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Design and analysis of production control scheme for Kanban-based JIT environment

Mohammad D. Al-Tahat[a,*], Adnan M. Mukattash[b]

[a]Industrial Engineering Department, University of Jordan, Amman 11942, Jordan
[b]Industrial Engineering Department, The Hashemite University, Zarka 13115, Jordan

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Abstract

This paper aims at designing production control scheme for Kanban-based just-in-time (JIT) environment. Synchronization mechanism for a single-stage single-product Kanban-controlled production line is developed, in such a way that yields a feasible operating cost as well as a feasible average of work-in-progress (WIP). The Kanban production line is formulated as $(M/M/s : GD/\infty/\infty)$ queuing model. A new approach for analyzing the queue model is discussed. An operating cost model is then developed to determine the unknown parameters of the system. Numerical examples are used to demonstrate the computations of different system parameters. Avenue for future research is also indicated.

Keywords: Kanban; Pull production systems; Shop floor control; Material control policies

1. Introducing the research problem

Partially completed products that are currently in the shop are referred to as work-in-progress (WIP). The WIP may be in a queue awaiting the availability of their next workstation, being loaded or processed on a machine, or being moved between workstations. In addition, WIP may exit because of parts being held in temporary storage pending approval from customer or instructions from engineering due to a design change,

*Corresponding author. Tel.: +962 6 535 5000x2793; fax: +962 6 535 5588.
E-mail addresses: altahat@ju.edu.jo, altahat@yahoo.com (M.D. Al-Tahat), adnanm63@yahoo.com (A.M. Mukattash).

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or a decision on disposition resulting from a quality problem, or arrival of other parts/materials to be mated with these parts in a next production operation.

Design of a single-stage Kanban-controlled production line that produces a single-product type is considered as the problem of this work. This Kanban station contains WIP parts that are currently being processed. The raw material enters the workstation after receiving them from the suppliers, and the WIP, as flows through the line. The process of transporting WIP continues until the finished product departs the workstation and then delivered to the customer in time. The output rate of the workstation is generally dictated by the demand of the final products. An important executive concern is how to control and synchronize the flow of materials among the line; so as to create a consistent integrated shop floor control system that successfully meets the customer demand just-in-time (JIT). Several researches have contributed to the development of many approaches for solving such dilemma, among which the Kanban control policy that was invented in Toyota in the 1970s, and has since been widely used in industry [1]. Flexible Kanban system is discussed by [2]. The CONWIP control policy is described and analyzed by Gstettner et al. [3] and Wen et al. [4]. The base stock control policy is also described and analyzed by Scott et al. [5]. The generalized Kanban control system is introduced by Buzacott [6]. The generic Kanban systems for dynamic environment is modified by Chang et al. [7]. The extended Kanban control system is proposed and discussed by Claudine et al. [8], and many others. A comparison of these control policies as well as other policies can be found in Liberopoulos and Dallery [9] and Zhao et al. [10]. Comparisons of the performance of these policies indicate that no one strategy completely dominates the other [11]. Deep exploration of the tradeoffs using analytical models could help differentiate regions where each policy dominates over the other. Ananth et al. [11] stated that queuing models seem to be the most useful tool for such analysis. They modeled Kanban policy as a closed cyclic queuing network with manufacturing stations and fork/join synchronization workstations. Consequently, they proposed parametric decomposition approach and followed two-moment approximations to analyze the system. Stefan et al. [12] present a generalized analysis technique for queuing networks with mixed priority strategy and class switching; they show how to transform a queuing network that cannot be solved into a network model that can be solved using a standard analysis technique. A general purpose analytical method for performance evaluation of multistage single part Kanban-controlled production line is developed by Dallery [13]. The system is modeled as a queuing network. Original Kanban system is decomposed into a set of subsystems, then each subsystem is associated with a particular workstation and analyzed in isolation using a product from approximation technique.

Akturk et al. [14] present a literature review on the classification techniques of determining both the design parameters and Kanban sequences for JIT manufacturing systems. They also summarized the model structures, decision variables, performance measures and assumptions in a tabular format. A key result on the throughput equivalence has been derived by Paik et al. [15] for a general fork/join queuing network with finite buffers and GI service time distribution. Bhaba et al. [16] constructed a cost function that is developed based on the cost incurred due to the raw material, WIP between workstations, and the finished goods. They obtained an optimal number of raw material orders that minimize the total cost function, which used to find the optimal number of Kanban.

A minimum level of WIP yields lowers total inventory cost as well as lowers unit production cost. Therefore, minimizing WIP inventory level is supposed to be considered