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Card-based delivery date promising in high-variety manufacturing with order release control

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ABSTRACT

Card-based systems – like Kanban and Constant Work-in-Process (ConWIP) – can be simple yet effective means of controlling production. Existing systems, however, can be criticized for their limited applicability and scope. First, card-based systems have not been successful in the production environments that are arguably most in need of their help: complex job shops that produce low-volume, high-variety products. Second, while most existing systems simplify shop floor control, other planning tasks – such as the estimation of short, feasible due dates during customer enquiry management – are not supported. To overcome these limitations, a card-based version of Workload Control – known as COBACABANA (*CO*ntrol of *BA*lance by *CA*rd-*BA*sed *NA*vigation) – was recently proposed that uses cards for both due date estimation and order release control. This unique combination makes COBACABANA a potentially important means of controlling production, particularly for small job shops with limited resources. However, the original approach had several shortcomings. This paper refines the due date estimation procedure of COBACABANA to make it more practical and consistent with the order release method applied. It then uses simulation to demonstrate – for the first time – the potential of COBACABANA as an integrated concept that combines customer enquiry management and order release control to improve job shop performance. Results also suggest that the need for processing time estimations can be simplified, further facilitating the implementation of COBACABANA in practice.

1. Introduction

Card-based systems, such as Kanban (e.g. Sugimori et al., 1977; Shingo, 1989) and Constant Work-in-Process (ConWIP; e.g. Spearman et al., 1990; Hopp and Spearman, 1996), provide a simple, visual approach to controlling production and have helped repetitive manufacturers reduce costly buffers while maintaining short lead times. However, researchers and practitioners have reported that these card-based systems are not equally effective in job shops producing a high variety of made-to-order, customized products (e.g. Germs and Riezebos, 2010; Harrod and Kanet, 2013). Even Paired cell Overlapping Loops of Cards with Authorization (POLCA; e.g. Suri, 1998; Riezebos, 2010), which was designed to cope with more variability than Kanban and ConWIP, still requires a certain degree of repetitiveness in order to be effective. Hence, to date, simple card-based production control systems have not been successful in complex job shops. But these shops are often small firms and, therefore, arguably in most need of card-based support since other solutions require an investment in expert knowledge and advanced technology that exceeds their resources. Moreover, existing card-based systems are restricted to controlling either the release of orders to the shop floor, e.g. ConWIP, or to controlling both order release and order progress on the shop floor, e.g. Kanban and POLCA. They do not support other planning tasks, such as due date estimations during customer enquiry management. This limits the advantage of using a simple, card-based control system and requires companies to maintain sophisticated planning and control processes to support these other tasks.

Production control in job shops that produce customized products to order is very challenging since finished goods cannot be stocked in advance of demand and detailed order specifications, e.g. processing and set-up times, are often uncertain as it may be the first time that an order has been placed. This makes many approaches to production planning and control presented in the

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literature, such as optimized scheduling approaches, unfeasible. In general, few production planning and control systems – irrespective of whether they are card-based or otherwise – have been developed that are suitable for such contexts (e.g. Stevenson et al., 2005). One exception is the originally non-card-based Workload Control concept, which has been demonstrated to improve job shop performance through simulation (e.g. Thürer et al., 2012, 2014a; Fernandes et al. 2015) and action research (e.g. Hendry et al., 2013). To use Workload Control, a manager must make complex workload calculations, which typically requires both an investment in software, to provide a decision support system, and an investment in hardware (e.g. barcode scanners) to collect data from the shop floor (see, e.g. Stevenson and Silva, 2008; Hendry et al., 2013). These complex calculations and the prerequisites for implementation affect Workload Control's suitability, particularly for small shops with limited resources. As a result, many studies have found implementing Workload Control in practice to be extremely challenging (e.g. Stevenson, 2006; Hendry et al., 2008; Stevenson et al., 2011).

In response to the need for simple, visual production control, Land (2009) developed COBACABANA (*CO*ntrol of *BA*lance by *CA*rd-*BA*sed *NA*vigation), which is a card-based approach for embedding the core principles of Workload Control. These principles are to: (i) stabilize the workload; and, (ii) ensure there is a short yet feasible allowance for the delivery time. COBACABANA operationalizes these principles by first controlling the release of orders to the shop floor and, second, by using the higher level customer enquiry management procedure to accept/reject orders and ensure appropriate delivery time allowances. Hence, COBACABANA is unique in that it incorporates card-based due date determinations during customer enquiry management and a card-based order release control system. Many rules for determining due dates in job shops have been presented (e.g. Weeks, 1979; Ragatz and Mabert, 1984; Thürer et al., 2013 for a recent review), but effective rules typically require software support. In contrast, and to the best of our knowledge, COBACABANA represents the first card-based approach to estimating due dates. As it is card-based, COBACABANA does not require software support.

Although COBACABANA provides a potential card-based solution for small job shops with limited resources, Land's (2009) original approach suffers from several shortcomings, which are addressed here. More specifically, this study refines COBACABANA's customer enquiry management stage, including its due date estimation procedure. It then demonstrates the effectiveness of our refinements and – for the first time – the potential of COBACABANA as an integrated concept to improve performance in job shops using simulation.

The remainder of this paper is organized as follows. COBACABANA is first described and then refined in Section 2. Section 3 outlines the job shop simulation model used to examine its performance, before the results are presented and discussed in Section 4. Finally, concluding remarks are made in Section 5, where managerial implications and future research directions are also outlined.

2. COBACABANA – a simple card-based approach to workload control

COBACABANA is based on the Workload Control concept, which integrates two control levels: order release and customer enquiry management. These two levels will be discussed in Sections 2.1 and 2.2, respectively before Section 2.3 summarizes COBACABANA as a comprehensive concept.

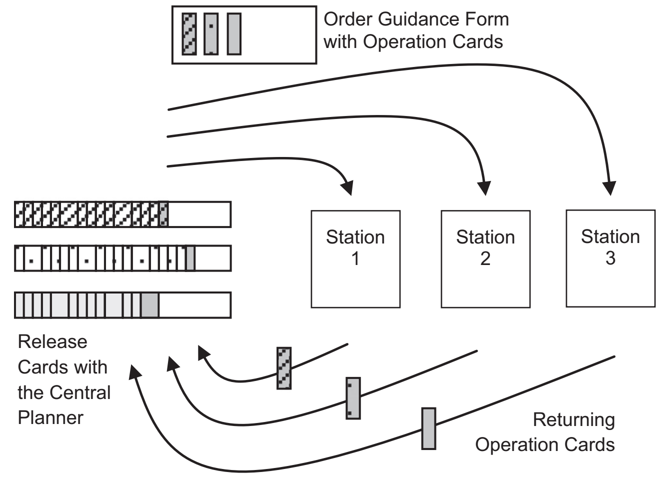

Fig. 1. Card-based order release with loops between the central planner and stations on the shop floor.

2.1. COBACABANA: card-based order release

Workload Control stabilizes the shop floor workload using order release control to decouple the shop floor from a pre-shop-pool of orders. Orders are released from the pool onto the shop floor in time to meet their due dates while keeping the shop floor workload balanced. The order release method outlined here follows the refinements proposed by Thürer et al. (2014b) to Land's (2009) original card-based concept; being its potential to improve performance in high variety contexts recently been demonstrated in Thürer et al. (2014b and 2015).

COBACABANA establishes card loops between the planner performing the order release decision and each station on the shop floor, as illustrated in Fig. 1. At fixed (periodic) intervals, orders in the pool are sorted according to their planned release dates. Orders are then considered for release in sequence.

Each operation in a job has one *release card* and one *operation card*. The size of the release card represents the corrected workload of the operation (as described in Section 2.1.1 below). To consider an order for release, the planner places the release card that corresponds to the corrected workload of the order at each station in its routing in each station's area on the planning board. The planner then compares the station workloads with the predetermined workload limits or norms. If, for any station in the routing of an order, the workload represented by the release cards on the planning board exceeds 100% of the workload limit, the order is retained in the pool and the order's release cards are removed from the planning board. Otherwise, the order's release cards remain on the planning board, the planner attaches the corresponding operation cards to an order guidance form that travels with an order through the shop, and the order is released. This process continues until there are no unexamined orders in the order pool. The shop floor returns each operation card to the planner as soon as the operation is completed. This closes the information loop and signals the planner can remove the release card that matches the operation card from the planning board. This process could be simplified by color coding the cards, so that each station is represented by a color, similar to POLCA (Riezebos, 2010).

Fig. 2 illustrates how the planning board is used when making a release decision. In this example, a new order with two operations is considered for release: one operation at Station 1 and one at Station 3. In this example, since both operations can be loaded into their respective stations without exceeding the workload norm,