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Cobacabana (control of balance by card-based navigation): A card-based system for job shop control

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ABSTRACT

Existing card-based production control systems such as Kanban are mostly dedicated to repetitive production environments. Cards-based systems for job shop control are lacking, while particularly this industry segment shows a need for simple control systems. This paper aims at filling the gap by presenting a simple card-based system for job shop control, the Cobacabana (control of balance by card-based navigation) system. It is based on the concept of workload control (WLC), which has already proven its value in job shops. Developments towards more robust norms now allow for transforming the WLC concept into a simple card-based system, with loops of cards accompanying orders from release until completion at critical work centers. Cards returning from work centers authorize the planner to release new orders. A card-based display supports the planner with an overview of the shop floor situation, based on non-released cards. An additional loop of cards between sales and planning enables support of the order acceptance and due date promising function. A card-based acceptance display indicates what delivery dates are realistic, considering the current workload situation. Both the scientific roots of the system and practical implementation issues are discussed in this paper.

1. Introduction

Particularly, the large industry segment of small make-to-order job shops is confronted with a lack of support for production planning and control. Industrial practice shows that hardly any job shop is able to use the planning and control modules provided in its ERP-package. Many solutions provided in ERP-packages focus on Gantt chart or Leitstand scheduling, which is generally doomed to fail in job shops because of the high data maintenance requirements and because of their high sensitivity to uncertainty, resulting in unstable schedules. Other ERP-packages only provide material-oriented planning solutions such as MRP, while capacity planning and control is critical in most job shops. To prevent from turning back to legacy systems, these companies often opt for a planning and control system which can be implemented with limited software support. This creates an obvious need for card-based systems in job shops.

The popularity of card-based control systems has been rising since the introduction of Kanban as a material control system for repetitive manufacturing environments. During the last decennium new card-based systems such as POLCA (Suri, 1998) have been developed, which can be implemented in capacity-oriented control situations. The Generic POLCA system (Fernandes and do Carmo-Silva, 2006) can be seen as an important step to make POLCA principles suitable for the specific situations of job shops. It links POLCA card loops with capacity allocations at the order release decision. Still, the basic idea of POLCA to use card loops for each possible combination of successive work centers will reduce its practical applicability in shops with high routing mix

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variability. In a computerized system, POLCA principles have been adapted for use in a job shop (Vandaele et al., 2005). But, as also concluded by Stevenson et al. (2005), none of the currently available card-based systems will meet the dynamic requirements of job shop manufacturing.

This paper aims at filling the gap in card-based systems by choosing a perspective, which is different from the existing POLCA variants. Instead it elaborates on the concept of workload control (WLC), a concept, which fits the typical characteristics of job shop manufacturing (Henrich et al., 2004a). The use of norms in this concept facilitates a translation into numbers of cards. Earlier research (Oosterman et al., 2000) shows that the workload norms used in classical methods of WLC are sensitive to changes in the order mix. But the developments towards more robust norms allow for transforming the concept into a simple card-based system.

The theoretical foundations for the new card-based system are presented in Section 2. Section 2 briefly discusses the basic principles of the WLC approach to job shop control. The recent developments towards robust norms are reviewed and supplemented such that norms can be translated into numbers of cards. Section 3 discusses the developed Cobacabana (control of balance by card-based navigation). Order release based on workload norms is transformed into cards loops between the planner and critical workstations. Additional card loops between Planning and Sales are introduced to support delivery date promising. Before concluding in Section 5, Section 4 briefly assesses the implementation issues related to the introduction of Cobacabana systems.

2. Conceptual backgrounds

The system developed in this paper finds its roots in the concept of WLC, a concept developed in the early 1980s. The concept has been built on release methods using workload norms for all critical workstations. The original release methods are best presented in Bertrand and Wortmann (1981), Bechte (1988), Hendry and Kingsman (1991) and first compared in Land and Gaalman (1996). Other decision functions in the framework built around these release methods are order acceptance and due date promising (e.g. Hendry and Kingsman, 1993; Bechte, 1994), output control in terms of capacity management (Kingsman and Hendry, 2002), and priority dispatching. However, when a release method functions well, priority dispatching decisions at individual workstations become less effective or even counterproductive (Land, 2004). Thus, the concept of WLC favors the use of simple priority rules. The original release methods have been intensively studied, evaluated and improved during the last 10 years. A recent overview of this research can be found in Stevenson and Hendry (2006). The improvement most relevant for the development of a card-based system has been researched proposed by Oosterman et al. (2000). Oosterman et al. discuss an adjustment of classical aggregate load calculations, which allows for constant workload norm levels, independent of routing mix variations.

The philosophy underlying WLC is based on creating predictable and short throughput times for each critical workstation. Particularly, predictable and short throughput times are lacking in most job shops because of all types of variability that characterize this environment. Nevertheless, predictable throughput times are important for a good timing of order releases, for quoting realistic delivery times and for a good timing of capacity adjustments. Short shop floor throughput times increase the flexibility to deal with possible customer order changes, changes which are not uncommon in most job shops. Besides, short throughput times encompass the direct advantages of a transparent shop floor with low WIP. A predictable short throughput time at a workstation is enabled by keeping its direct load at a constant level, the direct load being measured as the sum of the processing times of orders waiting or already being processed at the workstation. Before being released orders will wait in a centrally controlled order pool. The pool buffer can absorb both fluctuations in capacity requirements and capacity availability. It is obvious that constant direct loads can only be realized by releasing an appropriate set of orders to the shop floor. This function of order release has been indicated as its load-balancing function (Land and Gaalman, 1996). It should be recognized that order release is the last moment one can effectively contribute to a constant direct load. The effectiveness of load-balancing dispatching rules (e.g. Work-In-Next-Queue) after release is limited.

The direct load L_{st}^{D} of a workstation s at time t—being the sum of processing times of all orders waiting or being processed—can be specified by Eq. (1). In the calculations below orders will be addressed as jobs.

$$L_{st}^{\mathrm{D}} = \sum_{j \in J} p_{js} I(t)_{[t_{js}^{\mathrm{Q}}, t_{js}^{\mathrm{C}})} \quad (1)$$

with p_{js} is the processing time of job j at station s; J the set of all existing jobs; t_{js}^{Q} the time of arrival of job j at station s; t_{js}^{C} the time of completion of job j at station s.

The indicator function $I(t)$ is defined as $I(t) = 1$ at the specified interval, $I(t) = 0$ otherwise.

Notice that the release of a job will not directly affect the direct load of a workstation, unless the station performs the first operation in the routing of the job. Therefore a group of classical release methods focuses on controlling aggregate loads. Aggregate loads additionally incorporate all work which is still upstream of the workstation being considered. The aggregate load L_{st}^{A} of station s at time t can be specified by

$$L_{st}^{\mathrm{A}} = \sum_{j \in J} p_{js} I(t)_{[t_j^{\mathrm{R}},\, t_{js}^{\mathrm{C}})} \quad (2)$$

with t_j^{R} time of release of job j (all other variables as defined before).

However, it can be shown (Land, 2004) that control of aggregate loads does not necessarily leads to control of direct loads in case of a fluctuating routing mix. Moreover, the average direct load $\bar{L}_{st}^{\mathrm{D}}$ resulting from the set of jobs in the aggregate load of a workstation will be at the level