# Integration of multiple order picking planning problems and vehicle routing: state of the art

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This abstract gives a brief overview of the state of the art on the integration of order picking and vehicle routing. Based on this, research opportunities are identified which will be addressed during my PhD-study.

During the past decade, e-commerce was a booming business. Customers are ever more demanding and expect a fast delivery. While next-day delivery is already widespread, some companies are now even offering same-day delivery, sometimes within a few hours. In order to satisfy customer demand in such a short timeframe, companies need very efficient order handling. Upon receiving the order, the requested items have to be picked in the warehouse and afterwards shipped to the customer. Nowadays, the order picking and vehicle routing problems are solved separately. This means that a fixed cut-off time exists before which the orders have to be picked and handed over for delivery [2]. For some orders this cut-off time is too early as they will be delivered later anyway. With the integration of order picking and vehicle routing, this cut-off time is removed and more efficient order processing is possible. This was shown to generate cost savings of 5 to 20% [2] or a reduction in tardiness of 17.2% [3] on average.

The problem settings considered in Moons et al. [2] and Schubert et al. [3] are static, i.e., all orders are assumed to be known at the beginning of the planning horizon. Moreover, all orders are picked individually in the warehouse. Picking small orders individually often leads to long order picking travel times, time that can be considered unproductive. A solution is the use of order batching, which means combining multiple orders in a single pick round in order to reduce the order pick time per item considerably. In e-commerce most orders are small and here order batching is especially valuable [1]. However, order batching is not the only operational planning problem occurring during order picking: picker routing and job assignment have to be performed at the same time. Although these problems are often solved separately, they are interrelated and are best solved in an integrated way [4].

The past decade, researchers have been looking into the integration of these order picking planning problems. Nevertheless, only a few papers consider all three planning problems together. Van Gils et al. [4] solve this integrated order batching, routing and job assignment problem in the most elaborate way. In their setting, every four hours all orders are batched and a schedule for the next four hours is constructed. This means that some customer orders have to wait four hours before being included in a schedule. With the rise of e-commerce, however, shorter customer response times may be necessary for some orders. Therefore, a more dynamic solution method is useful. For the dynamic order batching problem, limited research exists, even more so for the dynamic problem dealing with the integration of order batching and picker routing or job assignment. A dynamic version of all three planning problems combined does not exist. A few dynamic order batching approaches exist. Orders can be batched after a certain amount of time has passed, or after a certain number of orders has been received. Some authors allow the rerouting of order pickers on their current routes to include new orders immediately. However, this may cause considerable uncertainty for order pickers.

We will look into integrating the dynamic order batching, picker routing and job assignment problems, wherein every time an order picker returns to the depot a new schedule is constructed. This way, new orders can be processed faster without changing the pick rounds already being executed. All new orders since the last optimization are combined with those from future pick rounds scheduled earlier. Only orders contained in pick rounds already being executed are excluded. This pool of orders is then used in the new schedule optimization. Once an efficient solution method for the dynamic, integrated order batching, picker routing and job assignment problem has been found, this solution method can be used in the integrated order picking and vehicle routing problem. We expect that a dynamic version of the problem considered in [2] and [3], including optimized order batching, should lead to a further reduction of the customer response times.


## Acknowledgements

This work is supported by the Special Research Fund (BOF) of Hasselt University.


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