Maastricht University

Improving supply chain performance

Citation for published version (APA):

Rajabighamchi, F. (2024). *Improving supply chain performance: order picking and service network design*. [Doctoral Thesis, Maastricht University]. Maastricht University. https://doi.org/10.26481/dis.20240305fr

Document status and date:
Published: 01/01/2024

DOI:
10.26481/dis.20240305fr

Document Version:
Publisher's PDF, also known as Version of record

Please check the document version of this publication:

• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.umlib.nl/taverne-license

Take down policy
If you believe that this document breaches copyright please contact us at:

repository@maastrichtuniversity.nl

providing details and we will investigate your claim.

Download date: 16 May. 2024

5
Summary

The overarching objective of this thesis is to develop some mathematical models and algorithms for optimizing two challenging and important problems in supply chain management, namely the order picker routing problem in the warehouse and the multi-commodity network design problem. In order to reach this objective, we started with an introduction chapter to understand the fundamental properties of the problems. In the second and third chapter, we studied the order picker routing problem in a standard warehouse layout since warehousing service is a very important component of the logistics system and plays a vital role in the supply chain process. Due to the many new technological advancements such as significant growth in digital marketing and e-commerce, introduction of operating programs such as Just-In-Time (JIT), cycle time reduction and quick response to orders and new marketing strategies such as micro marketing, the number of warehouses worldwide has seen significant growth. One of the processes within warehouses that provide significant increase in the efficiency and cutting the costs while ensuring high customer service levels is the so-called order picking. Order picking is often cited as one of the most critical process among the internal logistics operations due to its massive time and energy requirements. Researchers have already created a variety of exact and heuristic routing methods to reduce the price of order picking. However, the exact algorithms that do model the particularities of the order picking environment are not scalable and they only exist for small warehouses with only two blocks (see Roodbergen and De Koster [136] and Cornuéjols, Fonlupt, and Naddef [39], while for other larger warehouse layouts, some heuristic and meta-heuristic methods are provided. Moreover, the algorithms that solve the problem to optimality, are based on very general assumptions (solve it like a TSP) which leads to inefficient running times that are not applicable in real-life (same day delivery and JIT).

In the second chapter of this thesis, we proposed an exact model that relies on the particularities of a warehouse environment that is better scalable thanks to intensive graph reduction. The average graph reduction in comparison to the complete graph (before pre-processing) is 72.85%, which is really considerable. To the best of our knowledge our exact algorithm is the first proposed algorithm in the literature which can be implemented in warehouses with much more than two blocks and the computation time is comparable and less than one minute. Our mathematical model solves all the instances optimally. Furthermore, we proved that our proposed graph-reduction algorithm in addition to the exact model can be generalized for all planar TSPs, which leads to better performance for a whole set of optimization problems, not only order picker routing problem in the warehouse.

Planar graph reduction methods can be useful to researchers, industry, and society in several ways by designing efficient network topology since it has various applications such as transportation networks, biological network, electronic circuit design, image and video processing, graph theory, social networks, and communication networks and power grids. By reducing the complexity of the network, planar graph reduction methods can lead to simpler and more efficient network designs, and reduce the computational complexity of graph algorithms, which can save time and resources.

In an industrial perspective, our proposed algorithm could be easily integrated in existing warehouse management software, and it would help companies to rely on higher-quality solutions (optimal) for a realistic problem size resulting in a very fast and efficient delivery system. To do so, some additional steps are needed to put our results into practice, such as designing a new software, prototyping, programming, marketing etc.

In the third chapter, we went a step further, considering more general and realistic case of order picking within modern warehouses with scattered storage policies. In industry, many warehouses products are stored at multiple locations as a result of random / scattered storage policies. These policies are used since they are easy to implement, scalable and flexible in handling the seasonality without reserving unnecessary capacity for peak periods of a product. However, in industry, very simplified and basic algorithms are applied in such a picking environment (easier for operators), which is resulting in the routes far from the optimal solution. Our proposed exact GTSP model in addition to the heuristic algorithm could easily be used by warehouse operators and satisfies the current needs by saving time and increasing the efficiency.

In the literature, while the GTSP has received significant attention, the research has primarily focused on non-overlapping clusters. The existing algorithms rely on problem-specific characteristics that assume the clusters to be non-overlapping geographically. In our proposed order picker routing problem, we identified a field of application where this criteria no longer holds. Consequently, the existing algorithms would not be able to exploit this feature and would – likely – perform worse. Our goal was to develop an algorithm that can deal with the clustered substructure of the problem as good as possible, without having to rely on the assumption of non-overlapping clusters. This research was motivated not only by the potential efficiencies that can be achieved in a warehouse, but also by the fact that very little attention has been paid to this problem when accounting for the overlap of clusters. In the third chapter of this thesis, a new problem was introduced and mathematically formulated (GTSP with overlapping clusters), Moreover, we linked it to existing concepts and developed a heuristic algorithm for obtaining high-quality solutions. Our algorithmic ideas can easily be transferred to similar problems in the field of logistics.

Currently the models discussed in the chapters two and three of this thesis are limited to environments with only one picker. However, as a future research, one can consider the possibility to extend our models to multiple order pickers and analyze the impact of the employment of multiple order pickers on the average processing time of the orders. In this case we might consider the optimal number of pickers and order assignment policies to each order picker. Another approach could be assigning each order picker to a specific zone in the warehouse and try to assign them to only part of the items in each order, located in their zone. In addition to this modifications, various promising areas for further research can be identified in the field of order picker routing problem. One of these modifications to the current study might be taking into account numerous deposit locations (depots) and investigating its effects on tour lengths. Moreover, due dates for order list, dynamic customer orders, development of problem-specific solution procedures, and inclusion of uncertain expected orders should also be taken into account in the decision-making process. Furthermore, for chapter three of the thesis, future research could also focus on the pre-processing of the graph and developing a graph reduction method in the presence of overlapping clusters.

In the fourth chapter of this thesis, we consider a variant of multi-modal Multi-commodity Network design problem with delivery time and stochastic demand. The problem presented in this chapter is motivated by a case study in which a 3PL is responsible for coordinating all material flows that belong to the supply network of a large construction company within Europe (company names are confidential). This study contributes to the academic literature in the following ways. First, we consider multi-commodity service network design models over time to allow differentiation between the (periodic) scheduled truck services and the ad-hoc express delivery option. Moreover, we consider the delivery date for commodities, and finally fleet management by determining the allocation and fleet size of each type of transportation mode at each hub for each time period. These assumptions make our model more realistic. Second, we account for potential capacity limitations in the hub and manage inventory levels accordingly. Furthermore, we develop competitive solution approaches based on an integration of column generation and branch-and-price to solve this realistic variant of the MCND. Moreover, we extend our models and results to a setting with uncertain demand and present a two-stage, scenario-based stochastic model which is solved using the sample average approximation method. Finally, a broad range of managerial insights have been generated by means of an extensive sensitivity analysis.

Future contributions for this study can include considering heterogeneous vehicles with different capacities, improving the solution method (column generation and branch and price), taking into account the multi-period planning since our proposed model is focused on a single period with multiple time intervals. Moreover, robust optimization with service levels and time window for commodity delivery could be other future research directions.