Simulation Modelling Practice and Theory 49 (2014) 203–214

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

A simulation analysis of the impact of production lot size and its interaction with operator competence on manufacturing system performance

Long Che Mak, Wai Keung Wong *, Yung Sun Leung

Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong

ARTICLE INFO

Article history:
Received 17 March 2014
Received in revised form 15 August 2014
Accepted 24 September 2014

Keywords:
Computer simulation
Production loading
Operator learning effect

ABSTRACT

In the process of production planning, planners have to define the production quantity to be loaded to the production line (commonly referred as "lot size"). The decision is mainly based on the primary concerns of avoiding late completion of contracts and minimizing costs. To provide more insights to the decision, this research aims to explore the impact of lot size and its interaction with operator competence on manufacturing system performance using simulation technique. During the simulation process, two inadequacies which hinder the representativeness of the simulation analysis are identified in the existing literature. They concern the inadequacy in simulating realistic operator learning curves and incompetent approach of simulation experimental analysis. A simulation model is proposed to refine these inadequacies before it is applied to explore the mentioned research issue. The simulation results confirm the significant effect of lot size and its interaction effect with operator competence on all performance measures.

1. Introduction

In the process of production planning, one of the functions is to define the production quantity to be loaded to the production line. In the current manufacturing world which stresses short lead time and Quick Response supply, planners usually split the customer order into lots of different sizes before loading them to the production lines in order to enhance flexibility and responsiveness. The decision is very important as production quantity has been convincingly recognized as an influential factor affecting the operator performance curves [1,23,29]. However, the decision regarding the production quantity to be loaded is made mainly based on the primary concerns of avoiding late completion of contracts and minimizing costs [9]; minimal concern has been placed on the impact of the defined production quantity and its interaction with operator performance curves on the manufacturing system performance. In the related literature, researchers also neglect the close relationship between the production quantity and operator performance curves. They mostly emphasize on the modeling of different extensions in attempt to imitate a realistic manufacturing situation and generate line loading plan with minimum costs for different situations [3,5]. To provide more insights to the production planning process, this paper aims to explore the impact of the production quantity to be loaded to the production line and its interaction with operator competence levels on the manufacturing system performance in terms of average work-in-progress (WIP) level, flow time, machine and operator utilization rates.

* Corresponding author. Tel.: +852 2766 6471.
E-mail addresses: 10902052r@connect.polyu.hk (L.C. Mak), calvin.wong@polyu.edu.hk (W.K. Wong), sunny.leung@polyu.edu.hk (Y.S. Leung).

http://dx.doi.org/10.1016/j.simpat.2014.09.008
1569-190X/

A simulation-based factorial design is proposed in the research. The experimental design is carried out by simulating a manufacturing system using the ProModel package and output is analyzed using the SPSS statistical package. In the simulation process, two inadequacies are identified in the existing simulation literature which would affect the investigation on the above issue. They concern the failure in simulating realistic operator learning curves [6,12,16,18,28] and the incompetent approach of simulation experimental analysis [16,28]. Therefore, this research also aims to propose a practical simulation modeling approach by refining these inadequacies to aid accurate assessment of the manufacturing system performance.

The remainder of the paper is organized as follows. Section 2 is the background and motivation for the research. In Section 3, we will explain the proposed simulation modeling approach; the experimental factors considered and present an analysis of the experimental output including the main effect and interactions between factors. Finally, a conclusion is drawn in Section 4.

2. Background and motivation

In common practices when planners split the customer order into lots of different sizes, they decide mainly based on two primary concerns: to avoid late completion of contracts and to minimize costs [11]. Little emphasis has been placed on how the decision regarding lot sizes affects manufacturing system performance on operative level in terms of WIP level, flow time, machine and operator utilization rates. In academic prospective, researchers tend to focus on factors such as batch size, process layout, number of operators, number of machines and their impact on manufacturing system performance [7,8,12,20]. However, these are not the only factors affecting the system performance. In fact, especially in labor-intensive industry such as apparel and footwear manufacturing, there is a close relationship between the production quantity and operator performance [1,23,27,29]. Proficient operator performance will undoubtedly lead to improved production line efficiency. Many studies have proved the presence of learning effect associated with an increase in cumulative unit of practices which contributes to shortening of production processing time [15,17,22]. Little research has extended the investigation to explore the impact of the quantity loaded to the production line on the manufacturing system performance. Leung et al. [18] attempted to integrate customer order size as a factor in the simulation model of a Lean Production line to study its impact on machine utilization rate and set-up cost; the experimental result showed that the order size indeed affected machine utilization rate. A research to further explore the impact of the quantity loaded to the production line on the manufacturing system performance would be helpful in providing insights into the production loading process.

During the simulation process of exploring the impact of quantity loaded to the production line on manufacturing system performance, two inadequacies are identified in the existing simulation literature which would hinder the accuracy of the simulation analysis on the above issue. The first inadequacy is the failure in simulating the realistic trend in operator learning curves. Operator performance has a significant impact on manufacturing system performance [2]. However, in the existing simulation studies, the learning patterns of operators are often reflected by converting the raw data of their working time into statistical distribution [6,12,16,18,28]. The statistical distribution, acting as an instant input in the processing logic, gives random numbers within its range as operators working minutes. However, these numbers being drawn randomly from the distribution fail to reflect the descending trend in operator learning curves and the effect of operators' cumulative practices in the production line. This will certainly hinder the accuracy in exploring the impact of quantity loaded to the production line on the manufacturing system performance.

The second inadequacy concerns the simulation experimental analysis of machine and operator utilizations. In computer simulation, the analysis often begins when the system is at its start-up state when [18] most machines and operators are being idle [19]. This approach is not appropriate for most of the manufacturing industry as the cycle time of machines and operators recorded in the computer simulation is prolonged and will understate the actual utilization rates. Therefore, some simulation studies in the manufacturing field include warm-up period at the beginning of simulation run to avoid the negative bias of the start-up state caused to the simulation result [19]. However in these simulation studies [16,18,28] which involve operator learning curves, the operators start to learn at the beginning of the simulation run when it is still in warm-up period. As the system behavior in the warm-up period is not considered in the simulation analysis, the changes in processing time during the initial operator learning process are neglected. Thus, the impact of the initial operator learning process on production system performance is not reflected in the simulation result.

In this paper, with the use of computer simulation technique, we aim to explore the impact of quantity loaded to the production line and its interaction with operator competence on the manufacturing system performance which gained minimal concerns in the previous studies and refine the existing inadequacies in the simulation process which affect the simulation analysis. We propose a simulation-based experimental approach to explore how the quantity loaded to the manufacturing system and its interaction with the operators' competence and learning effect affect the performance measures of a manufacturing system.

3. Proposed simulation model

3.1. Framework of the proposed simulation model

A new simulation model is proposed to fill the above inadequacies before it is used for the mentioned research issue regarding the quantity loaded to the production line. The proposed simulation model consists of three phases (Fig. 1).