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On-line order batching and sequencing problem with multiple pickers: A hybrid rule-based algorithm

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ABSTRACT

Existing on-line order batching rules, namely fixed time window batching (FTWB) and variable time window batching (VTWB), try to choose the fixed time window in the case of FTWB or the fixed number of orders in the case of VTWB. However, these solutions are not appropriate for the fluctuating order environment. The reasonable assignment of batches to order pickers is also an important issue in order picking systems. Motivated by these issues, we study the problem of integrating on-line order batching and the assignment of the batches, which is called the on-line order batching and sequencing problem with multiple pickers (OOBSPMP). The objective is to minimize the turnover time. To solve the problem, a hybrid rule-based algorithm, referred to FTWB, is proposed in order to form batches and assign them to appropriate pickers under a fluctuating order environment. Three batching situations (off-peak, normal and peak arrival time) and two assigning situations (assigning to one busy picker and assigning to one idle picker) are distinguished. Through a series of experiments, we discover several enlightening findings: (i) the rule-based algorithm demonstrates high effectiveness and efficiency in turnover time with multiple pickers; (ii) the rule-based algorithm leads to an impressive improvement in both saving time and wage costs under different arrival rates, picking devices and time intervals compared with VTWB; (iii) to obtain both good warehouse performance and a reasonable workload distribution, the factors, such as the fixed time window, the average workload per picker and the average idle time per picker are also important issues in analysing the efficiency of order picking systems.

1. Introduction

Order picking is a warehouse function that deals with the retrieval of items from their storage locations in order to satisfy the requirements of customer orders [1,2]. It is the most labour intensive warehouse operation as it is often 60–70% of the total operating cost of a warehouse [3]. Moreover, order picking is one of the most significant functions in order fulfilment of business-to-consumer (B2C) e-commerce. Nowadays, on-time retrievals of customer orders have become increasingly important, so efficient order picking systems are needed to guarantee that items are delivered to customers in the required time period [4]. Therefore, improvement in order picking efficiency will lead to a decrease in operating cost

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as well as an increase in service level. However, with the big boom of B2C e-commerce, small lot-size, high frequency, and dynamic arrivals of customer orders offer big challenges to efficient order picking and on-time delivery [5,6]. Order batching is one of the most prominent strategies to improve the performance of order picking [3]. Therefore, under such a B2C e-commerce environment, effective on-line batching solutions are necessary to improve the work efficiency and maintain customer satisfaction. In practice, even though automated warehousing systems have seen big technological development in recent years, 80% of order picking systems are operated with humans due to the high flexibility in reacting to unexpected changes [3,7]. Many researchers have also focused on integrating human factors (e.g. learning, physical workload, and ergonomics) into order picking systems [7,8]. Therefore, we concentrate on the manual order picking system. The reasonable assignment of batches to pickers is one of the human factor topics in order picking systems, and should be considered to improve the performance and ensure impartial physical workloads.

Motivated by these observations, we study the problem of integrating on-line order batching and the assignment of the batches, which is called the on-line order batching and sequencing problem with multiple pickers (OOBSPMP). The OOBSPMP is closely related to the order batching problem (OBP), which has been discussed frequently in the literature [3,9]. OBP consists of the assignment of customer orders to minimize the processing time. In the OOBSPMP, however, it is also necessary to determine the on-line decision points of batching, and the sequences according to when and which batches should be assigned to the order pickers. The decision issues of OOBSPMP can be formulated as follows: when should the arrival of uncompleted orders be grouped into batches, which orders should be grouped into the same batch, when and how should these batches be assigned to a limited number of order pickers, and how should the batches be scheduled to minimize the turnover time?

Time window batching is the most popular batching method to solve the on-line order batching problem, and can be divided into two classes: fixed time window batching (FTWB) and variable time window batching (VTWB). The batching methods try to choose the fixed time window in the case of FTWB or the fixed number of orders in the case of VTWB. However, these solutions are not suitable for the fluctuating order environment. When the arrival rate is relatively high, a lot of arrived uncompleted orders will be collected during the fixed time interval in the case of FTWB, on the other hand when the arrival rate is relatively low, a long waiting time is needed to collect a fixed number of orders in the case of VTWB. We deal with such a fluctuating order environment by separating the arrival rates into three different situations: peak, normal and off-peak. Referring to the FTWB, a hybrid rule-based algorithm with such three different situations are proposed to form batches and assign them to appropriate pickers without any information on the arrival times of future orders.

The layout of this paper is as follows. In Section 2, we review the literature of OBP and OOBSPMP. In Section 3, we establish a new optimization model to minimize the turnover time of customer orders, with regard to multiple order pickers. To solve this problem, a hybrid rule-based algorithm and benchmarking rules are proposed in Section 4. In Section 5, we evaluate the performance of the hybrid rules through a series of experiments. A summary and the outlook for further research are given in Section 6.

2. Literature review

In this paper, we study the on-line order batching and sequencing problem with multiple pickers (OOBSPMP), which is a particular case of the order batching problem. In general, order batching is a method of grouping a set of orders into several sub-set batches, and each batch can only be completed by one picker [3]. Existing results on the order batching problem are summarized in Table 1. The picking environment includes on-line and off-line. The situation in which the information of all customer orders is known is called off-line, while the situation in which batching customer orders cannot be known beforehand is called on-line. Most previous researchers have focused on off-line order batching strategies, and only a few papers have studied order batching in a stochastic (on-line) context. The number of pickers can be categorized into three classes: one, multiple with picker blocking and multiple without picker blocking. The batching methods in the case of the off-line picking environment can be separated into five types, while in the on-line case, the batching methods include time window batching and on-line heuristic algorithms. Gademan and Velde [10] proved that the off-line order batching problem is NP-hard if the batch capacity is greater than 2. Many heuristic algorithms have been developed to tackle the NP-hard problem, which can be divided into five types. The first one is the priority rule-based algorithm, which contains two steps [11]: (i) assigning priorities to customer orders; (ii) batching orders in accordance with their previously assigned priorities. The second kind is the seed algorithm [12], which contains seed order selection and order addition procedures. The third one is the saving algorithm [13], based on the algorithm of the vehicle routing problem [14,15]. Meta-heuristic algorithms, such as genetic algorithms [16–18], simulated annealing algorithms [19–21], ant colony algorithms [22], tabu search algorithms [23,24], variable neighbourhood search method [25,26] and particle swarm optimization [27] are the fourth kind. Other researchers have applied data mining approaches (the fifth kind) to the batching problem [28,29].

As can be seen, the majority of current order batching models assume that information on customer orders is known at the time the batching decision is taken, and then focus on which orders to assign to the same batch. However, these models are not suitable to guide batching decisions in a realistic on-line order picking environment. Time window batching is the most popular batching method to solve the on-line order batching problem. It can be divided into two classes: fixed time window batching (FTWB) and variable time window batching (VTWB) [35]. Rather than assigning orders to different batches, the central question is how to choose the optimal time window in the case of FTWB or the optimal batch size in the case of