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Improving Fleet Solution – A Case Study

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Abstract. Transportation management is a logistical activity with a high impact on a company's ability to compete in the market. Although the focus on cost reduction is the most usual concern with this activity, lead times and the quality of the service provided should also be considered depending on the market to be served. The goal of this research was to compare different fleet alternatives for a specific construction materials company and discuss which scenario is the most suited to fulfil the company's customer service policy. A case study approach was developed, and four alternative scenarios were considered. These were compared both regarding the costs they involve, which was analysed using a vehicle routing problem heuristic, and the quality of the customer service they allow, which was assessed based on their ability to provide flexibility in the fleet occupancy rate to respond to unexpected orders. Evidence showed that the current fleet solution is not adequate and investment should be made only if the demand level increases, otherwise outsourcing should be considered along with a minimum level of the self-owned fleet.

Keywords: A case study · Fleet management · Logistics · Transportation · VRPH

1 Introduction

Transportation is considered a typical logistics activity [1] and is probably the most visible logistics activity. Decisions at this level influence the company's ability to compete in the market. Its value to the customer is widely recognised [2–5]. Finding the best fleet solution to each company at any given moment is a challenge that is never completely fulfilled.

The current economic world scenario presents itself as an additional challenge to companies. Although keeping their customer service level is critical in commercial terms and owning a private fleet is considered as a “strategic asset” [6], cost reduction is currently a survival issue.

Literature is rich in terms of research focused on route optimization, either for private fleet see, for instance, [7, 8], or for a dual option of private fleet and outsourced

transportation services see, for instance, [9, 10] or even just focused on fleet size see, for instance, [11]. This perspective, although also aiming for lead time fulfilment, has its optimization routines based on cost (which can be transportation and/or inventory costs) and/or distance/time reduction. It is possible to research focused on the fleet replacement issue [12], but the focus is still on cost reduction. Not much can be found on the trade-off between the quality of the logistics service provided and the cost the system has to support to deliver it. This is the gap in the literature that the present research aims to reduce.

This research emerged from the request of a Portuguese construction materials company to have its fleet solution analyzed. This company is considered a medium size one. Its main activity is the production and distribution of plaster for construction and porcelain industry. It holds a factory warehouse, and three large warehouses spotted in populous regions from where it supplies its customers. Transportation in bulk is outsourced as loads are random and always in full. Packed products, which represent 82% of products sold, are moved using both the company's fleet and outsourcing. The company's customer service policy aims for due dates fulfilment and a lead time of up to one week. Due to the economic crisis in Europe, the company was not able to renew its fleet but is currently challenged by the fact that it is old and has high maintenance costs.

This research aims to compare and discuss different fleet alternative scenarios for packed product's transportation taking into consideration the company's customer service policy.

In order to fulfil the goal, a literature review focus on the relevance of logistical value and fleet solution. A case study approach is considered taking into consideration [13] recommendations. Firstly, the company is briefly characterized as to identify customer service challenges and scenarios are developed taking into consideration both the company's desire and best practices from literature. Then data from one year of deliveries is analyzed using a vehicle routing problem heuristic (VRPH). Lastly, both quantitative and qualitative analysis is conducted to better fulfil the goal of this research.

2 Literature Review

There are several ways in which a company can generate value to its customers with its offer. One of them is using its logistical system [14]. In fact, it is argued that as long as logistics is "managed as an integrated effort to achieve customer satisfaction at the lowest cost possible", it will create value [15]. This value creation, or the logistics value proposition of a company, should be defined according to an individual or selected customer group [15] and as a result of the trade-off between the time the logistics system requires to respond to the desired value proposition, the cost of the logistic system has to support to perform it, and the quality of the logistic service provided that should be considered in terms of the availability, support and commitment provided to the customer [4, 14].

Customer service, as the set of activities that provide product availability in a way that customers recognize as valuable, requires availability, operational performance and service reliability [5]. On-time delivery, in-full delivery and error-free deliveries are

common measures of customer service. These are part of the product surrounding services that customers require when they purchase a product, and although they only represent a small part of the cost of product ownership for the customer [5], they represent a very high impact in terms of purchasing decision (20–80 rule).

Transportation is the logistic activity that directly impacts on-time delivery and customer service quality, but at the same time, it can heavily influence costs. It is known that costs increase with distance travelled but decrease with increased cargo load [5]. This means that companies in search for cost reduction tend to focus on fleet and routing solutions that allow them higher occupancy rates. As a consequence, they might be sacrificing customer service levels, which is of high impact when commodities are involved [15].

There are several routing problem solutions each aimed at situations with specific characteristics. These are highlighted by several authors see, for instance, [16–18] and [17] provide a literature review on the referred variances as well as on exact resolution methods and heuristics. Although whole linear programming is popular, it is sometimes unpractical due to computer capacity constraints to deal with the dimension and complexity of real situations [5]. As so, heuristics have become more popular.

Among the routing problem approaches, one is focused on defining the route each vehicle has to follow without exceeding its capacity (both in terms of cargo and availability of time). The route is only completed when the vehicle returns to its origin. This routing problem is known as the Vehicle Routing Problem (VRP) and was initially introduced by Dantzig and Ramser [19]. Among these, the improvement heuristic from [20, 21], VRPH, applicable using the program made available by [28], is a very recent one in terms of the heuristic techniques it uses. This metaheuristic can perform several types of local search in the vicinity of initial solutions generated by the heuristic of Clark and Wright [22] and also to the diversification of solutions, returning, in the end, the best solution found. Because it is a heuristic improvement process, the routes obtained by VRPH are at least as good as Clarke and Wright's. VRPH also provides routes for VRP in which not only vehicle capacity constraints are considered but also maximum distance ones for each vehicle.

Research has mostly been focused on cost reduction, basically on finding the best fleet size see, for instance, [11, 23], or identifying the best route for a specific case see, for instance, [24, 25].

The required trade-off within the logistics attributes [5] and the influence the transportation option has on the company's competitive position in the market have not been the focus of much research. In fact, not much has been published in this area, and even the "make-or-buy" decision is mostly based on cost, as argued by Coase [26], even if service quality is also mentioned see, for instance, [27].

Although the use of private fleets was mentioned in the past as the option to obtain lower costs or higher service levels than the ones available from for-hire carriers, the development of logistics service providers reduced, and most times even eliminated, the relevance of the argument. Nonetheless, arguments in favour of keeping private fleets remain, as long as they are properly supervised in terms of the costs they implicate, as the value it can bring in terms of customer satisfaction and visibility is of a strategic nature [6], but not much research is focused on customer service using cost as a relevant but secondary concern.

3 Methodology

3.1 Scenarios

In order to access the most adjusted solution for the company's fleet, several scenarios were developed and compared. These were developed based not only on the scenario the Company is considering (Scenario 2) but also on taking into account other possible solutions (Scenarios 3 and 4). They are as follows:

- Scenario 1 – Company's current situation: self-owned fleet composed of one 24.5 tons vehicle and two 16.5 tons vehicles, and outsourcing deliveries are performed whenever this fleet is insufficient. With this scenario, the current company costs are evaluated (it is the reference scenario).
- Scenario 2 – Solution proposed by the Company: a new 24.5 tons vehicle substitutes the two 16.5 tons vehicles, and outsourcing whenever needed. The company will consequently have two 24.5 tons vehicles. The age of the two 16.5 tons vehicles, which will reach their lifespan in the medium term, motivates this scenario.
- Scenario 3 – Reduce the self-owned fleet: discard the two 16.5 tons vehicles, keeping the 24.5 tons vehicle, and outsourcing when needed. The present Portuguese economic situation and forecasts about the end life of the two 16.5 tons vehicles substantiate this scenario.
- Scenario 4 – Full outsourcing of deliveries: discard all the self-owned fleet. Many companies have been increasingly outsourcing their transportation needs, which explains this scenario.

The age of the current vehicles of the company is shown in Table 1.

Table 1. Characterization of the fleet

Vehicle	Age (years)
16.5 tons (1)	24
16.5 tons (2)	22
24.5 tons	8

3.2 Steps in the Analysis

This study was developed considering the company's consignment notes for a full year associated with products delivered from its factory warehouse. Additionally, and in order to access qualitative information, informal interviews with the manufacturing director and the transportation operations coordinator were conducted. This initial phase allowed evaluating the company's customer service policy and competitive positioning.

In the second phase, and according to the objectives of the research, the aim was to determine individual customer demand for each day of the year and their delivery location based on the collected data. All the outsourced deliveries of bulk products or

products transported by the customer were excluded from the analysis as they do not occupy the fleet under analysis.

Daily routes were determined for each scenario, minimizing transportation costs. The heuristic method VRPH [20, 21, 28] was used to deal with the limited capacity of the vehicles and the legal driving times allowed. The vehicle routes planning started running the interface GenRoutes for 24.5 tons vehicles since the VRPH heuristic determines trips for the VRP, which assumes homogeneous capacity vehicles. Thus, for each day, initial vehicle trips not exceeding 24.5 tons nor 1080 km were obtained (this last limit is detailed in the next sub-chapter).

As a result of this planning, for each scenario, day and vehicle, the number of trips performed, the delivered quantity and the travelled distance (in kilometres) were obtained. Then, based on this information, the total cost related to each scenario was computed, taking into account the associated fixed and variables costs, the purchase vehicle costs (when applied), and the outsourcing costs. All data needed to compute the referred costs was made available by the company.

Finally, in order to accomplish the objective of this research, the advantages and disadvantages of each scenario are outlined according to the established criteria, namely the cost and customer service policy.

3.3 Data Collection and Treatment

This study was conducted considering the Company's deliveries for one full year. Completion of deliveries was assumed for the day they were actually delivered, i.e., the possibility to fulfil the delivery after that day was not considered. According to the company, this year is a good representation of its current delivery level. All the data needed to be was registered in Microsoft Excel worksheets. This included, for each delivery: document number; order date; deliver date and time; vehicle registry; customer name and address; delivery place; products details: reference, description, and quantities.

Data was then summarized regarding its usage by the VRPH software to determine the daily vehicle routes. For each day, this included the identification of the customers to serve (identification of customer and delivery location) and the demand level in kilograms. It was also considered:

- a matrix with the distances between all pairs of delivery locations, including the production center (based on a distance matrix between all pairs of councils);
- legal driving times per day;
- data for each vehicle (average velocity and maximum cargo weight per trip).

The 9 h driving time per day and per driver agreement between the Company and its drivers were converted into kilometres assuming a 60 km/h average driving time, resulting in a maximum of 540 km per driver per day. However, since two drivers are available for each type of vehicle and adding the fact that they may perform trips together, twice of 540 km were considered, as it is used by the company, resulting in 1080 km per day per type of vehicle.

Products can be divided into two categories regarding shape, volume and weight, with consequences in its packaging solutions for distribution purposes. One product category considers homogeneous products, which are high-density products disposed of in standard pallets; the other category considers heterogeneous products, which are low weight and small size ones, and these have a residual volume per delivery.

Almost all products distributed are from the homogeneous category. Their high density suggests that vehicles' weight capacity is reached before the cargo volume limit. Furthermore, these are good stability and easy handling products.

On the contrary, heterogeneous products are residual in terms of volume per order. Adding to this, the fact that they are low weighted and small-sized leads them to have no significant impact on cargo weight and volume. In practice, the Company places these small bags manually on the top of the pallets of homogeneous products. This motivated the exclusion of the heterogeneous products from the analysis.

3.4 Costs

In order to evaluate the total cost associated with each scenario, the following information was obtained from the Company:

- fixed costs of each vehicle: driver, insurance;
- variable costs of each vehicle: fuel, tolls, and maintenance and repair;
- outsourcing prices;
- acquisition cost of a 24.5 tons vehicle, in the conditions the Company would be willing to acquire it – second-hand vehicle but in good conditions.

The costs for 2017 were assumed. For the variables costs, the 2017 costs were actualized from the real costs in 2015. Increases of 41% in cost for fuel, 3% for tolls, and 5.15% for maintenance and repair were considered, based on the information obtained, respectively, from the Portuguese National Council for Energy and Geology, from the company running the highways in Portugal, and the National Institute of Statistics.

3.5 MatLab Interface to Generate Daily Routs

An interface software GenRoutes was developed using the MatLab programming language to generate daily trips. First, GenRoutes reads all the data collected in the excel files. Afterwards, for each day, GenRoutes calls the VRPH software. VRPH produces the trips for that day, and GenRoutes writes that solution to an excel file.

3.6 Vehicle Route Planning for Each Scenario

On a daily basis, each vehicle may perform a route not exceeding the legal driving time. This route is composed of one or several trips, each of them not exceeding the vehicle's weight capacity. Each trip must start and end at the production centre and may visit one or more customers.

Each of the 16.5 tons vehicles may perform one shift a day, since one driver is allocated to each, whereas the 24.5 tons vehicle may execute two shifts a day, due to the two drivers allocated to it. It is worth to point out that the allocation of drivers to vehicles is flexible.

The cost evaluation for each scenario is based on its routes planning. For each scenario, the fleet characteristics are considered, namely the number of vehicles and their weight capacities.

The vehicle routes planning started running the GenRoutes interface, considering a weight capacity limit of 24.5 tons and a maximum of 1080 km per trip. Thus, for each day, initial vehicle trips not exceeding 24.5 tons nor 1080 km were obtained. Afterwards, these trips were used to define, for each day, the routes planning for the Company's own fleet in each scenario, as described hereafter.

For each scenario and day, and taking the number of vehicles and their capacities into account, the steps carried out were:

1. allocate the initial trips to the vehicles, as far as 1080 km length is not exceeded for each vehicle. The deliveries not allocated to any vehicle are outsourced;
 2. identify the trips, the weight quantity delivered and the kilometres associated with each vehicle, as well as the weight quantity delivered by outsourcing;
 3. determine the cost per trip and the outsourcing cost.
-
- Scenario 1 – Company's current situation (one 24.5 tons vehicle, and two 16.5 tons vehicles): the initial trips are allocated to the 24.5 tons vehicle, as far as the 1080 km length is not exceeded. The deliveries not allocated to this vehicle have then to be allocated to 16.5 tons vehicles. Thus, GenRoutes is run again, now for the remaining deliveries and assuming 16.5 tons of weight capacity and 1080 km of length. This followed literature recommendation [16], for cases with heterogeneous vehicles;
 - Scenario 2 – Situation proposed by the Company: a new 24.5 tons vehicle substitutes the two 16.5 tons vehicles, and outsourcing whenever needed. The age of the two 16.5 tons vehicles, expecting its end life in medium future, motivated this scenario. Procedures were performed as for Scenario 1, but only for the two 24.5 tons vehicles. Cargo exceeding the weight capacity of these vehicles or the 1080 km limit in the distance was considered for outsourcing.
 - Scenario 3 – Reduce the self-owned fleet: discard the two 16.5 tons vehicles, keeping the 24.5 tons vehicle, and outsourcing when needed. The present economic world situation and forecasts about the end life of the two 16.5 tons vehicles substantiate this scenario. Procedures were conducted as for scenario 1 except for its second part (the allocation to the 16.5 tons vehicles, as they do not exist in this scenario).
 - Scenario 4 – Totally outsource deliveries: discard all the self-owned fleet. Many companies have been increasing outsourcing their transportation needs, which explains this scenario. Costs considered based on the prices the outsourcing companies offered.

4 Case Study Analysis

4.1 Customer Service Criteria

Despite being the only plaster manufacturing company in the country, other payers share this market and the Company directly competes with other companies. The Company thus reinforces customer service and product quality as a means to obtain the customer's preference.

The Company uses the following criteria in its internal policy:

- price per deliver: varies depending on the delivery zone;
- minimum dispatched quantities: one pallet;
- maximum response times: two working days for complete cargos, and 5–7 working days otherwise;
- cargo occupancy rate: minimum of 70%, with exceptions for small distances or special customers, but with no less than 50% occupancy rate;
- incoterms: the Company assumes the responsibility for the products until they arrive at the customer, supporting loss and damage costs, except for outsourcing.

As competition is fierce in this type of business and unplanned deliveries due to last minute request are usual, the Company also wants to have the ability to fulfil these orders. Consequently, the 70% vehicle occupancy rate is relevant for the Company.

4.2 Product Delivery

Due to the irregularity of the ordered quantities and customers locations, vehicle routes have to be planned daily. Presently, routes are derived based on the professional experience of the transports operations manager. Figure 1 presents examples of daily routes.

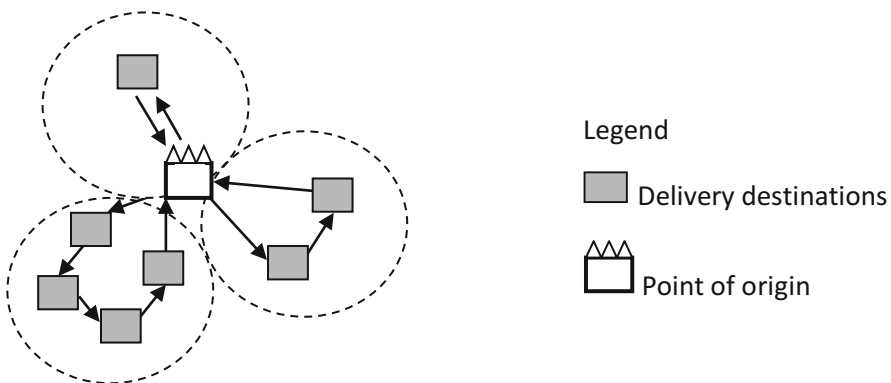


Fig. 1. Current route types performed by the company

4.3 Findings

Taking into consideration the criteria previously defined, the results for each scenario under analyses, specified per vehicle (or outsourcing), number of kilometres per year, tons carried per year, variable fixed and total cost are shown in Table 2.

Each scenario was also analyzed in terms of the average occupancy rates of the vehicles so that the flexibility of the solution and its consequent impact on customer service quality might be assessed. The average occupancy rates per vehicle in each scenario are shown in Fig. 2.

Table 2. Total annual cost per scenario

Vehicles	Kms travelled	Quantity transported (tons)	Variable cost (€)	Fixed cost (€)	Total cost (€)
<i>Scenario 1 - Company's current situation</i>					
24,5 tons	112.823	6.526	85.420	41.744	127.164
16,5 tons	110.168	5.163	43.532	40.006	83.538
Outsourcing	13.680	1.220	36.681	–	36.681
Total annual cost (€)			165.634	81.750	247.384
<i>Scenario 2 - Solution proposed by the company</i>					
24,5 tons	238.421	12.586	149.354	91.202	240.556
16,5 tons	n.a.	n.a.	n.a.	n.a.	n.a.
Outsourcing	4.446	323	7.564	–	7.564
Total annual cost (€)			156.918	91.202	248.120
<i>Scenario 3 - Reduce self-owned fleet</i>					
24,5 tons	177.822	10.356	113.298	41.744	155.042
16,5 tons	n.a.	n.a.	n.a.	n.a.	n.a.
Outsourcing	34.656	2.553	97.687	–	97.687
Total annual cost (€)			210.985	41.744	252.730
<i>Scenario 4 - Totally outsourced deliveries</i>					
24,5 tons	n.a.	n.a.	n.a.	n.a.	n.a.
16,5 tons	n.a.	n.a.	n.a.	n.a.	n.a.
Outsourcing	141.219	12.909	369.659	–	369.659
Total annual cost (€)			369.659	–	369.659

(Legend: n.a. - not applicable)

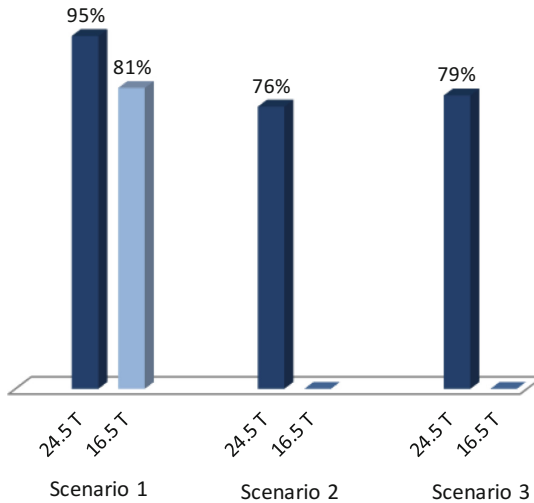


Fig. 2. Average vehicle occupancy rate in each scenario

5 Discussion

The analysis in Table 2 is solely based on cost. Nonetheless, the Company has a dual goal: reduce costs and provide good quality customer service, for which flexibility of the solution has to be taken into consideration when deciding which one is the most adjusted for the Company's present and future.

Although the tendency to outsource [5], Scenario 4 – totally outsourced deliveries, is the most expensive one with a cost 46.3% higher than the second most expensive scenario. Adding to the cost situation, this Scenario of total outsourcing, although allowing the Company to use a specialized company to perform delivery, prevents the company to contact the customer during product delivery directly and makes it lose control over the pipeline during transportation, therefore limiting customer service quality [5, 14]. Both arguments support that Scenario 4 should not be adopted by the Company.

If the decision was to be based solely on costs, Scenario 1 – maintaining the current fleet solution, presents itself as the most economic, although Scenario 2 – selling the two small vehicles and purchasing a new 24 tons vehicle, shows almost the same level of cost. In fact, Scenario 2 is only about 0.3% more expensive than the first one, but it involves the purchase of a new vehicle that requires less maintenance and downtime. At the same time, according to (Legend: n.a. - not applicable), Scenario 2 provides the company with lower vehicle occupancy rates, with is to say that it has more flexibility to receive urgent orders and fulfil them immediately. Scenario 1 is based on three vehicles, two of which are old and more probable to breakdown. As so, Scenario 2 is preferable to Scenario 1, allowing more consistent on-time deliveries and a larger capacity buffer for urgent deliveries.

Taking into consideration the decrease in construction activity in Europe due not only to the economic crisis but also the fact that it is said that in Portugal a new crisis may emerge shortly, investing in new vehicles might seem like a risk. As so, Scenario 3, of keeping only the 24 tons vehicle, might present itself as an intermediate solution while the crisis lasts. In fact, this Scenario is less than 2% more expensive than Scenario 2, but has the advantages of not requiring immediate investment in a new vehicle and keeping similar buffer capacity (see Fig. 2) as Scenario 2, allowing flexibility for urgent orders. At the same time, it shows more dependency of outsourced companies, but it can be considered as a lesser evil during this uncertain economic period when compared to the need to invest in new equipment.

6 Conclusion

This case study is based on the request from a specific company from the construction industry that has undertaken the challenges of the economic crisis and wanted to find a better fleet solution that would not only allow it to keep distribution cost low but also to fulfil demanding customer service criteria in terms of flexibility and on-time deliveries.

Taking into consideration the previous discussion, Scenario 3 – keeping a single 24 tons vehicle, is recommended for the Company as the Scenario to be implemented immediately, but Scenario 2 – purchasing an additional 24 tons vehicle, should be considered in the future when the construction industry starts to show recovery from the Economic crisis. Consequently, this article provides contribute to practice.

Although much research has been conducted on the fleet cost minimization (see for instance, [11, 23]) or route optimization (see, for instance, [24, 25]), this research aimed for a gap in literature in which not only the cost perspective is considered but also the quality of the service provided is taken into consideration. As so, this articles also contribute to literature.

As a single company was analyzed, findings cannot be generalized to other companies [13]. Nonetheless, it would be interesting that similar research is conducted in other companies that run their own transportation fleet to access if the findings from the present research are only applicable to the analyzed Company or in fact, they show a tendency that when contact with the final customer is relevant costs might be overruled.

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References

1. CSCMP (2014). <http://cscmp.org/>. Accessed 23 Jan 2014
2. Porter, M.: Competitive Advantage. The Free Press, New York (1985)
3. Poist, R.F.: Evolution of conceptual approaches to designing business logistics systems. *Transp. J.* **26**(1), 55–64 (1986)
4. Christopher, M.: Logistics and Supply Chain Management – Creating Value Adding Networks, 4th edn. Financial Times – Prentice Hall, Upper Saddle River (2011)

5. Rushton, A., Croucher, P., Baker, P.: *The Handbook of Logistics and Distribution Management*, 4th edn. Kogan Page Limited, London (2010)
6. Pitt, B., Reiss, M., Hirsch, S.: Private fleet management: from necessary evil to strategic asset. *Logistics Management*, November 2011
7. List, G.F., et al.: Robust optimization for fleet planning under uncertainty. *Transp. Res. Part E* **39**, 209–227 (2003)
8. Lee, Y.H., Kim, J.I., Kang, K.H., Kim, K.H.: A heuristic for vehicle fleet mix problem using tabu search and set partitioning. *J. Oper. Res. Soc.* **59**, 833–841 (2008)
9. Potvin, J.Y., Naud, M.A.: Tabu search with ejection chains for the vehicle routing problem with private fleet and common carrier. *J. Oper. Res. Soc.* **62**, 326–336 (2011)
10. Dondo, R., Cerdá, J.: A cluster-based optimization approach for the multi-depot heterogeneous fleet vehicle routing problem with time windows. *Eur. J. Oper. Res.* **176**, 1478–1507 (2007)
11. Braysy, O., Dullaert, W., Hasle, G., Mester, D.: An effective multirestart deterministic annealing metaheuristic for the fleet size and mix vehicle-routing problem with time windows. *Transp. Sci.* **42**(3), 371–386 (2008)
12. Hritonenko, N., Yatsenko, Y.: Fleet replacement under technological shocks. *Ann. Oper. Res.* **196**, 311–331 (2012)
13. Yin, R.: *Case Study Research*. Sage, Thousand Oaks (2009)
14. Christopher, M., Peck, H.: *Marketing Logistics*. Butterworth-Heinemann, Oxford (2003)
15. Bowersox, D.J., Closs, D.J., Cooper, M.B.: *Supply Chain Logistics Management*, 3rd edn. McGraw-Hill, New York (2010)
16. Ballou, R.: *Business Logistics/Supply Chain Management*. Pearson Prentice Hall, New Jersey (2004)
17. Toth, P., Vigo, D.: *The Vehicle Routing Problem*. SIAM Monographs on Discrete Mathematics and Applications. Society for Industrial and Applied Mathematics, Philadelphia (2002)
18. Golden, B., Raghavan, S., Wasil, E.: *The Vehicle Routing Problem*. Springer, Heidelberg (2008). <https://doi.org/10.1007/978-0-387-77778-8>
19. Dantzig, G.B., Ramser, J.H.: The truck dispatching problem. *Manag. Sci.* **6**, 80–91 (1959)
20. Groer, C.: Parallel and serial algorithms for vehicle routing problems. Ph.D. thesis, University of Maryland, USA (2008)
21. Groer, C., Golden, B., Wasil, E.: A library for local search heuristics for vehicle routing problem. *Math. Program. Comput.* **2**, 79–101 (2010)
22. Clarke, G., Wright, J.R.: Scheduling of vehicle routing problem from a central depot to a number of delivery points. *Oper. Res.* **12**, 568–581 (1964). <https://doi.org/10.1287/opre.12.4.568>
23. Huang, S.-H., Yang, T.-H., Tang, C.-H.: Fleet size determination for a truckload distribution center. *J. Adv. Transp.* **48**, 377–389 (2014)
24. Hassold, S., Ceder, A.: Public transport vehicle scheduling featuring multiple vehicle types. *Transp. Res. Part B* **67**, 129–143 (2014)
25. Laporte, G.: The vehicle-routing problem – an overview of exact and approximate algorithms. *Eur. J. Oper. Res.* **59**(3), 345–358 (1992)
26. Coase, R.: The nature of the firm. *Economica* **4**(16), 386–405 (1937)
27. Hall, R.W., Racer, M.: Transportation with common carrier and private fleets – system assignment and shipment frequency optimization. *IIE Trans.* **27**(2), 217–225 (1995)
28. Groer, C.: VRPH software (2010). <http://sitesGoogle.com/sites/vrphlibrary>