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DESIGN AND ANALYSIS OF MULTI STAGE MULTI PART ADAPTIVE KANBAN SYSTEM USING HYBRIDE METHADOLOGY

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Abstract: Kanban was developed for Toyota Car Plants in Japan as a program to smooth the flow of products throughout the production process. Kanban system is efficient and easiest tool to be implemented. In pull production system, kanbans are used as production orders and signals used to replenish the inventory of items used repetitively within a plant. In Traditional Kanban system, the number of cards used in manufacturing process is kept constant. But TKS with fixed number of cards doesn't work satisfactorily in unstable environment. In Adaptive Kanban System, the number of cards allowed to change with respect to the inventory and backorder level. In this work, Multi stage with do Multi part AKS is developed. Hybrid methodology is developed to estimate the optimal parameters of Multi stage and multi part. A similar model is developed for TKS also and used as the base for comparison. Using these optimal values, the Multi Stage with Multi part AKS is designed and analyzed.

Keywords: Kanban system, Adaptive Kanban System, Traditional Kanban System, Heuristics

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INTRODUCTION

The production control system can be generally classified into push and pull systems. The pull production system employs kanban as the controlling mechanism. In a kanban controlled production system, kanban cards are used as production orders. In the Traditional Kanban System (TKS) the number of cards used in a Manufacturing Process (MP) is kept constant. Hall (1983) proved that TKS is successful in production environment with stable demand and lead time. In order to compare the relative performance of AKS over TKS, a detailed discussion of modeling and design of TKS is presented in this chapter.

SINGLE STAGE TRADITIONAL KANBAN SYSTEM

In the traditional kanban system the number of cards in use is fixed as K. Customer demand drives the manufacturing process (MP), and the demand is assumed to be stable. Each part is attached with a kanban. When a customer demand arrives, the finished part is released to the customer and the kanban attached to that part is transferred to upstream for initiating the production. The demand that cannot be met, due to non availability of finished part, stays as back ordered demand.

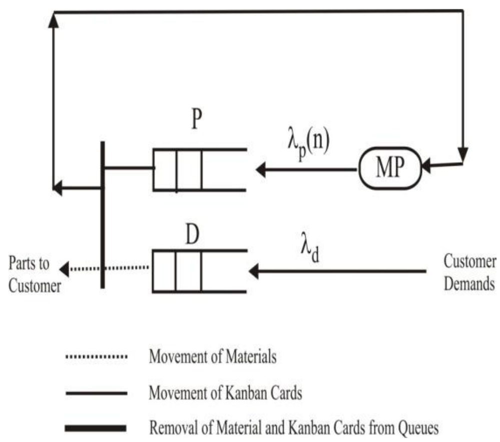
$$\lambda_d / \lambda_p (K) < 1$$

And are defined by the rate balance equation where the net inflow of particular state is equal to net out flow of that state. Therefore,

$$\lambda_d P_K (i) = \lambda_P (\min(K - i + 1, K)) P_K (i - 1)$$

The normalization equation is

$$\sum_{i=-\infty}^{K} P_K(i) = 1$$



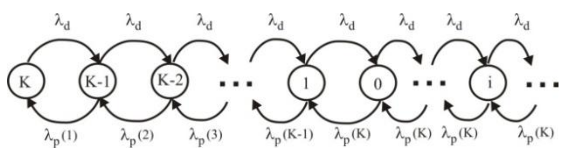
Model for single stage traditional kanban system

For certain systems, the expected throughput rate $\lambda_P(n)$ is simple to calculate. For systems with single workstation consisting of c identical parallel servers with a mean rate μ (processing time), can be calculated as

$$\lambda_P(n) = \begin{cases} n\mu, & n < c, \\ c\mu, & n \geq c \end{cases}$$

According to Spearman (1991), for balanced systems with M workstations, each consisting of a single server with mean rate μ is

$$\lambda_P(n) = n\mu/(n + M - 1)$$



State - diagram representing the behavior of the system

In this system the release of raw part in MP is completely synchronized with the release of a finished part to a customer. Therefore the number of parts in the system is constant and equal to K.

To optimize the single-stage kanban system, one can choose the parameter K that minimizes the long-term average cost associated with backordered demands and inventories, both WIP and finished goods. It is often assumed that there is a given cost for holding a WIP or finished inventory unit. In many situations, the same assumption is valid for each unit of backordered demand. Let ‘b’ be the cost ratio per unit time of backordering one finished part in queue D versus holding one unit of inventory in the system. When the number of kanban cards is K, the expected finished goods inventory, denoted by I(K), is

$$\sum_{i=0}^{K} iP_K(i)$$

The expected WIP inventory, WIP (K), is

$$\sum_{i=0}^{K} (k-i)P_K(i) + \sum_{i=1}^{\infty} kP_K(-i)$$

The expected backlog, B(K), is

$$\sum_{i=1}^{\infty} iP_K(-i)$$

Here, I(K) + WIP(K) = K. Therefore, the optimization problem is to find the parameter K such that the objective function is minimized.

Z (K) = K + bB (K)

2.1 MULTISTAGE TRADITIONAL KANBAN SYSTEM (MTKS)

The multistage the manufacturing system is decomposed into stages and the stages are in a tandem configuration. Each stage is controlled by a kanban mechanism. Thus the parameters of the control policy are the number of kanbans for each stage. Therefore once the system has been decomposed into stages, the design of kanban control system reduces in setting of the number of kanbans for each stage. These parameters play an important role in the efficiency of the kanban control system.

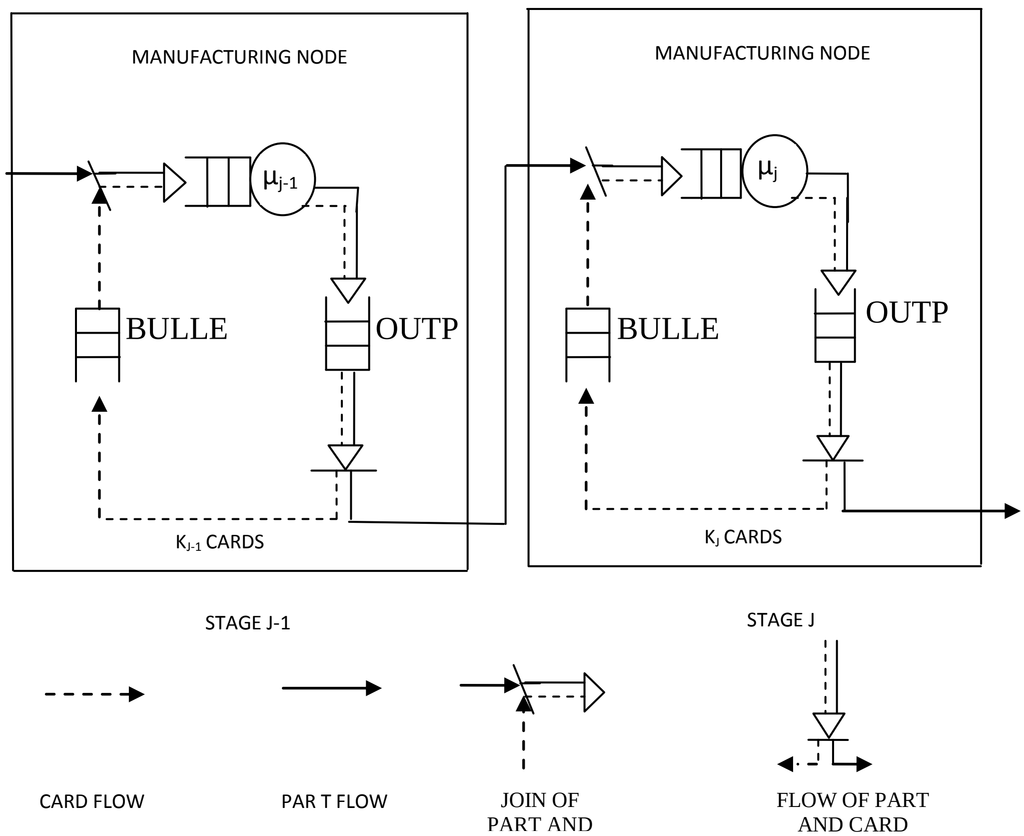


Figure 3. 4 Schematic diagrams for MTKS

2.2 Calculation of Throughput and Average Production Capacity Per Machine in Each Stage

Since the stages of the system are in tandem the throughput of stages are equal $\lambda_P(K_1)$ = $\lambda_P(K_2)$ = $\lambda_P(K_3)$.

Throughput of stage 1 = throughput of stage 2 = … =throughput of stage N.

i) Using equation (3.4) the throughput for stage 1 is

$$\lambda_P(K_1) = \begin{cases} K_1\mu_1, & K_1 < c_1, \\ c_1\mu_1, & K_1 \geq c_1 \end{cases}$$

ii) For the subsequent stages (j=2,3,…N), the average production capacity per machine or average service rate per machine μ_j value is computed based on K_j and c_j.

$$\mu_j = \begin{cases} throughput/K_j & , K_j < c_j \\ throughput/c_j, & K_j \geq c_j \end{cases}$$

2.2 Calculation of Mean Demand Rate

In a long run the number of parts in the output buffer of stage N is K_N. When the mean demand arrived in the stage j, this demand is satisfied and cards are sent to the bulletin board of stage j. These numbers of cards are the mean demand rate for j-1 stage. For stage N, the demand rate is the actual arrival rate of the customer.

$\lambda_{dN} = \lambda_d$

If the number of demand arrival is less than the number of kanban card in circulation then number of cards sent to the bulletin board depends on the demand arrival rate; otherwise it depends on the number of cards in circulation. Here the number of cards in the bulletin board is based on the demand arrival rate or number of cards in circulation of that stage.

The number of cards in bulletin board of stage j = min $\{\lambda_{dj}, K_j\}$

$\lambda_{dj-1} =$ min $\{\lambda_{dj}, K_j\}$ where j= 1, 2, 3,… N-1

2.3 Objective Function

After calculating the mean demand rate and production capacity of each stage, the objective functional value of each stage is computed using equation (3.9). The overall objective function value of multi stage system is obtained by the summation of stage Z's as given below which should be minimized.

$Z_{mult} = Z_1 + Z_2 + \ldots + Z_N$

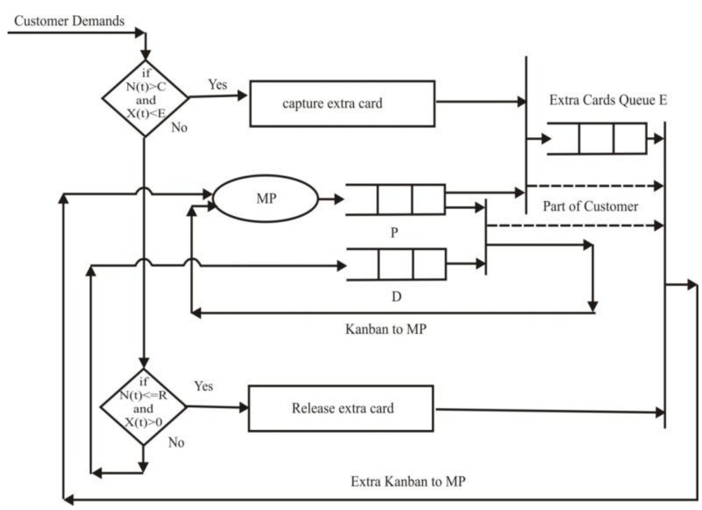
ADAPTIVE KANBAN SYSTEM

3.1 INTRODUCTION

Traditional Kanban System (TKS) is successful in a production environment with stable demand and lead time. However, when there is a wide variation in demand, with fixed number of cards the manufacturing process experiences either excess inventory or shortages. To overcome this problem AKS is proposed in which, the number of cards can be varied. A detailed study of AKS for single stage kanban system is presented in this chapter.

3.2 SINGLE STAGE ADAPTIVE KANBAN SYSTEM

Tardif and Maaseidvaag (2001) devised AKS to handle the variable supply and demand condition. Here the number of cards in use is allowed to vary, based on the current inventory and backorders. An extra card is added to the system if a demand arrives while the inventory level is below a release threshold (R). When the inventory level exceeds a capture threshold (C) a card is retrieved from the system. Queue P contains finished parts, and queue D contains backordered demands. The single stage adaptive mechanism uses K kanban cards and E extra cards. Again, MP represents the manufacturing process. Initially, before any customer demands arrive at the system, P has a base stock of K finished parts, queue E contains all the extra cards, and D and MP are empty. Let N (t) be the total number of parts in queue P minus the total number of backorders in queue D at time t. Let X (t) be the number of extra cards not in use at time t.



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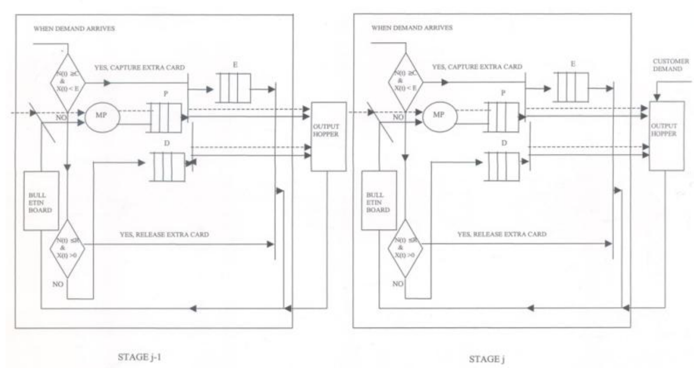


3.3 Calculation of Throughput and Average Production Capacity per Machine in Each Stage

Since the stages are in tandem throughput of all the stages are equal.

Throughput of stage 1 = throughput of stage 2 = ...= throughput of stage N.

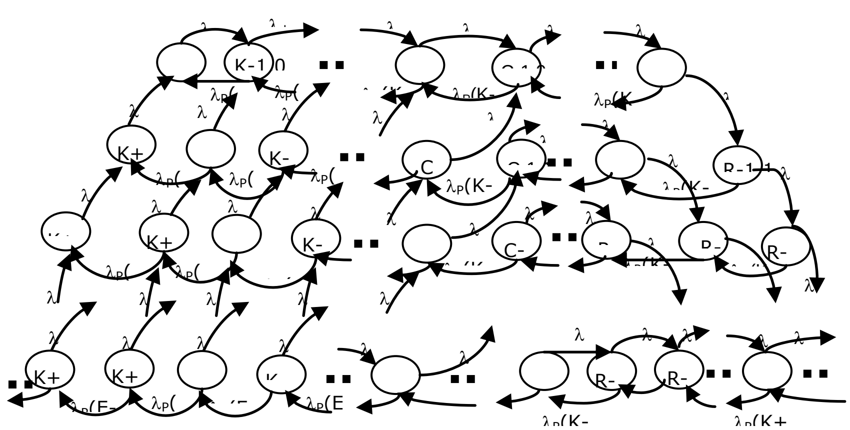
i) Using the equation the throughput for stage 1 is

$$\lambda_P(K_1+E_1)=\begin{cases}(K_1+E_1)\mu_1, & (K_1+E_1)<c_1,\\ c_1\mu_1, & (K_1+E_1)\geq c_1\end{cases}$$

ii) For the subsequent stages (j=2,3,...N) the value μ_j based on K_j and C_j.

$$\mu_j \quad =\begin{cases}\text{throughput } /(K_j+E_j)\ , & (K_j+E_j)<c_j\\ \text{throughput } /c_j, & (K_j+E_j)\geq c_j\end{cases}$$

Markovin Chain process used for Multi Stage Adaptive kanban system



The above diagram is only for example

3.4 Calculation of Mean Demand Rate

In the long run the number of parts in the output buffer of stage N is K_N+x. This number of parts is based on the mean demand rate, where x is number of extra cards in circulation. When the demand arrived in the stage j, this demand is satisfied, cards are sent to the bulletin board of stage j. These numbers of cards is used to determine the demand rate for j-1th stage. For stage N, the demand rate is the actual arrival rate of the customer.

$$\lambda_{dN} = \lambda_d$$

If the number of demand arrivals is less than the number of kanban cards in circulation then the number of cards sent to the pervious stage bulletin board depends on the demand arrival rate. Otherwise it depends on the number of cards in circulation. Here the number of cards in the bulletin board is the demand arrival rate of the previous stage.

The number of cards in bulletin board of stage j = min $\{\lambda_{dj}, K_j+x_j\}$

$$\lambda_{dj-1} = \min \{\lambda_{dj}, K_j+x_j\} \text{ where } j= 1, 2, 3,\ldots N-1$$

3.5 Objective Function

After calculating the mean demand rate and production capacity of each stage, objective functional value of each stage is computed using equation. The overall objective function value of MAKS is similar to MTKS given in equation.

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