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Technical Paper

Improving performance in POLCA controlled high variety shops: An assessment by simulation

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ABSTRACT

POLCA (i.e. Paired-cell Overlapping Loops of Cards with Authorization) is a card-based production control approach developed to support the adoption of Quick Response Manufacturing. The approach has received significant research attention but has remained largely unchanged since its introduction in the late 1990s. The main improvements have occurred in the context of an electronic POLCA system, but such developments undermine the simplicity of the original card-based concept. We ask: is there any refinement possible to enhance the performance of POLCA without jeopardizing its simplicity? By analyzing POLCA, two possible refinements are identified: (i) the choice of rule to support both the card allocation and dispatching decisions; and (ii) the use of a starvation avoidance mechanism to overcome premature station idleness, as reported in the context of load limiting order release. Using simulation, we demonstrate that performance gains can be obtained by using different rules for card allocation and dispatching other than the earliest release date rule typically applied in POLCA for both decisions. Further, results demonstrate performance improvements for all combinations of card allocation and dispatching rules considered via the addition of a simple starvation avoidance mechanism. Both refinements significantly enhance POLCA performance, potentially furthering its application in practice.

1. Introduction

POLCA (i.e. Paired-cell Overlapping Loops of Cards with Authorization) is a production planning and control system that combines a card-based pull element (the "POLC" in "POLCA") with a higher-level Material Requirements Planning (HL/MRP) system for release Authorization (the "A" in "POLCA"). Suri [32] was the first to present POLCA as a production planning and control approach to support the adoption of his Quick Response Manufacturing philosophy, or the pursuit of time-based competition (Stalk [30]). POLCA has been argued to be an alternative to *kanban* systems specifically for companies that produce a high variety of products on a make-to-order basis (e.g. Krishnamurthy & Suri [18]; Riezebos [26]).

POLCA however has remained largely unchanged since its introduction in the late 1990s (Riezebos [26]). One of the few improvements reported has been the introduction of color-coded cards by Pieffers & Riezebos (2006, cited in Riezebos [26]). Stations were given a specific color, meaning each POLCA card consists of two colors, which allowed POLCA cards and routes to be identified more easily. Vandaele et al. [35] presented two further refinements but in the context of an electronic POLCA system. First, a method for dynamically determining lead time allowances based on a queuing model and a so-called ARP (Advanced Resources Planning) system instead of fixed lead time allowances. Second, an approach for setting the work-in-process limit per POLCA loop based on input data derived from the ARP system. The first refinement addressed a weakness in the prioritization of orders while the second addressed a weakness in capacity control. Vandaele et al.'s [35] refinements however rely on the use of an electronic POLCA system, which in turn requires rather specific expert knowledge. This undermines POLCA's simplicity and, as a consequence, hinders its application to smaller shops with limited resources. These shops often operate as high variety make-to-order companies – the type of shop for which

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POLCA was originally designed (e.g. Suri [32]; Krishnamurthy & Suri [18]; Riezebos [26]).

Against the above backdrop, the question remains: is there any refinement possible to enhance the performance of POLCA without jeopardizing its simplicity? This paper seeks to address this question in order to enhance the performance of POLCA, thereby furthering its application in practice. To achieve our objective, POLCA is first analyzed to identify possible refinements before extensive simulation experiments are used to assess the effectiveness of our proposed refinements.

The remainder of this paper is structured as follows. In Section 2, we review the mechanisms underlying POLCA and outline possible means of refinement. The simulation model used to evaluate performance is then described in Section 3 before the results are presented, discussed, and analyzed in Section 4. Finally, conclusions are drawn in Section 5, where managerial implications and future research directions are also outlined.

2. Background – the POLCA production planning and control system

POLCA is a production planning and control system that combines a card-based pull element with a HL/MRP system for release authorization. It can consequently be classified as a hybrid push/pull system (Esmaeilian et al. [8]); using a pull system local information about the status of production and inventories to control order release, while a push systems relies on global information (Selçuk [28]). This section does not aim to present a comprehensive review of the POLCA literature; although no explicit review paper on POLCA exists, an extensive literature review is provided within the work of Riezebos [26]. The aim of this section is twofold: (i) to outline the POLCA system in order to provide insights into its underlying mechanisms; and, (ii) to outline proposals for refinement. Section 2.1 describes POLCA before Section 2.2 discusses proposals for refinement.

2.1. Mechanisms underpinning a POLCA system

POLCA links the different stations, often referred to as cells in the POLCA literature, in the routings of orders using card loops. POLCA uses card-loops between pairs of stations, e.g. between stations A and B. Each pair of consecutive stations in the routing of a job has a POLCA card that identifies the two stations. A major difference between POLCA and, for example, *kanban* systems is that POLCA cards are job anonymous (Riezebos et al. [27]; Ziengs et al. [36]) while *kanban* cards are not (Shingo [29]). In this aspect, POLCA cards resemble ConWIP (Constant Work-In-Process) cards. In other words, POLCA cards do not indicate which job to work on – just that a job requires processing at two consecutive stations of the loop (e.g. A-B). As a consequence, there is still a need to choose between alternative jobs waiting in the queue of a station. In the POLCA system, this is provided by the release Authorization – the "A" in POLCA. POLCA's authorization element uses earliest job release dates for each station, calculated by a HL/MRP system.

Let us consider an order that moves from Station A to Station B to Station C. When the order arrives at Station A, three conditions have to be met to start processing the order:

(i) Station A must be available;
(ii) A POLCA A-B card (which circulates between the station pair A and B) must be available, indicating the future availability (of capacity) at Station B; and,
(iii) The order must be authorized, i.e. the earliest release date calculated for this order at Station A must have been reached.

If this is the case, the POLCA A-B card is attached to the order and the order can be processed at Station A. Once complete at Station A, the order moves to Station B (and the A-B card remains attached to the order) where the same three conditions as above have to be met, replacing Station A by Station B, and so on. When the order is finished at Station B (and only then), the A-B card is freed and moves back to Station A; and the order moves to Station C, and so on. The overall POLCA system is depicted in Fig. 1.

2.2. Proposals for refinement

This study started by asking:

Is there any refinement possible to enhance the performance of POLCA without jeopardizing its simplicity?

A first indication of where to look when refining POLCA is given by the refinements proposed by Vandaele et al. [35] in the context of an electronic POLCA system. These refinements focused on two areas: (i) improved prioritization of orders; and, (ii) capacity control. Therefore, and focusing on the structure of POLCA systems, two aspects with potential for improvement can be identified: (i) improved prioritization through the choice of different rules for card allocation and dispatching; and, (ii) improved use of capacity via the introduction of a starvation avoidance mechanism. Both will be discussed below, in Sections 2.2.1 and 2.2.2, respectively.

2.2.1. Refinement 1: improved prioritization through card allocation and dispatching rules

In the original POLCA system, an order must be authorized, i.e. the earliest release date calculated for a particular order at a station must have been reached. But this condition is myopic since there could be a better sequence of jobs for processing at a station; better in terms of different performance objectives. Therefore, we argue that the highest priority should be given to the job that is likely to contribute the most to system performance regardless of whether the earliest release date calculated for this job has been reached or not.

Jobs in a queue waiting to be processed may or may not have the required card from the next station in their routing. So, two rules for prioritization are required within POLCA. First, a card allocation rule that determines which job from the set of jobs without a card should receive the next card. Second, a dispatching rule that determines which job in the set of jobs with a card will be processed next at the station. In this aspect, POLCA is significantly different from ConWIP, where the acquisition of a card triggers release, and from *kanban* systems, where a *kanban* card always is associated to a specific order making a card-acquisition rule meaningless (see the third and fourth *kanban* rules presented in Ohno [23] (p.30) – 'No items are made or transported without a *kanban*' and 'Always attach a *kanban* to the goods').

POLCA typically assumes the same rule – earliest release dates (ERDs) – is applied for both card acquisition and dispatching decisions. This assumption is revisited in our study and POLCA is refined as follows: (i) other rules in addition to ERD are considered; and, (ii) the use of different rules for card allocation and for dispatching is trialed. A first indication of the potential impact of the dispatching rule was given by Braglia et al. [3]; however, this was in the context of an m-POLCA system in which POLCA cards are part number specific – as for m-ConWIP (Duenyas [6]) – rather than job anonymous as for the original POLCA system and ConWIP. Meanwhile, the card acquisition rule is important since there may be a relevant time lag between the time the card allocation decision is taken and the time that the processing of the job starts. Therefore, different jobs may be accumulated in the queue of a station. The card allocation