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An evaluation of the DBR control mechanism in a job shop environment

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Abstract

This study is an evaluation of the drum–buffer–rope (DBR) control mechanism compared to the modified infinite loading (MIL) control mechanism in a job shop environment. Although previous research has shown that the MIL mechanism works well in this environment, this study finds that the DBR control mechanism performs significantly better. The performance of the DBR mechanism improves when the shortest processing time (SPT) dispatching rule is used. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Drum–buffer–rope; Job shop scheduling; Simulation

1. Introduction

Two aspects of job shop control mechanisms are widely recognized as effective shop floor techniques—the dispatching rule and the release mechanism. A great deal of research has been focused on these two aspects. Over the years, several dispatching rules have been developed and tested to determine the relative priorities of multiple jobs in a shop. Two consistent findings from these studies are: simple rules perform fairly well [1] and shortest processing time (SPT) performs well over a wide variety of shop measures [2,3]. To show the importance of a release mechanism, Harty [4] introduced the concept of releasing jobs based on the bottleneck operation. An expansion of this idea by Wight [5], and Plossl and Wight [6] claimed that some form of controlled release, with simple dispatching rules, provided shorter and consistent manufacturing lead-times. In the years that followed, many additional studies have been conducted to determine the relative merits of different release mechanisms. One general finding from the studies has been that controlled release is necessary for managing shop environments [7,8]. Some conclude that release mechanisms play a more important role than dispatching rules for good shop floor control practices [9,10].

Recently, a new control mechanism has evolved which is related to Harty's approach of focusing on the bottleneck operation. This newer approach is called the drum–buffer–rope (DBR) control mechanism. Several authors have provided an explanation of the DBR logic [11–13]. Since their purpose was to explain a relatively new control mechanism, the shop environments used were fairly simple. Consequently, only one or a few products were used in a flow shop. In these environments, the DBR has been shown to work quite well [14,15]. Advocates of the DBR claim that this mechanism also works very well in job shop environments [13,16,17]. No research has been conducted to support these claims on the DBR control mechanism in a job shop environment. In fact, rigorous research comparing the DBR control mechanism with other control mechanisms is virtually non-existent [17]. The purpose of this research is to evaluate the performance of the DBR control mechanism along with an existing control mechanism in a job shop environment. This study is

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necessary because many companies have implemented the DBR control mechanism (see [18,19]) and there is a growing interest in the mechanism among practicing managers [20].

In the following section, a description of various control mechanisms is provided. The research design and experiment factors section provides an explanation of the model and the experimental factors used to evaluate different control mechanisms. The results section provides findings of the experiment. Finally, the conclusions section summarizes the study and includes directions for future research.

2. Control mechanisms

To conduct the research, three control mechanisms were used. Each control mechanism was a combination of a release mechanism and a dispatching rule. The first release mechanism was based on the DBR logic. The DBR releases jobs to the shop based on the processing capability of the system's bottleneck operation and plans for extra capacity at non-bottleneck operations. The logic of the DBR can be explained in three steps [21,13]. First, the system's bottleneck operation is identified and then, using the bottleneck operation (*drum*), jobs are released into the system. Second, to protect the bottleneck operation from disruptions, sufficient jobs are allowed between the bottleneck operation and the order release point (*buffer*). To ascertain that non-bottleneck operations do not process more than the bottleneck operation, a feedback mechanism (*rope*) is used to indicate the release of an order as soon as the bottleneck operation finishes completing an order. Once the jobs are released, they proceed from one station to another using the first come first serve (FCFS) dispatching rule as an initial setting.

The second control mechanism was based on the modified infinite loading (MIL) logic. Studies conducted by Ragatz and Mabert [22] and Philipoom, Malhotra, and Jensen [23] found that the MIL release mechanism worked significantly better than other release mechanisms in many situations. The MIL releases jobs to the shop based on release date computations. According to Philipoom, Malhotra, and Jensen [23], the release dates are computed by subtracting two components from the due date. The first component is the work content of a job multiplied by a planning factor. The second component is the work content of all the jobs waiting in queue multiplied by another planning factor. The computations for the release date are:

$$\mathrm{RD}_j = \mathrm{DD}_j – n_1\mathrm{WC}_j – n_2\mathrm{WQ}_j$$

$\mathrm{RD}_j =$ release date of job j,

$\mathrm{DD}_j =$ due date of job j,

$\mathrm{WC}_j =$ work content of job j,

$\mathrm{WQ}_j =$ work content of all the jobs waiting in queue,

$n_1, n_2 =$ planning factors.

Under a set of shop conditions such as shop utilization level and due date setting, Philipoom, Malhotra, and Jensen [23] have shown that the SPT dispatching rule works well with MIL release mechanism. Since these shop conditions were closely emulated in this study, SPT dispatching rule was included.

The third control mechanism consisted of immediate (IMM) release, sometimes referred to as a 'naïve' release mechanism. This mechanism releases jobs to the shop as soon as they arrive regardless of their priority. In this manner, shops do not consider release mechanism functions tacitly. For this reason, IMM release mechanism was used as a base case. In addition, previous studies [22,24] have shown that IMM release mechanism performs well under many shop conditions.

3. Research design and experimental factors

3.1. Summary

The factors used in the research are summarized in this section and detailed descriptions of the factors are provided in subsequent sections. To conduct the research, three factors were selected. The release mechanism was studied at three levels (DBR, MIL and IMM), the dispatching rule set at two levels (FCFS and SPT), and the due date setting set at two levels (Tight and Loose). For DBR, when the FCFS rule was used the buffer size was 10 and when the SPT rule was used the buffer size was 16. For the MIL, when the FCFS rule was used $n_1 = 9$, $n_2 = -0.4$, and when the SPT rule was used $n_1 = 10$, $n_2 = -0.8$. The due date setting was done using the total work content (TWK) method, which is the sum of processing time requirements to complete a job multiplied by a constant or a TWK parameter. To represent the Tight due date setting, the TWK parameter was 3.4, and to represent the Loose due date, the TWK parameter was 4.9. The performance criteria were total cost and various shop measures. The total cost consisted of inventory cost and late delivery cost. The shop measures included mean number of jobs in the shop (JOBS), mean earliness or on time (EARLY), mean percentage of jobs early or on time (PEARLY), mean tardiness (TARDY), and mean percentage of jobs tardy (PTARDY).

3.2. The model

In this study, a four-machine job shop representing a made-to-order environment was used. Similar shops have extensively appeared in other studies [25,22]. The simulation model for the job shop was written in Awesim 3.0 [26] language. Several steps were performed to validate the model. First, detailed traces from the model were generated consisting of listings of simulation output. The output confirmed that the simulation models performed properly. Second, operational statistics such as machine utilization,