Joint Order Batching and Picker Routing Problem including congestion

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1 Introduction

One of the most important processes in warehouse management is the order picking, concentrating the majority of the total operational warehouse costs. The picking tasks deal with the preparation of customer orders. In human picker-to-parts systems, which is considered in this work, pickers walk around the warehouse collecting all the necessary products from their locations to prepare a set of customer orders. Pickers usually walk pushing a capacitated trolley in which the products are transported. To abstract this situation we consider a rectangular warehouse divided in parallel vertical aisles and horizontal cross aisles. Vertical aisles are composed of racks that contains the products to be retrieved. Cross aisles are used to navigate into the warehouse.

At the operational level, the management of the order picking process involves the joint resolution of two problems: order batching and picker routing. The order batching problem (OBP) consists in determining the set of customer orders assigned to each picker, considering the capacity of the trolleys. The picker routing problem (PRP) is to define for each picker, the optimal tour to collect all the products of the assigned orders. Each tour starts and ends at a common location in the warehouse. Since the batching decisions strongly impact the picker routing decisions, the integrated solution of these two problems allows to find better solutions. The joint order batching and picker routing problem (JOBPRP) considers both decisions in an integrated way. Recent works have proposed solving JOBPRP to optimality, with a Branch-and-Cut approach [4] or with a column generation based approach [1].

A common assumption of the works in the literature on PRP, OBP and JOBPRP is the non-existence of congestion produced by the pickers. It is assumed that all the pickers are performing their tour independently whereas it is clearly not the case in practice since the pickers are walking in the same zone. When several pickers are in the same space at the same time, this produces congestion that implies delay for the pickers. In the warehouse, congestion has consequences on costs and performance [2]. In this work we propose to model the delay produced by picker congestion, and provide a Mixed Integer Linear Program (MIP) formulation for the JOBPRP with picker congestion.

2 Congestion consideration: modeling and solving

Considering the characteristics of the warehouse operation, congestion is produced when two or more pickers are sharing the same space at the same time, producing a delay compared to the normal operation. As the products are located only in vertical aisles, we consider the sub-aisle as the physical reference to quantify the delay produced by congestion. A sub-aisle is the part of a vertical aisle delimited by two consecutive horizontal cross-aisles. In addition, due to the characteristics of the human behavior, it is not appropriate to generate an exact coordination of the different pickers. Thus, we propose a rough estimation of the level of congestion. To do so, we introduce a time discretization to divide the planning horizon of the order picking process into homogeneous time intervals, quantifying the number of pickers in a sub-aisle for each one. To quantify the delay, we consider a piecewise linear and convex function, that permits to represent an increase in the delay when there is more congestion.

To include congestion into a mathematical model it becomes necessary to know the place in which each picker is located at each time period. Thus timing variables are necessary. Given the structure of an optimal solution of the PRP [3], a single picker can visit a single node at most four times, and a single directed arc at most once. As a consequence, it is impossible to compute the time by associating a single timing variable with each node of the underlying graph of the warehouse. To deal with this problem, we propose a graph transformation. Following the aforementioned property of optimal solutions [3], the graph is transformed. In the transformed graph any feasible tour visits each node not more than once. The core of the proposed transformation is the generation of a new node for each arc in the original graph. These nodes are then connected with the feasible transitions between them.

Considering the transformed graph we propose a MIP, that we validated and analysed with computational experiments. Due to the computational complexity, optimal solutions were obtained only for very small size instances. To analyze larger instances we implemented a two-steps procedure. First, we solve the JOBPRP without considering the effect of congestion. Then, the routes generated in the first step are timed taking into account the effect of congestion. This two-steps procedure represents a general scheme to solve the JOBPRP including congestion, and also allows us to obtain a lower and an upper bound for the complete MIP, solving the first and second step respectively.

3 Conclusions

In this work, we proposed a way to integrate the concept of congestion in the JOBPRP, quantifying the delay produced by congestion. A MIP is proposed and validated. Given the complexity of the model, a two-steps solution procedure allows us to adress larger instances. Although the two-steps procedure represents a first solving approach, an interesting perspective is to develop an efficient solving method to compute good lower and upper bounds. An approach based on column generation seems appropriate.

Références

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