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Work In Process Control for a High Product Mix Manufacturing System

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Abstract

This paper presents the development and application of a Work In Process (WIP) control approach to manage inventory in order to reduce manufacturing throughput time and its variation in a high product mix case study company. The approach involves a stage level regulation of WIP, which also serves as the means of sequencing production at the workstations. Its stage level regulation of WIP is similar to that of the Kanban (supermarket-based) control approach; however, its own set WIP levels are not for stock keeping, but are thresholds that the stage WIP should not exceed for each product type. Therefore, it avoids the proliferation of WIP that has been identified as a hindrance to the application of Kanban control in high product mix manufacturing environments.

It is applied under the CONWIP and the Push production control mechanisms and its performance is compared against the first in first out (FIFO) rule for the prioritisation of products for processing and a sequencing rule that is based on the similarity of products, and this provides an opportunity to compare the improvements obtained from it against the company's current application of FIFO rule under the Push control.

The results obtained show that the CONWIP's regulation of total system WIP reduces throughput time and facilitates the application of sequencing rules in selecting the next product for processing. In real life, this might reduce the time needed by personnel to decide and identify the next product for processing. On the other hand, the Push control delivers a higher throughput rate, but can also lead to the proliferation of WIP which in turn increases the mean and variation of the throughput time. However, the application of the WIP control approach to sequence production under the Push control is able to avoid this negative outcome of the Push control.

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Keywords: Simulation modeling; High-mix; Production control

1. Introduction

The research presented in this paper is part of a project titled SØM4.0, which is aimed at streamlining and improving the process flow at a furniture manufacturing company. A value stream map developed in a previous phase of the project has shown that there is a significant amount of deviation between the value adding time and the throughput time [1]. Additionally, the throughput time is highly variable, and this has resultant effect on subsequent stages of the process, where the components produced are to be assembled. It would be highly beneficial to have a high level of predictability at the upstream stages of the production process, such that the downstream assembly operation can be planned in accordance with the expected arrival of components for specific product types. More importantly, this could serve as a prelude to a more advanced synchronisation between the components manufacture and the downstream assembly, as found in just in sequence (JIS) disciplines.

This work aims to achieve the two objectives of reducing throughput time mean and its variation through a production control approach that regulates inventory to address the first problem. It would also through the same inventory regulation facilitate the process of sequencing items for processing at workstations, in order to reduce the throughput time variation. This production control approach, which will be referred to as WIP control, will be explained in Section 4 of this paper. Prior to this, in Section 2, a more detailed overview is presented of the case study company and its existing approach to production control and sequencing. Section 3 will review similar works in literature that have covered the aspects of production control and sequencing rules. In Section 5, simulation experiments are set up to compare the company's current approach to that proposed in this paper, as well as other existing alternatives.

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The results of the simulation experiments are presented and discussed in Section 6. The paper is then concluded in Section 7 with an overview of the outcomes and plans for future improvements to the WIP control approach.

2. Overview of Case Study Company

The case study company is a typical example of high-mix production. The product line consists of 36 different models, most of which are offered in two or three different sizes (small, medium and large), while other models are offered with two differential models. Furthermore, all the products are offered with a wide selection of materials and colours. The main variety explosion occurs right from the beginning of the production process where the model and materials are selected. All these customisation options result in approximately 60,000 possibilities from the first process step.

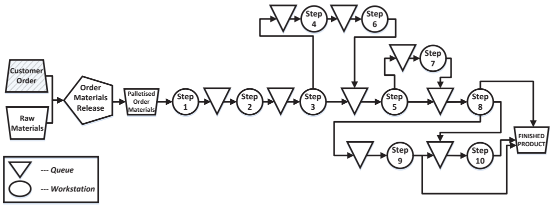

Figure 1. Process Flow

Table 1. Breakdown of Product Routing and Processing time Requirements

	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	STEP 6	STEP 7	STEP 8	STEP 9	STEP 10
Percentage of Product Models requiring each step	100%	75%	100%	9%	93%	7%	16%	100%	36%	5%
Percentage of total production volume requiring each step	100%	96%	100%	25%	99%	24%	15%	100%	20%	5%
Range of processing times at each step (minutes)	1.84-25.41	0.39-0.97	0.50-1.00	0.50-2.25	1.00-14.20	0.74-3.13	1.13-9.93	2.35-64.12	1.03-15.00	0.44-10.40

This research focuses on 10 processing steps, which are the most labour intensive and value-adding processes of the whole production. The routing possibilities through these processing steps and the processing time requirements differ from one product model to another, as shown in Figure 1 and Table 1.

The company applies a Push control mechanism to release items into production, followed by applying a FIFO rule to sequence their processing at the workstations. Barring any capacity constraints, this should ensure that the products are completed as planned in the production order. However, as shown in the value stream map in Figure 2, a large deviation exists between the value adding time and the manufacturing

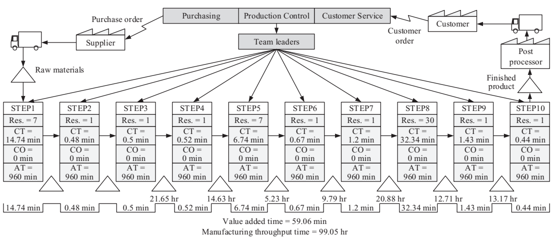

Figure 2. Value Stream Map

throughput time, and a significant amount of this is spent queued for processing at the workstations. A connection between the long throughput time and the amount of inventory allowed in the system is clear from Little's Law [2]; therefore, a first step towards reducing the throughput time is to regulate the amount of inventory in the system. Furthermore, alternatives to the FIFO rule will be experimented for the sequencing of products at the workstations, as explained in Section 5.

3. Background and Literature Review

Production control mechanisms that exist in literature are mainly classified into two, namely Push and Pull, and there tends to be a wide consensus that Pull controls are better at minimising system inventory, while Push controls are better for maximising throughput [3]. The criteria for classifying them is usually based on whether they initiate production in response to actual demand or just in anticipation of it, and if they limit the amount of system inventory or not [4]. However, depending on the criterion used for classification, some control mechanisms – such as the CONstant Work In Process (CONWIP) – exhibit traits of both classes. As a result, such mechanisms are able to combine the low inventory benefits of Pull control with the high throughput benefits of Push control [3].

Furthermore, the single globalised Pull control of WIP under CONWIP makes it a suitable approach for high mix manufacturing system. However, its use of a Push control at the manufacturing stages necessitates that a sequencing rule be developed separately and applied to determine the order of processing of products at the manufacturing stages. This has been the focus of many research works that seek to determine suitable sequencing rules to apply under the CONWIP [5, 6]. These rules can be categorised as static or dynamic depending on the type of information they consider in determining the sequencing of production and how they apply the information [7]. The static rules use products' attributes to prioritise them for processing at the workstations, and the rules are usually set in order to have products that meet specific criterion given priority [8]. Examples of rules commonly applied are the Earliest Due Date (EDD) which gives priority to the product that has the earliest due date; the First In First Out (FIFO) which processes them in the order of arrival; the Shortest Processing time (SPT) which gives priority to a product that requires the least amount of processing time; and this also has a reverse version – the Longest Processing time (LPT) – which gives priority to the product that requires the longest amount of processing time. These are among the many options that have been applied in literature. On the other hand, dynamic rules are time dependent and are not based on static attributes of the products, but on information derived from the current state of the system or of the products [7, 9]. Such current state information would then be compared against a desired state to determine the best course of action, in terms of the type of product processed to attain the desired state. Such system state could be the current service level, throughput volume or throughput mix level at a specific point in time measured against the desired state. An example of this is that which seeks