Asymmetrical buffer allocation in unpaced merging assembly lines

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A R T I C L E   I N F O

Article history:
Received 12 July 2016
Received in revised form 10 March 2017
Accepted 5 May 2017
Available online 6 May 2017

Keywords:
Unpaced merging assembly lines
Asymmetrical buffer capacity allocation
Buffer imbalance patterns
Throughput
Average buffer
Simulation

A B S T R A C T

Asymmetrical merging assembly lines are a research area which is rising in prominence due to increasing use in reverse logistics, remanufacturing, and developing economies. This paper studies the performance of reliable, unpaced merging assembly lines with asymmetric buffer storage sizes. Lines are simulated with varying line lengths, mean buffer storage capacities and uneven buffer allocation configurations. Contrary to typical manufacturing expectations, results indicate that production line imbalances do not always result in detrimental performance. Higher throughput and lower average buffer levels, as compared to a balanced merging line, are found where total available buffer capacity is allocated as evenly as possible, and with a higher buffer capacity concentration towards the end of the line. This paper contributes to total production line knowledge by providing performance improvement methods for unpaced merging assembly lines with asymmetrical buffer allocation, and inexpensive or no cost managerial options to increase productivity and resource utilization, and decrease waste, in asymmetrical merging assembly lines.

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1. Introduction

Due to their unique characteristics, reverse logistics and remanufacturing processes, as well as developing economies, commonly use asymmetrical and unpaced assembly lines. Research has indicated that production planning and control is an area of need of supply chain managerial skills development (Lorentz, Töyli, Solakivi, & Ojala, 2013) and that the implementation of lean production practices may result in greater uncertainty and variance (Marodin, Frank, Tortorella, & Saurin, 2016). With substantial global production taking place in lesser developed economies, this research has significant implications across industries. Also of increasing importance, supply and demand patterns in the growing industries of reverse logistics and remanufacturing differ significantly from those typically experienced in traditional manufacturing (Erol et al., 2010; Fleischmann, Beullens, Bloemhof-Ruwaard, & Wassenhove, 2001; Guide & Wassenhove, 2001), resulting in inconsistent buffer spaces, which are sometimes unavailable to meet consistent and quality source demand requirements. In addition, unpaced assembly lines may be quickly implemented to meet short-term needs, increasing process variability (Hudson, McNamara, & Shaaban, 2015). A combination of these unique characteristics reinforces the value of unbalanced and unpaced assembly line research.

Unpaced parallel merge lines are considered stochastic serial queuing systems with high volume. They involve no mechanical pacing; hence line workers are free to set their own pace. Work-in-process (WIP) inventories are commonly kept between stations so that partially finished items are transferred to a buffer or storage location. Fig. 1 illustrates a common merging assembly line which includes a series of parallel work stations and asymmetrical capacity buffers, leading to a merge or assembly station.

Merging lines with asymmetrical buffer capacities are an important research and practical topic since technical considerations often constrain available line space, resulting in uneven allocation of total buffer capacity across the line. Since this is a common experience, determining how to best to allocate asymmetrical buffer space to meet desired performance objectives contributes value to both research and industry.

Previous simulation research on reliable lines with unequal allocations of buffer space (Conway, Maxwell, McClain, & Thomas, 1988) suggests that buffer imbalance can be managed to (1) minimize its deleterious consequences, and (2) improve performance results under certain conditions, when compared to similar balanced lines. Despite this, research on asymmetrical buffer
effects on unpaced merging lines is scarce and provides a strategic gap which this paper attempts to fill.

The remainder of this paper is structured as follows. A brief literature review is followed by a presentation of the research questions. Subsequent sections discuss the methodology and design details, and describe the results and analyses. The paper ends with a discussion of implications and conclusions, with future research directions suggested.

2. Literature review

Literature on buffers first began following the post-World War II economic expansion and parallels the growth and evolutionary development of manufacturing. One of the earliest reported investigations on buffers was carried out by Koenigsberg (1959), who discussed basic production line problems and internal storage characteristics. Later, Buzacott (1967) arrived at an analytic method for determining the throughput and buffer management of a two-station production system (i.e. automatic transfer line). Gershwin (1987) then derived a decomposition method for buffering lines with unreliable machines, with Dallery, David, and Xie (1988) formulating an analytical method capable of evaluating systems with more than two stations.

Various aspects of the efficient allocation of buffers in automated and transfer lines have also been addressed and further refined over time. Ho, Eyler, and Chien (1983) derived a novel method for optimizing transfer line performance in which the “history” of the production line is incorporated into the computations. Altiok and Perros (1986) developed a decomposition method capable of analysing merging queues subject to blocking. Jafari and Shanthikumar (1989) framed the BAP for automated transfer lines with unreliable machines, with Dallery, David, and Xie (1988) formulating an analytical method capable of evaluating systems with more than two stations.

An asymmetrical assembly line with 5 parallel stations, 4 unequal capacity parallel buffers, and a merge station.

Fig. 1. An asymmetrical assembly line with 5 parallel stations, 4 unequal capacity parallel buffers, and a merge station.
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