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Reconfigurable express logistics center: a simulation study

Xiang T.R. Kong[1,*], Hao Luo[2]

[1]*HKU-ZIRI Lab for Physical Internet, Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong (e-mail: xtrkong@qq.com)*

[2]*Department of Transportation Economy and Logistics Management, College of Economics, Shenzhen University, Shenzhen, P.R. China (e-mail: luohao403@qq.com)*

Abstract: This paper is motivated from a rapidly expanding express delivery service provider that has recently reengineered its express logistics center in one region with high demand and is planning to reproduce such operations in other regions with seasonal and volatile demands. A simulation model is built to enable a reconfigurable express logistics center. Three main control policies: sequencing, order releasing and machine flexibility are considered. To generalize the research findings from the simulation study, experimental design technique has been applied to carry out sensitivity analyses by using full combination of control factors, demand orders and system parameters.

Keywords: Express logistics center, Configuration and control, Simulation, Design of experiments

1. INTRODUCTION

In express delivery industry, express centres play the significant role in an organization's business decision-making processes and have a long-term impact on the support for enterprise achievements (Kathy Roper et al. 2009). The challenge for today's express centres is not only how to handle colossal order fulfilment commitments, but how to draw a competitive advantage from the way in which they flexibly respond to dynamic variations (Apte and Viswanathan 2000). As the core component of express logistics center, the sorting system is of crucial importance. It determines whether a physical commodity that traded via the e-commerce can be delivered smoothly to the buyer or not.

However, there are several decision variables concerned with the sorting system in express centres in terms of configuration and control policies such as optimal number of sortation slots, placement of the induction stations, and order release mechanism. Moreover, these design decisions involve complex trade-offs where the parameters for making these trade-offs are often not well understood. Practical uncertainties make the problem more complicated (Kong, Chen et al., 2016). The uncertainties can be produced by the unexpected booming demands or disruptive machine breakdowns which all affect the actual performance and incur costs. The decision support is required for facility managers who need to prioritize what is important rather than simply urgent to gain maximum effectiveness. Hence, proactive decision makers are more concerned with identifying specific performance trends or levels and analysing trade-offs in operations to quantify management and service (Kong, Fang et al., 2015).

Many researchers have paid great attention on designing and implementing cost-effective order sortation approaches for manufacturing factories and logistics warehouse (Bozer and Sharp 1985, Bard et al. 1993, Johnson and Lofgren 1994, Galbreth and Blackburn 2006). However, the sortation operation that integrates design and operational decisions for express logistics is rarely discussed.

Reconfiguration express center (REC) is thus put forward for sortation operations, which involves the system layout design and control policies evaluation to provide flexible responses to dynamic changes. The significances of REC for sortation operations can be summarized as follows. Firstly, both machine set-up and control approaches should be reconfigured and scalable under uncertainties through investigating performance trade-offs. REC for sortation operations helps facility managers become more proactive when they are faced with increasingly changing customer requests, due dates and regulations. Secondly, express centres located in dispersed geographical markets have different demand variations and order patterns. These facilities are usually equipped with various system layout, order sequence, batch size and machine flexibility. REC for sortation operations can offer important guidance on design and operation of express centres over time and across geographical regions.

This paper aims to explore a systematic study of express center configuration with the following research questions:

(1) How can we define an integrated control policy for REC including order sequencing, releasing and machine flexibility strategies?

(2) How to assess the impact of combined control schemes on sortation performance of REC in different geographical regions (e.g. South, East and West China)?

(3) What kinds of managerial insights could be gained from results analyses?

We use discrete-event simulation to model REC for sortation operations. Two main reasons include: (1) none of related analytical models considered were suitable for this study due to REC is intractable in a single mathematical model, not to

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mention to obtain the optimal results within feasible solution time and (2) simulation provides a user-friendly interface for logistics professionals while it is a powerful analysis tool to capture the complexities of the real world to a reasonable level, which allows implementation of what-if, sensitivity scenarios and alternatives comparison on a computer (Marinov and Viegas 2009).

Next section, the related works will be reviewed. The description of motivating case and associated challenges are illustrated in section 3. In section 4, simulation experiments are conducted for analysing sortation operations. Results analysis and managerial insights are obtained in section 5. Finally, observations and contributions are synthesized and suggestions are made for future developments.

2. LITERATURE REVIEW

The problem of sorting system design and control has been discussed in past decades in manufacturing, logistics and service industries. Cost and efficiency analysis of order sorting system have been evaluated (Galbreth and Blackburn 2006). The impacts of number and length of sorting slots, and optimal order-to-lane assignment as well as sorting strategies on order sorting performance have examined (Bozer and Sharp 1985, Bard et al. 1993, Johnson and Lofgren 1994). Johnson and Meller (2002) comprehensively investigated the induction processes of split-case sorting system. Jarrah and Bard (1994) presented three interrelated models to find a minimum cost configuration for a typical general mail facility associated with daily machine schedules.

Adjusting a single control parameter may not change the recommended system configuration while varying several parameters simultaneously has a critical influence on the system. The impacts of alternative policies and configurations are simulated and quantified in the design and control of a logistics order picking system (Manzini, Gamberi et al. 2005). These authors also argued that an improved customer service can be achieved through effective order releasing. Moreover, it exists the trade-offs between order releasing mechanisms, work-in-process inventory and on-time completion (Chan, Humphreys et al. 2001). It is also worth noting that a balance must be struck between the resulting uncertainty a firm faces and the use of flexibility that can accommodate uncertainty. There is the potential to improve sorting productivity by utilizing some flexibility strategies such as machine flexibility.

Design of experiments is a useful technique with a series of tests for improving process design (Ekren, Heragu et al. 2010, Chackelson, Errasti et al. 2013), which provides the observation and analysis through inputs, processes and outputs variations. Computer simulation is often employed during the experimentation phase for assisting managers and engineers in the design of a new system. The relative better design alternative can be obtained through the comparison of simulation results before the system is actually implemented. According to Bard (1997), discrete event simulation is able to test alternative solutions for express delivery service efficiently, especially when process uncertainties and interdependencies occur. Meanwhile, simulation is one of the effective tools to evaluate control mechanisms under demand variations (Chan and Chan 2005).

The facility design and sequencing/dispatching controls of manufacturing shop-floor or logistics warehouse have been examined. However, the systematic study integrating both design and operational issues in the express center is still scarcely. Problem also remains to be solved on determining the optimal quantity and position of sorting slots in the express sorting system.

3. MOTIVATING SCENARIO

The motivating case comes from one of the largest express delivery enterprises in China; it operates around 200 express centres and employs 90,000 people. The company currently employs manual sorting system (MSS) and all express freights are sorted while picked manually from a line-type conveyor.

Recently, the firm has realized the importance of express center configuration for order sortation. Its senior managers want to know if changing its facilities configuration and control would enable it to achieve significant cost savings and service enhancement. Therefore, it commences the design and pilot test of a new semi-automated sorting system (ASS) to fulfil the increasingly complicated commitments in the existing express centres. The new system is equipped with advanced Internet-of-things (IoT) sensors such as automated bar-code sorters and it can accurately identify and dispatch express freights. In addition, the information control system of ASS is linked with enterprise high-level management system. Thus, the real-time freight information can be traced and tracked.

Figure 1 illustrates the reengineered express logistics center layout and workflow with ASS. It can be considered as a queuing system along with inbound dock, receiving zone, sorting zone, dispatching zone and outbound dock. Particularly, sorting zone consists of both manual sorting area and automated sorting area. The detailed processes and management issues have been defined as follows.

A few parts of outgoing express freights are cross-docked directly to the destination and other parts of freights have to be processed through the ASS in fixed sorting waves commonly ranging from 30 minutes to 2 hours. The orders are mainly sorted using a high-speed conveyor network, a control system and barcodes on the individual package. The next available sorting strategy is used in current system (Johnson 1997). It is a rule which assigns the next available order to a sorting lane with little blocking. Based on this sorting strategy, the control system decides whether to divert the orders into the proper sorting slots based on the congestion in the sorting lane or push the orders for a round trip on the dog-track until it can be sorted. However, the existing field management totally depends upon the experience and skills of managers and the operations fulfil the daily commitments in the front-line with little regard to what was planned.