VEHICLE ROUTING PROBLEM WITH CROSS-DOCKING AS PART OF INDUSTRY 4.0 LOGISTICS

Květa Papoušková[1]

[1] Ing. Květa Papoušková, University of West Bohemia, Faculty of Economics, kvetapapouskova@gmail.com, ORCID 0000-0002-7620-1672

Abstract: The trends associated with the onset of Industry 4.0 are obvious and require a prompt response from the company. An indisputable advantage is the use of the cross-docking strategy, which makes it possible to coordinate all logistics processes and achieve optimization of transport costs while maintaining minimal handling and storage. The goods are directly redistributed within the distribution system to specific customers according to their requirements without the need for storage. This logistic method is very often associated with various types of vehicle routing problem. It enables the introduction and use of Industry 4.0 principles. The aim of this contribution is to find out the possibilities of using Cross-docking within the vehicle routing problem. The output is a classification of five vehicle routing problems and their further breakdown, which are successfully connected with the idea of Cross-docking technology. This is a Capacitated vehicle routing problem with cross-docking, Open vehicle routing problem with cross-docking, Vehicle routing problem with cross-docking for multi-products, Multi-echelon distribution networks and Rich vehicle routing problem with cross-docking. Literature analysis shows that it is not an isolated technology but a tool offering a comprehensive logistics service connecting several processes. Offer various combinations of technologies in conjunction with vehicle routing problems to provide economic benefit and reduce the environmental impact of logistics chains.

Keywords: Cross-docking, Vehicle routing problem, Logistics, Industry 4.0, Sustainability

JEL Classification: Q55

INTRODUCTION

This article is devoted to the use of the Cross-docking strategy in circular traffic problems, hereinafter referred to as VRPCD. Cross-docking is a principle that is introduced within Industry 4.0. It is a very clever and powerful system, during which goods are redistributed directly to customers according to their requirements without the need for storage. Cross-docking makes it possible to eliminate unwanted costs arising from inconsistent storage and return of shipments or incorrect delivery processing. It will ensure the acceleration of supplier-customer relations, reduce the need for long-term storage and thus the total costs associated with distribution (Apte & Viswanathan, 2000).

Cross-docking is being implemented in several areas of industry. It experienced the greatest boom in the automotive sector. It is not just a matter of supplying trade networks with spare parts, but in connection with Industry 4.0, distribution chains in the form of shipment transport up to just in sequence are provided to production plants literally all over the world. The so-called value-added services are part of the cross-docking. As part of this technology, it is possible to provide preassembly, quality control, sorting, or services associated with reverse logistics. Škapa (2005) defines reverse logistics: "*The main content of reverse logistics is the collection, sorting, disassembly and processing of used products, components, by-products, surplus stock* *and packaging material, where the main goal is to ensure their new use, or material appreciation in a way that is gentle environmentally friendly and economically interesting."*

Another area where cross-docking can be found is the chemical industry. In addition to dangerous substances - caustics, explosives or self-igniting substances - the chemical industry also supplies products for everyday consumption - hygiene items, food supplements, synthetic fibre products or fuel. In connection with this branch of industry, there are many restrictions and strict safety rules for handling, transport, and storage. The logistics of dangerous substances and products must be ensured by highly qualified workers. For optimal integration of logistics chains, it is necessary to combine security requirements and cost efficiency very well. To ensure cross-docking in this industry, it is necessary to have specially adapted warehouses.

Industrial goods can be understood in many forms. These are light to oversized products from the aforementioned Automotive area. In addition, various states of substances from the chemical industry. Industrial goods logistics service requirements differ in many requirements. Industry 4.0 is associated with just in time or just in sequence deliveries, it is possible to deliver in time windows or to ensure express deliveries. As part of cross-dock, it is possible to create such a concept as part of supply chain management.

The world of trade is another very important part of the cross-dock. As the business strategy changes, so do the products that respond to customer behaviour. Distribution routes to the retail network are optimized. Products for daily consumption come to us from all over the world. Modern trading companies use the trend to transfer their logistics requirements to an external logistics partner. This agreement includes not only services related to logistics and distribution, but also assembly of goods, training, service, or return collection. We can summarize these services under the term Home Delivery.

From the point of view of sustainability, paper logistics combined with reverse logistics is very interesting. Paper waste is transported for recycling as part of reverse logistics. This contributes to reducing the burden of paper production and fulfilling the principles of sustainability.

Cross-docking technology is not just warehouse space and related services. This also includes port logistics. It provides connections to international transport chains and handles customs services. The exception is, for example, the operation of a sawmill or the mediation of services related to ship cleaning.

Many studies have addressed the conceptual benefits of Cross-docking (Kreng & Chen, 2008; Van Belle et al., 2012; Kiani Mavi et al., 2020). However, it is also important to consider the operational point of view to find the optimal delivery and collection plan.

The cross-docking strategy does not have to be understood only as large storage spaces or as a concept offered to the company by a third party. Cross-docking is also the idea of a warehouse that is part of a company in which the goods are only redistributed for individual centres of the company.

1. METODOLOGY

1.1 Vehicle routing problem

The vehicle routing problem (hereinafter referred to as VRP) solves the optimization of the route between customers and a warehouse or multiple warehouses subject to the fulfilment of restrictive conditions. It exists in many variants, which differ precisely in the limiting conditions. The result of optimization using VRP is a sequence of locations that guarantees the lowest possible total distribution costs or minimizes the distance traveled according to the objective function (1) while respecting the limiting conditions (2)-(5).

VRP is defined by a mathematical model (Fábry, 2006):

$$z = \sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij} x_{ij} \rightarrow MIN \qquad i \neq j \tag{1}$$

$$\sum_{i=1}^{n} x_{ij} = 1, \qquad i = 1,2,\dots,n \quad i \neq j \tag{2}$$

$$\sum_{j=1}^{n} x_{ij} = 1, \qquad j = 1,2,\dots,n \quad i \neq j \tag{3}$$

$$u_i + u_j - n x_{ij} \leq n - 1, \qquad i = 1,2,\dots,n,\ j = 2,3,\dots,n \quad i \neq j \tag{4}$$

$$x_{ij} \in \{0,1\}, \qquad i,j = 1,2,\dots,n, \tag{5}$$

The possibility of serving each customer x_{ij} exactly once is given by conditions (2) and (3). Condition (4) is used to prevent the creation of sub-cycles without a starting point. Any numbers in the field of real numbers that meet the condition are denoted by the variables u_i and u_j. The value u_i represents the order in which the i-th vertex is served. The binary variable x_{ij} (5) takes only two values:

$$x_{ijk} = \begin{cases} 0 \text{ when there is no circle from } i \text{ to } j \\ 1 \text{ otherwise} \end{cases}$$

We rank it among the classic VRPs capacitated vehicle routing problem (CVRP), problem with time windows (VRPTW), vehicle routing problem with pickup and delivery (VRPPD), periodical problem (PVRP), VRP with multi depots (VRPMD), vehicle routing problem with split delivery (VRPSD), stochastic (SVRP) and dynamic vehicle routing problem (DVRP) and open vehicle routing problem (OVRP).

1.2 Cross-docking

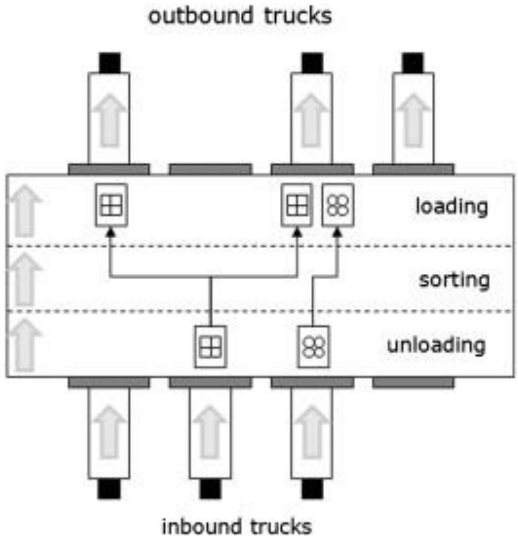
Cross-docking is among the logistics strategies that are used to speed up distribution chains while reducing overall distribution costs. Currently, two types of cross-docking technology can be found:

- Production-supplier cross-docking
- Distribution cross-docking

Production-supplier cross-docking ensures delivery and collection of material or semi-finished products required by production directly at the plant. It also includes services related to preassembly or follow-up to production in the just-in-time mode or just in sequence. Implementing this strategy requires a high level of cooperation between inbound vehicles and internal operations. That is why it is most often implemented as part of Industry 4.0.

Due to the limited availability of resources such as forklifts, coordination and scheduling of incoming and outgoing vehicles becomes a difficult problem to solve with a significant impact on the overall network performance. When planning a cross-docking, the number of dock doors and the overall layout of the terminal must be determined. Cross-docking doors are around the perimeter of the building. This gives a good idea of the distance between any pair of doors and easily determines the time delay for manipulation (Boysen & Fliedner, 2010). A similar variant of the same problem is the solution to maximize the number of products that can be handled in cross-docking while maintaining vehicle capacity (Zachariadis et al., 2022).

Fig. 1 The pickup and delivery process in a distribution cross-docking



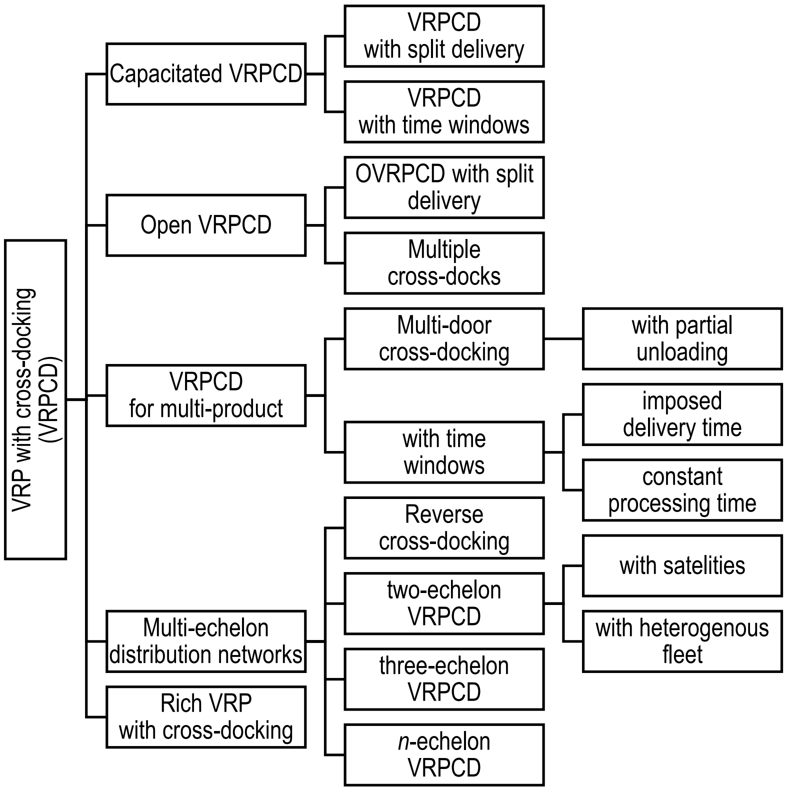
Source: Boysen, N., & Fliedner, M. (2010)

Distribution cross-docking includes the distribution of shipments, see Fig. 1 from one or more suppliers, to a central warehouse, where the shipments are subsequently divided and delivered to the final customer.

2. LITERARY RESEARCH

As part of the literature search of the distribution cross-dock, several VRPs were found that are successfully solved in connection with the cross-dock; see Fig. 2. The cross-dock routing problem (VRPCD) consists of designing routes that meet customer requirements. Vehicles transport goods from pick-up points to cross-dock where items are consolidated for efficient delivery (Grangier et al., 2017).

Fig. 2 Classification of vehicle routing problem with cross-docking



Source: (Author) (2022)

2.1 Capacitated VRPCD (CVRPCD)

The capacitated routing problem with cross-docking uses a homogeneous fleet to transport goods, each customer can be visited only once, and the total amount of goods in the vehicle must not exceed the capacity of the vehicle. The goal of the problem is to determine the number of vehicles and the set of timetables of individual vehicles. The sum of operating costs and transportation costs is minimized (Liao et al., 2010; Nikolopoulou et al., 2019).

Capacity VRPCD solutions for a heterogeneous fleet are elaborated in several studies (Tarantilis, 2013; Birim, 2016; Baniamerian et al., 2019). This is the routing of vehicles with different capacities in a cross-docking environment. All routes start and end at the cross-dock, and only one vehicle visits all drop-off and pick-up locations. The objective of this study is to design routes that minimize total transportation costs and fixed vehicle costs.

If the time window constraint (VRPCDTW) is added to the capacitive VRPCD, we get another optimization option. The aim is to minimize the total travel time while respecting the time horizon of the entire transport. Cross-docking thus lacks the ability to hold inventory for a long time (Wen et al., 2009; Sadri Esfahani & Fakhrzad, 2014). Another interesting variant of the time window problem was later optimized (Rahbari et al. (2019). This is cross-dock vehicle scheduling for perishable products. Time-window constraints are very often used in multi-layer distribution network problems or in combination with other classic VRPs.
For distributed delivery VRP (SDVRPCD), customers (suppliers) are willing to receive (send) goods in multiple shipments, and each node can be served by more than one vehicle (Hasani-Goodarzi & Tavakkoli-Moghaddam, 2012).

2.2 Open VRPCD (OVRPCD)

The problem is a variant in which vehicles do not have to return to the warehouse and the delivery cycle is not closed. The advantage of this variant of VRP is the reduction of the burden on the retailer in the form of vehicle acquisition costs. The study (Vincent et al., 2016) considers the transport of one commodity and the use of a single cross-docking. Vehicle routes are scheduled to arrive at cross-docking at the same time. Each customer is served only once, and deliveries must be completed within a predetermined time. The goal is to minimize total costs.

Another variant of open VRP is open VRPCD with split delivery (SDOVRP). This solution is attractive for a company that, to reduce fixed costs, outsources its vehicle fleet to a logistics company. This creates an open routing problem with cross-docking and split delivery (Afsharpour and Rbani, 2021).

Cross-dock heterogeneous vehicle routing problem that considers the use of multiple cross-docks in a distribution system (Vincent et al., 2021). This approach aims to minimize penalties caused by customer service delays (Cota et al., 2022).

2.3 VRPCD for multi-products (VRP-MPCD)

The classic VRPCD is extended by the possibility of supplying more products. Even for this variant, inside the cross-docking, the goods are directly transferred from the arriving vehicles to the departing vehicles, without being stored in the meantime (Gunavan et al., 2020b).

Multi-door cross-docking is a problem where the main limiting conditions are the number of dock-doors and the uncertain arrival time of heterogeneous vehicles at the cross-docking (Dondo & Cerdá, 2015; Wisittipanich & Hengmeechai, 2017; Joo & Kim, 2013; Liao et al., 2013). It is a multi-door cross-docking system with queuing approach (Goodarzi et al., 2022). This problem occurs in the case of queueing, where delays in the queue reduce the quality of service and generate the economic costs associated with waiting. This problem is addressed in the study by Ardakani et al. (2020), who proposed ordering sequences of arriving vehicles according to common (repeating) formulas.

An interesting extension of previous studies is the possibility of splitting the delivery. Incoming vehicles are used at the same time as outgoing vehicles. In addition, incoming vehicles do not have to unload and translate the demand but can be partially unloaded (Shahmardan & Sajadieh, 2020).

Multi-product VRP with time windows was introduced by Vahdani & Sadigh (2014). This contribution not only considers the delivery of multiple types of products in time windows, but also considers a heterogeneous fleet of capacity-constrained vehicles arriving at the cross-docking location simultaneously. For this type of problem, a contribution should be mentioned that assumes a constant time for unloading the vehicle in order to plan activities such that to minimize the completion time of the entire process (Gaudioso et al., 2021).

2.4 Multi-echelon VRPCD (VRPCD-SCM)

Multi-echelon distribution networks are quite common in supply chain and logistics. Multiple item deliveries from factories to customers are provided by cross-docking, which consolidates incoming shipments and delivers them immediately according to customer requirements (Dondo et al., 2011). It is a strategy that combines direct shipping, storage, and cross-docking. The goal of the problem is to route vehicles according to customer requirements in a multilayer distribution network with minimal total transportation costs.

Two-level production routing issue with cross-docking satellites. This issue is important in e-Commerce, delivery services, and urban logistics (Qiu et al., 2021). The combination of heterogeneous vehicle routing using cross-docking and two-dimensional load constraint, referred to as 2L-MVRPCD, provides an effective solution for another combination of capacitive VRP (Cuda et al., 2015; Ji et al., 2022).

Baniamerian et al. (2018) presented a vehicle routing and scheduling problem with cross-docking and time windows in a three-level supply chain that considers customer satisfaction. In addition to the classic type of fixed time window, a customer satisfaction window is also introduced. The satisfaction window is a subset of the classical time window, and violation of its time is not allowed. The customer satisfaction window can be understood as the time during which customers tend to accept their requests.

Reverse Cross-docking (VRP-RCD) is research that extends the benefits of cross-docking to reverse logistics. Management of the return process has become an important element in many areas of waste management within sustainability and environmental improvement. There are several factors that influence the boom in reverse logistics: government requirements, social responsibility, principles of sustainability, and indisputable economic benefits. This philosophy is reflected in all processes. Manufacturers must produce goods that meet the strictest measures associated with them with the improvement of the environment, but also collect used products and obtain additional values from them. Thus, it is the movement of used products from the point of consumption to the point of origin for the purpose of regaining value or for recycling (Mahaboob Sheriff et al., 2012).

Several studies (Gunawan et al., 2020a; 2021; Widjaja et al., 2020) developing a mathematical model to minimize product movement costs in a four-level supply chain network that includes suppliers, cross-docking, customers, and stores to minimize vehicle operating and transport costs.

2.5 Rich VRP with cross-docking (MTVRPGC)

Rich VRPs are such problems that contain elements of several classic VRPs. In the study of Smith and the collective (2022) are specifically VRP with time windows, Multi depot VRP and Multi-objective VRP. Moreover, it represents a variant of the pickup and delivery problem and the cross-docking problem. In the literature, it is possible to find this problem under the name multi-tiered vehicle routing problem with global cross-docking.

Another interesting study (Goodarzi et al., 2020) addresses cross-docking vehicle routing that considers vehicle scheduling, distribution of pick-up orders, and time-windowed deliveries at suppliers and vendors, optimizing two conflicting objectives (i.e., cost efficiency and ability to respond). The goal is to minimize total operating costs and the sum of maximum punctuality and lateness.

CONCLUSION

Cross-docking is a technology that, when properly implemented within distribution chains, leads to a reduction of the economic burden and the need for storage space while maintaining efficient material flows and customer satisfaction. Cross-docking occurs in two variants such as distribution and production-supplier. The second one is cross-docking, which is directly part of the company, through which products only "pass" and are redistributed for further processing by production or assembly in the form of just in time or just in sequence. This strategy is implemented most often in connection with the introduction of Industry 4.0, because it is characterized by the direct synchronization of several factors of production.

The use of cross-docking within the vehicle routing problem is proving to be a very promising area, offering a whole range of possibilities within the framework of distribution cross-docking. This article focuses on vehicle routing problems that are solved and optimized in conjunction with cross-docking. Five basic routing problems with cross-docking were defined in the literature search. The first variant is Capacitated VRPCD. This variant of classic VRP, using the advantages of cross-docking, has made a significant mark among trends in distribution logistics. Capacitated VRPCD also offers extensions for split delivery or the often-discussed time windows. Open VRPCD are vehicle routing problem with cross-docking, which enable the delivery of goods without returning to the original warehouse. The cycle is not closed. These are significant savings, especially for the retailer, who is spared the expensive purchase of a vehicle. Open VRPs in their classic version are often associated with outsourcing, which for OVRPCD becomes cross-docking. This will allow the company to save a lot of fixed costs. Again, it is possible to find solutions to problems by split delivery or cases with a larger number of cross-docking, so-called multiple cross-docks. Using this variant, companies gain a significant competitive advantage, thanks to a reduction in service delays and associated penalties. VRPCD for multiproducts is the variant that comes closest to the real situation. It is about the possibility of delivery of several products. In cross-docking, it is redistributed and transported according to customer requirements. Again, this is a variant that successfully uses the possibilities of time windows. It is also expanded with a multi-door variant offering the possibility of sorting queues before cross-docking and thereby eliminating delays caused by queues. Multi-echelon distribution networks are a comprehensive solution for logistics chains. The strategy combines direct shipping, storage and cross-docking. Routing problems occur at several levels of distribution networks. It also includes problems associated with reverse logistics. These types of vehicle routing using cross-docking are a valuable link in ensuring the principles of sustainability and reducing the intensity of production. Rich VRPs with cross-docking are problems that combine several classic VRPs with the possibility of cross-docking.

The output of the research is a classification of vehicle routing problems, which include technology Cross-docking. Most of the published problems can be classified into one of the variants and further breakdown in Fig. 2. Cross-docking technology is a complex business activity including transportation, logistics solutions, provision of innovative value-added services, storage logistics, and much more. Therefore, it is very important to have an overview of the VRPs that are combined with this strategy.

Acknowledgements

The work presented in this paper has been supported by West Bohemia University in Pilsen (project No.SGS SGS-2021-022 - Financial (stock) markets, modeling and prediction of behavior).

REFERENCES

Afsharpour, B., & Rbani, M. (2021). Open Vehicle Routing Problem with Cross-Docking and Split Deliveries. *Journal of Industrial Engineering Research in Production Systems*, *8*(17).

Apte, U. M., & Viswanathan, S. (2000). Effective cross docking for improving distribution efficiencies. *International Journal of Logistics*, *3*(3), 291-302.

Ardakani, A., Fei, J., & Beldar, P. (2020). Truck-to-door sequencing in multi-door cross-docking system with dock repeat truck holding pattern. *International Journal of Industrial Engineering Computations*, *11*, 201-220.

Baniamerian, A., Bashiri, M., & Zabihi, F. (2018). Two phase genetic algorithm for vehicle routing and scheduling problem with cross-docking and time windows considering customer satisfaction. *Journal of Industrial Engineering International*, *14*(1), 15-30.

Baniamerian, A., Bashiri, M., & Tavakkoli-Moghaddam, R. (2019). Modified variable neighborhood search and genetic algorithm for profitable heterogeneous vehicle routing problem with cross-docking. *Applied Soft Computing*, *75*, 441-460.

Birim, Ş. (2016). Vehicle routing problem with cross docking: A simulated annealing approach. *Procedia-Social and Behavioral Sciences*, *235*, 149-158.

Boysen, N., & Fliedner, M. (2010). Cross dock scheduling: Classification, literature review and research agenda. *Omega*, *38*(6), 413-422.

Cota, P. M., Nogueira, T. H., Juan, A. A., & Ravetti, M. G. (2022). Integrating vehicle scheduling and open routing decisions in a cross-docking center with multiple docks. *Computers & Industrial Engineering*, *164*, 107869.

Cuda, R., Guastaroba, G., & Speranza, M. G. (2015). A survey on two-echelon routing problems. *Computers & Operations Research*, *55*, 185-199.

Dondo, R., Méndez, C. A., & Cerdá, J. (2011). The multi-echelon vehicle routing problem with cross docking in supply chain management. *Computers & Chemical Engineering*, *35*(12), 3002-3024.

Dondo, R., & Cerdá, J. (2015). The heterogeneous vehicle routing and truck scheduling problem in a multi-door cross-dockingsystem. *Computers & Chemical Engineering*, *76*, 42-62.

Fábry, J. (2006). Dynamické okružní a rozvozní úlohy. *Doktorská disertační práce, Katedra ekonometrie, Fakulta informatiky a statistiky, Vysoká škola ekonomická v Praze, Praha*.

Gaudioso, M., Monaco, M. F., & Sammarra, M. (2021). A Lagrangian heuristics for the truck scheduling problem in multi-door, multi-product Cross-Docking with constant processing time. *Omega*, *101*, 102255.

Goodarzi, A. H., Tavakkoli-Moghaddam, R., & Amini, A. (2020). A new bi-objective vehicle routing-scheduling problem with cross-docking: Mathematical model and algorithms. *Computers & Industrial Engineering*, *149*, 106832.

Goodarzi, A. H., Diabat, E., Jabbarzadeh, A., & Paquet, M. (2022). An M/M/c queue model for vehicle routing problem in multi-door cross-docking environments. *Computers & Operations Research*, *138*, 105513.

Grangier, P., Gendreau, M., Lehuédé, F., & Rousseau, L. M. (2017). A matheuristic based on large neighborhood search for the vehicle routing problem with cross-docking. *Computers & Operations Research*, *84*, 116-126.

Gunawan, A., Widjaja, A. T., Vansteenwegen, P., & Yu, V. F. (2020a, September). Vehicle routing problem with reverse cross-docking: An adaptive large neighborhood search algorithm. In *International Conference on Computational Logistics* (pp. 167-182). Springer, Cham.

Gunawan, A., Widjaja, A. T., Gan, B., Yu, V. F. and Jodiawan, P. (2020). *Vehicle routing problem for multi-product cross-docking*. Proceedings of the International Conference on Industrial Engineering and Operations Management 2020: Dubai, UAE, March 10-12. 66-77.

Gunawan, A., Widjaja, A. T., Vansteenwegen, P., & Yu, V. F. (2021). Two-phase Matheuristic for the vehicle routing problem with reverse cross-docking. *Annals of Mathematics and Artificial Intelligence*, 1-35.

Hasani-Goodarzi, A., & Tavakkoli-Moghaddam, R. (2012). Capacitated vehicle routing problem for multi-product cross-docking with split deliveries and pickups. *Procedia-Social and Behavioral Sciences*, *62*, 1360-1365.

Ji, B., Zhang, Z., Samson, S. Y., Zhou, S., & Wu, G. (2022). Modelling and Heuristically Solving Many-to-many Heterogeneous Vehicle Routing Problem with Cross-docking and Two-dimensional Loading Constraints. *European Journal of Operational Research*.

Joo, C. M., & Kim, B. S. (2013). Scheduling compound trucks in multi-door cross-docking terminals. *The International Journal of Advanced Manufacturing Technology*, *64*(5), 977-988.

Kiani Mavi, R., Goh, M., Kiani Mavi, N., Jie, F., Brown, K., Biermann, S., & A Khanfar, A. (2020). Cross-docking: a systematic literature review. *Sustainability*, *12*(11), 4789.

Kreng, V. B., & Chen, F. T. (2008). The benefits of a cross-docking delivery strategy: a supply chain collaboration approach. *Production Planning and Control*, *19*(3), 229-241.

Liao, C. J., Lin, Y., & Shih, S. C. (2010). Vehicle routing with cross-docking in the supply chain. *Expert systems with applications*, *37*(10), 6868-6873.

Liao, T. W., Egbelu, P. J., & Chang, P. C. (2013). Simultaneous dock assignment and sequencing of inbound trucks under a fixed outbound truck schedule in multi-door cross docking operations. *International Journal of Production Economics*, *141*(1), 212-229.

Mahaboob Sheriff, K. M., Gunasekaran, A., & Nachiappan, S. (2012). Reverse logistics network design: a review on strategic perspective. *International Journal of Logistics Systems and Management*, *12*(2), 171-194.

Nikolopoulou, A. I., Repoussis, P. P., Tarantilis, C. D., & Zachariadis, E. E. (2019). Adaptive memory programming for the many-to-many vehicle routing problem with cross-docking. *Operational Research*, *19*(1), 1-38.

Qiu, Y., Zhou, D., Du, Y., Liu, J., Pardalos, P. M., & Qiao, J. (2021). The two-echelon production routing problem with cross-docking satellites. *Transportation Research Part E: Logistics and Transportation Review*, *147*, 102210.

Rahbari, A., Nasiri, M. M., Werner, F., Musavi, M., & Jolai, F. (2019). The vehicle routing and scheduling problem with cross-docking for perishable products under uncertainty: Two robust bi-objective models. *Applied Mathematical Modelling*, *70*, 605-625.

Sadri Esfahani, A., & Fakhrzad, M. B. (2014). Modeling the time windows vehicle routing problem in cross-docking strategy using two meta-heuristic algorithms. *International Journal of Engineering*, *27*(7), 1113-1126.

Shahmardan, A., & Sajadieh, M. S. (2020). Truck scheduling in a multi-door cross-docking center with partial unloading–Reinforcement learning-based simulated annealing approaches. *Computers & Industrial Engineering*, *139*, 106134.

Smith, A., Toth, P., Bam, L., & van Vuuren, J. H. (2022). A multi-tiered vehicle routing problem with global cross-docking. *Computers & Operations Research*, *137*, 105526.

Škapa, R. (2005). *Reverzní logistika*. Brno: Masarykova univerzita.

Tarantilis, C. D. (2013). Adaptive multi-restart tabu search algorithm for the vehicle routing problem with cross-docking. *Optimization letters*, *7*(7), 1583-1596.

Van Belle, J., Valckenaers, P., & Cattrysse, D. (2012). Cross-docking: State of the art. *Omega*, *40*(6), 827-846.

Vahdani, B., & Sadigh, B. S. (2014). A multi-product vehicle routing scheduling model with time window constraints for cross docking system under uncertainty: A fuzzy possibilistic-stochastic programming. *IJIM*, *6*(3), 215-228.

Vincent, F. Y., Jewpanya, P., & Redi, A. P. (2016). Open vehicle routing problem with cross-docking. *Computers & Industrial Engineering*, *94*, 6-17.

Vincent, F. Y., Jewpanya, P., Redi, A. P., & Tsao, Y. C. (2021). Adaptive neighborhood simulated annealing for the heterogeneous fleet vehicle routing problem with multiple cross-docks. *Computers & Operations Research*, *129*, 105205.

Wen, M., Larsen, J., Clausen, J., Cordeau, J. F., & Laporte, G. (2009). Vehicle routing with cross-docking. *Journal of the Operational Research Society*, *60*(12), 1708-1718.

Widjaja, A. T., Gunawan, A., Jodiawan, P., & Vincent, F. Y. (2020, April). Incorporating a reverse logistics scheme in a vehicle routing problem with cross-docking network: a modelling approach. In *2020 IEEE 7th International Conference on Industrial Engineering and Applications (ICIEA)* (pp. 854-858). IEEE.

Wisittipanich, W., & Hengmeechai, P. (2017). Truck scheduling in multi-door cross docking terminal by modified particle swarm optimization. *Computers & Industrial Engineering*, *113*, 793-802.

Zachariadis, E. E., Nikolopoulou, A. I., Manousakis, E. G., Repoussis, P. P., & Tarantilis, C. D. (2022). The vehicle routing problem with capacitated cross-docking. *Expert Systems with Applications*, *196*, 116620.