain at an effective level. Through employing the implementation of the CTMC model and the sensitivity analysis for the throughput rate, one can easily to estimate the flow balancing index and calculate the number of single (withdraw) kanban(s) circulated in the workpool.

For further research, one can aims at the dynamic kanban control system to develop a flexible capacity management system with the CTMC model and simulation model as well. Furthermore, those issues such as: dynamic kanban allocation of one-to-one in reliable-unreliable workpool, unreliable-unreliable workpool, multiple-to-one workpool etc. could be further studied.



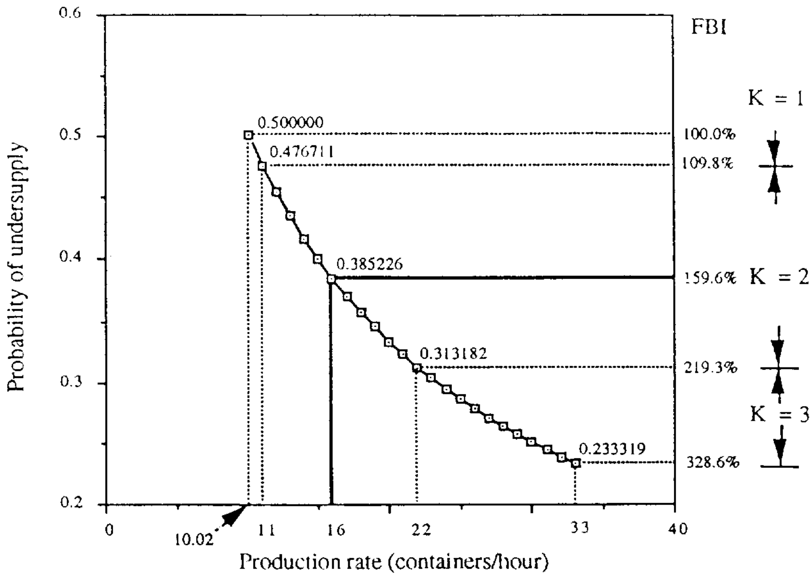
Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

Figure 2 The Production Rate versus the Throughput Rate (Unreliable)



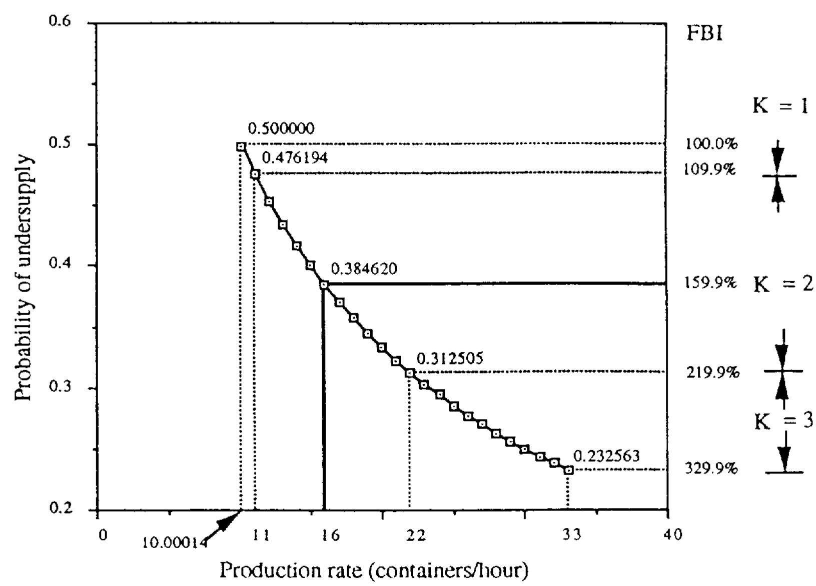
Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

Figure 3 The Production Rate versus the Throughput Rate (Reliable)



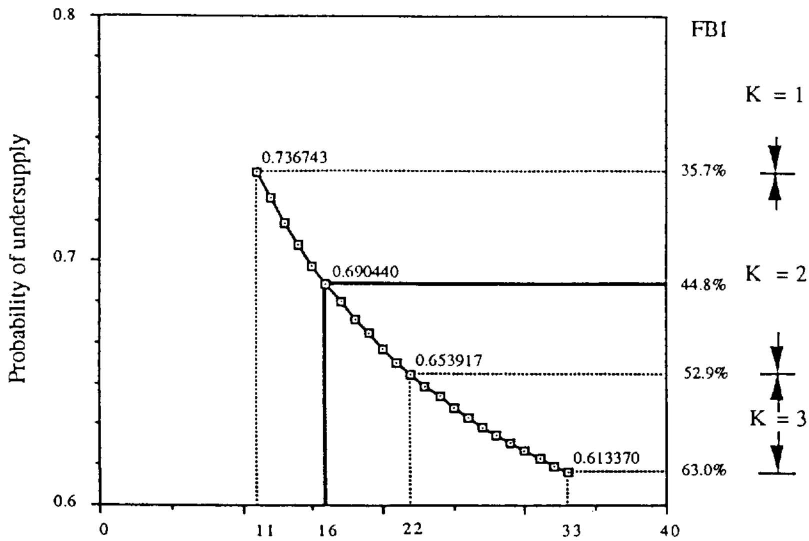
Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

Figure 4 The Production Rate versus the Throughput Rate with



Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

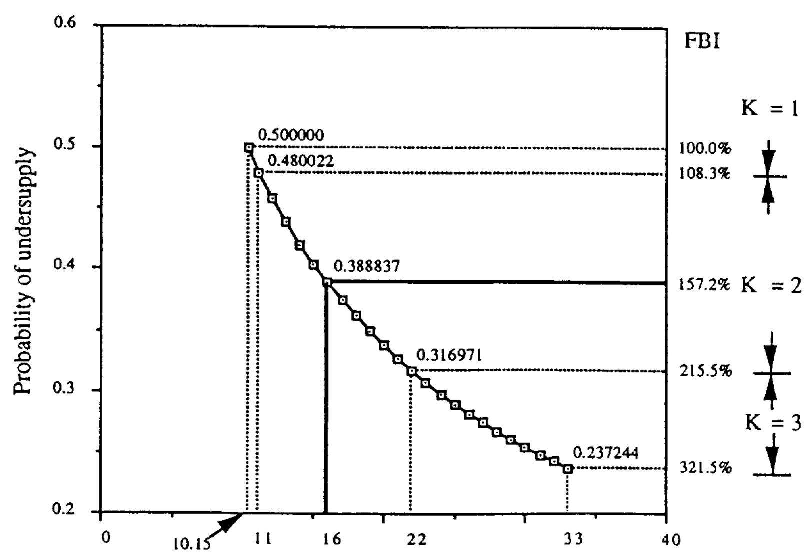
Figure 5 The Production Rate versus the Throughput Rate with Low Failure Rate and High Repair Rate



Production rate (containers/hour)

Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

Figure 6 The Production Rate versus the Throughput Rate with High Failure Rate and Low Repair Rate



Production rate (containers/hour)

Note: FBI = Flow-balancing index
K = Number of kanbans allocated in the workpool

Figure 7 The Production Rate versus the Throughput Rate with High Failure Rate and High Repair Rate

References

Congdon, W. S., and Rapone, R.M. (1995). "JIT and Lean Production." *Production*, August, 22-26.

Karmarkar, U. S., and Kekre, S. (1990). Batching policy in kanban system, *Journal of Manufacturing System*, 8, 4, 317-327.

Monden, Y. (1983). "Toyota Production System: Practical Approach to Production Management," *Industrial Engineering and Management Press*, Norcross, GA.

Muckstadt, J. A., and Tayur, S.R. (1995). A Comparison of Alternative Kanban Control Mechanisms, *IIE Transactions*, 27, 140-161.

Richard, L. J. (1988). "*Just-in-Time Manufacturing*," McGraw-Hill, New York.

Schonberger, R. J. (1983). Application of single-card and dual-card kanban, *Interfaces*, 13, 56-67.

Schonberger, R. J. (1982). Some observations on the advantages and implementation issues of Just-in-Time production systems, *Journal of Production Management*, Fall.

Wang, H.L. and Wang, H.P. (1990). Determining the number of kanbans: A step toward non-stock-production, *International Journal of Production Research*, 28, 11, 2101-2115.

在上游不完全可靠一下游可靠工作群體的及時生產環境下生產系統效能的估算

林政榮*

摘要

本文針對及時生產情況上游工作站不完全可靠及下游工作站完全可靠的環境下，生產效能如何估算的探討。本研究乃是透過連續性時間馬可夫鏈(CTMC)的模式來探討在一個工作群體(workpool)含上下游的兩站中，上游工作站處於不完全可靠情況下，其損壞故障率與修護率設為已知，上下游的生產率與需求率亦為已知的前提下，透過單一傳票的運作來估算上下游之間的配合，並藉以討論在損毀率及修護率的高度不同組合情況下，生產系統效益變化的敏感度。透過模式的發展及實例計算經驗，可供學術及實務的研究與應用的參考。

關鍵字：生產效能；損毀率；修護率；連續性時間馬可夫鏈(CTMC)；工作群體(workpool)。

* 東海大學企業管理學系