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Algorithm for the design of single-stage adaptive kanban system ☆

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Abstract

The traditional kanban system with fixed number of cards does not work satisfactorily in unstable environment. In the adaptive kanban-type pull control mechanism the number of kanban is allowed to change with respect to the inventory and backorder level. It is required to set the threshold values at which cards are added or deleted which is a part of the design. Previous studies used the local search method to design the adaptive kanban system. In this paper Genetic Algorithm- and Simulated annealing-based heuristics are developed and used to set the design parameters of adaptive kanban system. The numerical results indicate that simulated annealing based heuristics produces better solution with improved computational efficiency.

Keywords: Kanban systems; Adaptive control; Markov chain; Genetic algorithm; Simulated annealing

1. Introduction

In pull-production system kanbans 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. Di Mascolo, Frein, and Dallery (1996) developed an analytical method for performance evaluation of TKS. Wijngaard (2004) and Karaesmen et al. (2004) used inventory control policies which resulted in, significant cost savings in the TKS through inventory reductions and improvement in customer service. Liberopoulos and Koukoumialos (2005) have presented a simulation model of TKS in which the effect of advanced demand information is analyzed. However, in unstable environment the TKS does not work satisfactorily. Philipoom, Rees, Taylor, and Huang (1987) and Rees, Philipoom, Taylor, and Hwang (1987) investigated the key factors that affect the number of kanbans in the system. Few authors have discussed systems in which the number of kanban cards

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in use is adjusted according to the status of the MP. Such systems are called flexible or adaptive kanban system (AKS) (Valerie Tardif & Lars Maaseidvaag, 2001). In this paper, based on a Markovian model of kanban system use of meta-heuristic are explored to estimate the design parameters of the AKS. The performance of such system is compared with TKS and AKS reported in literature.

2. Traditional kanban system (TKS)

In the traditional kanban system the number of cards in use is fixed as K. Customer demand drives the MP. 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 upstream for initiating the production. The demand that cannot be met with, due to non availability of finished part, stays as backordered demand.

2.1. TKS model

Valerie Tardif and Lars Maaseidvaag (2001) have developed kanban system as closed queuing model. In this system demand follows Poisson process with demand rate λ_d, the finished parts leave the manufacturing process according to state-dependent Markovian process and its processing rate $\lambda_p(n)$ depends on the number of parts n in the MP. The processing rate can be obtained by studying equivalent closed queuing network. For systems with single workstation consisting of c identical parallel servers with mean rate μ,

$$\lambda_p(n) = \begin{cases} n\mu, & n < c, \\ c\mu, & n \geqslant c \end{cases} \tag{1}$$

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

$$\lambda_p(n) = n\mu/(n + M - 1) \tag{2}$$

The behavior can be modeled as a birth and death process with infinite number of states. Let $P_K(i)$ be the stationary probability of state i with K cards. These probabilities exist only if

$$\lambda_d/\lambda_p(K) < 1 \tag{3}$$

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

$$\lambda_d P_K(i) = \lambda_p(\min(K - i + 1, K)P_K(i - 1)) \tag{4}$$

$$\sum_{i=-\infty}^{K} P_K(i) = 1 \tag{5}$$

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

The single-stage kanban system is optimized by choosing the parameter K, that minimizes the long-term average costs associated with backorders as well as holding inventory. Let b be the ratio of backorder cost to holding cost in the system. Let $B(K)$ be the expected backlog for K number of kanban cards. Hence, it is required to determine the value of K, such that the total cost is minimized as stated below

$$\text{Minimise } Z(K) = K + b * B(K) \tag{6}$$

3. Adaptive kanban system

In MP with fluctuation in demand, TKS with fixed number of cards leads to either huge WIP or heavy backorders. Hence the concept of dynamically varying the number of kanban card to suit the situation is given due consideration. Al-Tahat and Mukattash (2006) designed a synchronized single-stage kanban single-product kanban controlled production line in such a way that sustain a feasible WIP level in the system. Framinan,