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Effect of product mix on multi-product pull control

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ABSTRACT

Product mix influences the performance of pull production control strategy in multi-product manufacturing systems. The complexity of product mix on the performance of a manufacturing system is primarily based on the characteristics of the demand and production control strategies. Demands are mainly characterised by volume and product-type while production control strategy is characterised by material release time, part flow, inventory control and throughput times. In multi-product systems, pull production control strategy operates dedicated or shared Kanban allocation policy. This paper examines the performance of the Generalised Kanban Control Strategy (GKCS), Extended Kanban Control Strategy (EKCS) and Basestock Kanban-CONWIP (BK-CONWIP) control strategy operating Shared Kanban Allocation Policies (S-KAP) or Dedicated Kanban Allocation Policies (D-KAP) for a healthcare parallel/serial assembly line with setup times. A simulation based multi-objective optimisation technique was adopted to examine the effect of different product mixes on the strategies and policies. A ranking and selection technique for multiple systems was used to screen the performance of the strategies. It was shown that product mix variability in a system influence the inventory levels of the pull control strategies examined. However, the performances of the strategies vary with strategies operating S-KAP having better inventory control than strategies operating D-KAP. Similarly, BK-CONWIP outperformed its alternatives.

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1. Introduction

Pull production control strategy initiates production of parts in a system based on actual demand and it uses signal cards commonly referred to as production authorisation cards to authorise the release of parts in a system such as in Kanban control strategy [1]. However, some pull production control strategies use only the actual demand information to authorise the release of parts into a system for instance, the Basestock control strategy [2]. Kanban control strategies have been widely studied resulting in its variations and they are referred to as pull production control strategies based on their ability to use actual demand to authorise the release of parts into a system [3]. The effective implementation of pull production control strategies especially in single product manufacturing environments led to the acceptance of pull as a superior strategy over the push strategy [4–6]. Furthermore, Krishnamurthy et al. [6] noted that the success of pull production control strategies in certain original equipment manufacturers led to the suggestion that the implementation of pull production control strategy in all areas of the supply chain would be valuable. However, their paper suggested that pull control strategies perform poor in multi-product systems with different demands and/or processing requirements, and in cases of highly engineered

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products in small batches. In addition, the implementation of pull production control strategies in complex assembly lines results in proliferation of Work-In-Process (WIP) inventory in order to maintain a minimum WIP inventory in the system [7].

On the other hand, various research studies have integrated push and pull production control strategies to enhance the performance of these strategies to suit certain manufacturing conditions such as systems with a high-level of instability [3,8]. One of these newly developed pull production control strategies is the Paired-cell Overlapping Loops of Cards with Authorisation (POLCA) [9]. POLCA was developed for quick response manufacturing and appropriate for assembly lines [9–12]. The findings of these studies show that POLCA is a promising pull production control strategy designed for make-to-order manufacturing environments. However, the comparison of the paired-cell overlapping loops of cards with authorisation and generic paired-cell overlapping loops of cards with authorisation (GPOLCA) and material requirement planning showed that POLCA was not the best production control strategy for complex multi-product systems or make-to-order systems [13]. POLCA was shown to perform poor with respect to machine utilisation, cell efficiency and response to irregular product mixes and demand volumes.

In response to the problems of cell efficiency and machine utilisation, the cellular manufacturing was developed from the principles of group technology [14]. The importance of cellular manufacturing is that it minimises the WIP inventory, setup times, lead times and workforce [14–16]. Studies on cellular manufacturing and/or cellular manufacturing designs based on stochastic or deterministic models [14,17,18], show that increase in number of machines and/or cells increase the systems' performance in terms of a higher service level and a lower WIP inventory and at the same time decrease the efficiency of the cell and the utilisation of the machines. Nonetheless, the poor performances of cellular manufacturing to erratic product mixes and volumes have not been addressed [19–21]. Therefore, the issues of product mix and demand volume require further attention.

This paper studies the behaviour of three pull production control strategies (GKCS, EKCS and BK-CONWIP) in S-KAP and D-KAP modes, in a four-product multi-stage parallel/serial assembly line with setup times under different product mixes. Simulation based multi-objective optimisation technique was used to optimise and generate Pareto-frontier for the control parameters. The focus is on configuring a system with optimal settings based on a dataset. Then, study the performance of the control strategies in terms of inventory control and service level, while varying the product mix at constant demand volume without re-optimisation of the system parameters. The remainder of this paper is organised as follows: Section 2 presents a review of the relevant studies of multi-product pull production control strategies. Section 3 provides a description of the assembly line and the experimental setup. Section 4 presents the results obtained from the simulation, while Section 5 presents the conclusion, insight and future research of the study.

2. Background

In recent years, a growing interest has been observed in the literature regarding research studies on multi-product manufacturing systems [22]. The literature showed that a substantial number of these studies concentrated on the scheduling and planning issues in a system, optimisation of the control parameters of a system, while few others evaluated the performance of various production control strategies [3]. The works of Akurk and Erhun [23], Hum and Lee [24] showed different approaches for resolving scheduling issues; such as determining the product-type that enters a stage or manufacturing process from a buffer containing various product-types waiting for the same manufacturing process at the same time in multi-product systems. Bard and Golany [25] proposed an analytic model for optimisation of the production authorisation cards to decrease the WIP inventory in a multi-product system. Park and Lee [26] developed an approximation method for evaluating a multi-product CONWIP system with correlated external demands. Similar studies on multi-product CONWIP systems and its variations include [27–31]. Their studies focused on the effect of the WIP cap of CONWIP in multi-product systems.

Other areas of interest in multi-product systems found in the literature include the studies on issues of routing of product-types, issues regarding setup times and capacity. Li and Huang [32] proposed a recursive technique to determine a split and merge process in multi-product systems. Altiok and Shiue [33] examined one-machine multi-product system with sequence independent setups. Krieg and Kuhn [34] studied multi-product systems with sequence independent setups, Kanbans and cyclic scheduling policy. Dasci and Karakul [35] evaluated a multi-product system with finite buffers and sequence dependent setups via an iterative method. Feng et al. [36] evaluated the performance of a multi-product system with sequence dependent setups, finite buffer and cyclic policy. These works provide insights on the impact of routing, finite buffers and setups in multi-product systems.

2.1. Production authorisation card

Additional innovation in pull controlled multi-product systems is the design and implementation of the production authorisation cards. Also, the literature shows a growing interest on the effect of production authorisation cards policies on pull production control strategies in multi-product systems [37,38]. Gurgur and Altiok [39] examined the implementation of a two-card Kanban control policy in a multi-stage multi-product system. They proposed an approximation algorithm to evaluate the WIP inventory and service levels for each product-type. Baynat et al. [40] proposed the sharing of production authorisation cards between product-types in multi-product systems. Their paper showed two production authorisation

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