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Effect of kanban size on just-in-time manufacturing systems

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Abstract

Setting kanban sizes is one of the first decisions that users of kanban system must address, yet researchers have largely assumed kanban sizes to be given. This paper investigates the effect of varying kanban size on the performance of just-in-time (JIT) manufacturing systems. Two types of JIT production systems, the Pull-type and the Hybrid-type are analysed using computer simulation models. The performance measures considered simultaneously are the fill rate, in-process inventory, and manufacturing lead time. Parameters such as demand rate, processing time, and kanban size are taken into consideration, thereby finding the possible solutions of the kanban size that can be employed to achieve the most favourable conditions for production. A favourable condition usually refers to the ability of the system to produce finished goods at a shortest possible lead time, which the customers are always demanding for. Both the single product and multi-products manufacturing environments are investigated.

With reference to the analysis, for a single product, as the kanban size increased, the fill rate decreased, whilst with both the in-process inventory and the manufacturing lead time increased. Generally, for multi-products manufacture, it was observed that as the kanban size increased, the fill rate increased with a decrease in the manufacturing lead time. However, for multi-products the interaction between the manufacturing lead time and the fill rate is discussed in depth in this paper.

Keywords: JIT; Kanban; Simulation; Fill rate; Pull system

1. Introduction

In many high-tech manufacturing enterprises, the just-in-time (JIT) philosophy has been adopted widely in their production system to minimize the level of inventory. Prior to making any comments on the pros and cons of the application of JIT theory in manufacturing situations, it should be defined clearly. The American Production and Inventory Control Society (APICS) defines JIT as ''In broad sense, an approach to achieving excellence in a manufacturing company based on the continuing elimination of waste (waste being considered as those things which do not add value to the product). In the narrow sense, JIT refers to the movement of material at the necessary place at the necessary time. The implication is that each operation is closely synchronized with the subsequent ones to make that possible''.

From the narrow sense, the underlying principle of JIT manufacturing philosophy is to produce the right quantity at the right time with the right quality level. To produce the desired quantity that both internal and external customers demand, at the time that they demand it, the kanban manufacturing system would be the most appropriate. ''Kanban'' is the Japanese word meaning for a card. In JIT, production is triggered by a kanban signal, which usually comes from the customer order or the master production schedule, the signal then flowing backwards via each work centre. Each work-in-progress (WIP) container is attached with a kanban, specifying the details of that particular WIP such as product name, part code, card number, batch number, lot size, due date, etc. By implementing JIT concepts in manufacturing, many of the practitioners experience advantages such as shorter lead times, fewer inventories, and higher quality.

To achieve this specific goal, numerous parameters in optimizing the conditions for the production system should be determined carefully. Amongst those, the size of the kanban is a very obvious one to be concerned. Generally, a large kanban size implies a higher inventory level but a shorter lead time benefited by less frequent machine set-up time.

The specific aims of this research paper on JIT systems are as follows:

1. An investigation of the influence of kanban size on the performance of JIT production systems, including both Pull and Hybrid systems.

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2. An examination of the effect of kanban size on the interaction of the fill rate and the manufacturing lead time in a JIT production system.
3. With reference to the above findings, to determine a feasible kanban size to optimize the performance of production in terms of fill rate and manufacturing lead time.

2. Literature review

Studies on the influence of kanban size in a JIT manufacturing system have been a popular topic over recent decades. Many researchers have focused on finding the optimal number or size of kanbans in production systems. In fact, studies on the JIT system can be classified broadly into two categories: (i) evaluations on the performance of JIT systems in terms of system parameters such as makespan, inventory level, machine utilization and carrying cost, etc.; (ii) comparison between the traditional Push-type and kanban-based Pull-type manufacturing systems.

Chan and Tang [1] compared the performance of the Push and Pull systems via simulation models. Traditional Push, Pull, and Hybrid (long-Pull) systems were brought to comparison. Comparative analysis of results was further processed aided by the analytic hierarchy process (AHP) method [2]. The study concluded that the performance of Hybrid manufacturing system achieved the best rating amongst the three.

Huang and Kusiak [3] gave an overview and a detail description of three kinds of JIT systems, namely, single, dual and semi-dual kanban card systems. From the operational mechanisms, material flow, kanban flow, and the extent of the appearance of different types of kanban card, were explained clearly.

Several studies [3–5] agreed with Toyota's equation for computing the optimal number of kanbans required for production. The optimal number of kanbans, n, can be expressed generally by the following equation:

$$n = \frac{d_{\mathrm{ave}}(t_{\mathrm{w}} + t_{\mathrm{pc}})(s)}{k} \quad (1)$$

where d_{ave} is the average daily demand, t_{w} the waiting time, t_{pc} the processing time per container, s the safety factor, and k the container size.

Berkley [6] developed simulation models to determine the minimum number of kanbans in achieving a desired production rate for tandem queues. The models were further modified into a two-card kanban controlled system [7]. In the findings, it was emphasized that tandem queue models was not equivalent to two-card kanban controlled systems, especially in the case where processing stations were not located closely together, in which material handling occurs periodically such as in job–shop environments. Berkley [7] concluded that the optimal number of kanbans can be determined only at trade-offs between the costs of frequent material handling and the benefits of lower WIP levels.

Some other studies such as those of Karmarker and Kekre [8], and Yavuz and Satir [4] concluded that reducing the kanban size improves the performance of the system by lowering the inventory levels and the makespan. On the other hand, increasing the kanban size will accumulate WIP, but improve the fill rate, which implies better customer services.

Savsar [9] carried out a study on the optimal kanban size for production in an electronic assembly line. A simulation model was built by Siman for analysis, the kanban size in this case being fixed, instead the number of kanbans being varied in order to find the optimal number of kanbans for production to fulfil the weekly demand. Optimal results were judged by the percentage of demand met.

The integration of manufacturing information into the JIT systems was investigated by Pourbabai [10], information such as bills of materials, and process plans being utilized. Mathematical programming models were used to minimize the system objectives, such as maximum tardiness and makespan. The optimal operational plan was found by using iterative procedures, which minimize the congestion existing in the material handling system and the workstation.

In a high variety/low volume manufacturing environment, difficulties are encountered with the implementation of a kanban system. Stockton and Lindley [11] highlighted the limitations of traditional approaches in applying group technology in the captioned environment. A process sequence cells algorithm was proposed to balance the production of each working cell. The layout of equipment was generated, which enabled the appreciation of kanban signal to control the material movement.

Ohno et al. [12] determined the optimal number of kanbans by introducing a cost model into a two-card kanban system, with a fixed kanban size. The objective of the algorithm that was devised was to determine the optimal number of kanbans, that can be employed to minimize the expected cost per period. Ohno's paper deals with stochastic demand, and the results show that a certain value of number of kanbans can achieve the lowest average cost by balancing the backlogged inventory and ordering cost.

Muckstadt and Tayur [13] introduced four sources of variability into the kanban controlled system, namely, processing time variability, machine breakdowns, rework, and yield loss. Ref. [14] was actually a sequel of the previous paper [13], but was more concentrated on the study on the performance of the systems based on simulations, heuristics and sample path. The results were summarized in the form of a list of different situations where manufacturers may find useful for reference.

Anwar and Nagi [15] proposed a different point of view to the common belief of best JIT strategy. In their paper, they found that the product makespan and the production cost could be reduced further if efficient lot grouping combined with scheduling is adopted. Parameters such as due dates, number of units to be produced, processing time, set-up time