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Lower bounds for the joint batching, routing and sequencing problem

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1 Introduction

Warehouses are nowadays the scene of complex logistics problems integrating different decision layers. The scene takes place in a tall and dim building, lights flickering with a buzzing noise. Pickers move across the warehouse, collecting items, fulfilling customer's orders. A digital voice for companionship.

To increase the efficiency of the operations, several orders might be batched, i.e., put together to be collected by a picker in one single route. Batching is possible as long as orders grouped together respect capacity constraints, namely they fit in a trolley. Since customer satisfaction is at the core of competitiveness in e-commerce, each order is required to be prepared and shipped before a strict deadline that usually corresponds to the departure of a truck from the warehouse to deliver orders. Pickers must therefore collect their batches in an appropriate sequence in such a way that all orders meet their deadlines. Planning the entire process is referred to as the Joint Order Batching, Picker Routing and Sequencing Problem with Deadlines (JOBPRSP-D).

In the present work, we consider optimal routing policies in rectangular warehouse with several blocks (or cross-aisles). Such optimal routes can be efficiently computed with dynamic programming following the work of Pansart et al. [1].

2 A bin-packing formulation

In the literature, relatively efficient methods have been designed for single problems such as the picker routing problem, however the resolution of integrated

problems is receiving attention since significant gains can be achieved by taking into account the interrelations of the planning problems. These problems are very challenging to solve, and practical instances tend to be of large size which complicates even more the resolution. Consequently, heuristic approaches have been favoured so far to solve these integrated problems.

The algorithms proposed so far to solve the JOBPRSP-D are all based on metaheuristics like for example iterated local search [2]. In this work, we propose an approach to provide lower bounds for the JOBPRSP-D. The sequencing aspect of the JOBPRSP-D has been considered so far as a scheduling problem where the batches of each picker have to be scheduled in order to satisfy the orders' deadline.

In this work, we show that the JOBPRSP-D can be formulated as a (multiple) bin-packing problem instead of a scheduling problem. This is possible since there are no release date for the orders. The main advantage of such a bin-packing formulation is to provide a tractable exponential linear programming formulation, that is strengthened by classical valid inequalities derived from the bin-packing problem.

3 A column generation heuristic

We propose a column generation heuristic able to provide valid lower and upper bounds on the optimal value of the JOBPRSP-D. From the bin-packing formulation, we show that the methodology proposed by Briant et al. [3], that is a column generation heuristic with performance guarantees for the Joint Order Batching and Picker Routing Problem (JOBPRP), can be extended to tackle the sequencing question. Moreover, a key cutting plane that was used for solving the pricing of [3] can be considerably strengthened by using timing considerations related to the sequencing aspect of the problem.

The proposed algorithm is evaluated on publicly available data-sets. It is able to optimally solve instances with up to 18 orders in few minutes. It is also able to prove optimality or to provide high-quality lower bounds on larger instances with 100 orders. To the best of our knowledge this is the first work that provides optimality guarantee on large size instances for the JOBPRSP-D, thus the results can be used to assert the quality of heuristics proposed for the same problem.

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