Chapter 8

Recent Developments in Real Life Vehicle Routing Problem Applications

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Abstract In recent years, there is an increasing volume of research focusing on problems with real life applicability across the entire vehicle routing domain. Bringing academia closer to industry operations has enriched the literature significantly and led to the creation of multiple vehicle routing problem variants and streams. This chapter discusses some of the main vehicle routing problem categories motivated by real operations, namely integrated problems, problems with alternative objective functions and those problems which are highly problem specific and have unique characteristics. We provide a discussion on the evolution of real life routing problems and evaluate some important methodological considerations. We also discuss aspects, which are typically overlooked in the literature such as the role of data, methodological comparability, implementation and benefits realization. Finally, we offer guidance for best practice and future research in the area of real life routing problems.

8.1 Introduction

The evolution of Vehicle Routing Problem (VRP) and its variants is inspired by real life operations and there is a noticeable trend in the literature to bring VRP research closer to real life routing practice. The literature on real life vehicle routing problems (RVRPs) has developed rapidly since 2006, motivated by the different supply chain and routing challenges faced by businesses on daily basis. Academics increasingly

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work with practitioners to understand the important aspects of routing and some of the main trends in Operations Research (OR) have been influenced by bridging the gap between industry and academia. Accommodating various real life attributes has enriched the literature of the VRP variants and has contributed to the design of more flexible and powerful state of the art solution methodologies. Incorporating real life attributes into VRPs has created many variants of the problem, which fall in the following broader categories.

- Mixed VRPs: These problems are motivated by real operations and generally consist of a mix of existing VRP variants or extensions to the existing variants.
- Problem Specific: These are the VRPs which cannot be conformed to acronyms, as they contain specific constraints for a given industry or business. Once they are introduced to the literature, they are seldom revisited by other authors.
- Integrated problems: These problems also originate from industry operations where optimization is approached holistically and aspects such as routing, loading and production are solved simultaneously.
- VRPs with alternative objective: In some real applications the main objective of routing is not minimizing cost or time, but optimizing other aspects such as customer service, CO_2 emissions and sustainability factors, drivers working times, etc. These problems can be created with single or multi-objective framework, or even conflicting objective functions.

This chapter offers an evaluation of all categories of RVRPs, outlining some of the most recent applications and the methods used to solve the corresponding problems. We encourage the readers to investigate further the research we mention and gain more information on the specific mathematical formulation and methodology description. We also refer to useful review papers, which in some cases provide standard formulation and best performing methods for a given class of problems. Due to the problem-specific nature of RVRPs and the difficulty to summarize methodological aspects, we discuss some methodological and data considerations, which are not often highlighted in the literature.

The rest of the chapter is organized as follows. In Sect. 8.2 we present different definitions of RVRPs in the literature and offer our view on the important aspects of RVPRs. Section 8.3 contains a detailed literature review of the recent RVRP applications in the four main categories outlined above. Section 8.4 evaluates the main methodological issues that may arise when dealing with RVRPs, alongside directions for future research, where Sect. 8.5 concludes the chapter.

8.2 Background and Definition

The notion for real life problems is not new, because as early as 1993 there are papers in the literature, which were based on case studies or explicitly state that they were researching a real life problem. An example of that is the paper by Semet and Taillard [1], which tackles a real life VRP inspired by the grocery industry in Switzerland. Real life operations have been an inspiration for modelling in OR for the past 20 years. However, it was not until 2006 when real life problems were introduced as a class of the VRP. After the introduction of the Livestock Collection problem (LCP) [2], the authors formally categorize real life problems under the term ‘rich’ Vehicle Routing Problems (RVRP) and provide a loose definition of what a rich VRP is. Hasle et al. [3] state that a rich VRP includes aspects that are essential to the routing practice in real life and the richness of the problems can stem from many elements of the routing practice such as drivers, fleet, order types, depots, tours, etc. In addition, [4] states that rich VRPs should include different constraints or different objective functions. Vidal et al. [5] referred to the rich VRPs as Multi-Attribute VRPs (MAVRPs), which typically arise from real life situations. However, in their classification, any deviation from the Classical VRP is considered to be MAVRP. Goel and Gruhn [6] refer to the real life problem they propose as General VRP, whereas other authors do not adopt any classification terminology when dealing with these types of problems and simply refer to them as real life routing problems.

Caceres-Cruz et al. [7] state that RVRPs should incorporate relevant attributes of a real life vehicle routing distribution system, which may include dynamism, stochastic elements, heterogeneity, multi periodicity and many more. Lahyani et al. [8] also provide a comprehensive literature review of RVRPs as well as a theoretical framework. They investigate 41 publications since 2006, when the rich VRPs became a class of the VRP domain. The definition they provide states that a RVRP must have a sufficient number of real life routing elements in order to qualify as rich. It is mentioned that if the RVRP is defined in terms of physical characteristics, it should have at least nine additional elements to the classical VRP. If the problem is defined from a strategic or a tactical viewpoint, then it should have at least six additional elements. Rich VRP is a term that is becoming more popular in the literature, but there is no single definition of what exactly constitutes a rich VRP, which is accepted across the OR community. However, the argument on how much richness a problem should have in order to be categorised as rich can go beyond the number of features required in the nature of the problem. In our view, a RVRP should contain relevant aspects of a real life routing problem, which can aid the decision making process in practice and be significantly differentiable from other VRPs on the merits of their real life routing characteristics. In addition, when researching a real life VRP there should be some practical implications or recommendations for improving routing practice, which are relevant to a specific problem and ideally transferable to other applications. Working in collaboration with industry allows academics to measure the actual impact of their research, which can lead to interesting findings and contribution to our field.

8.3 Literature Review

Review papers on existing classes (variants) of VRP problems, such as the Fleet Size and Mix VRP (FSMVRP) or the VRP with Time Windows (VRPTW), typically summarize the most important aspects of the respective problems. Usually a standard formulation of the problem is provided alongside best known solutions on publicly available benchmark problem instances and outline of the best performing methods. However, RVRPs are very diverse and such a well-rounded summary could be very difficult to achieve. One of the main reasons for this is the loose definition provided for RVRPs. Another reason is that often a RVRP is introduced once and it is not revisited by another author under the same form with the same characteristics. Moreover, the nature of RVRPs changed over time and some of the problems referred to as rich in the past, may not necessarily qualify as ones today. RVRPs cannot be standardised, because their relevance and contribution stem from the diversity of real life routing practices.

We would like to note a few problem variants, which are not referred to as real life problems, but they are highly applicable in practice. The Two Echelon Vehicle Routing Problem (2E-VRP) considers a multilevel distribution system inspired by city logistics, where vehicles start at a depot, go to the nearest intermediate facility (satellite) and from there are routed to various customer locations. The purpose is to minimize pollution and congestion in big cities and avoid sending large trucks into the city. Instances with 21 customers are solved to optimality so far [9]. The Cumulative Vehicle Routing Problem (CumVRP) is motivated by customer satisfaction and relations. Its objective function is to minimize arrival times as opposed to cost. This is perhaps the most consumer centric variant in the VRP family, which incorporates issues like just in time service, equity and fairness [10] and [11]. The Multi-compartment Vehicle Routing Problem (MCVRP) arises when m products must be delivered to customers by k vehicles, which all have different compartments for each product. This variant considers the benefits of co-transportation as opposed to un-partitioned trucks and independent distribution. The Open Vehicle Routing Problem (OVRP) occurs when a given fleet of vehicles does not have to end the tour at the depot, but at the last customer. This variant is highly applicable for leased vehicles or any fleet that is not an asset of the company or in cases where drivers go home or another parking location after the tour is complete. Last, but not least is the Truck and Trailer Vehicle Routing Problem (TTRP) introduced by Chao [12]. It is inspired by the ability to access customer locations in difficult areas. TTRP consists of finding shortest routes to serve a set of customers either by the full vehicle (truck and trailer) or truck only.

8.3.1 Mixed Variants

It is rare in the industry that a fleet optimisation will be only constrained by time window alone, or heterogeneous fleet alone. Usually a combination of requirements and constraints is present, which need to be considered simultaneously. Therefore, academics become more creative and practical by introducing to the literature ‘mixed’ or ‘extended’ variants. An example of a mixed variant is a combination between VRPTW and VRP with Pickup and Delivery researched by Bent and van

Hentenryck [13]. Bektas and Laporte [14] combine VRP with Stochastic demand and time windows and [15] address a mixed variant between Multi Depot VRP and FSMVRP. Bortfeld [16] includes the presence of three-dimensional loading constraints, which makes the problem a mix of routing and loading decisions. Kang et al. [17] combine Multi Depot and Multi Period VRP, whereas more recently [18] combine Multiple Trip VRP with Backhauls. There are many other mixed variants, which exist in the literature and cannot be exhaustively listed, but are following the same principle. Extensions to the main variants are also common in the literature such as the VRPmiTW, which is VRPTW with multiple independent time windows [19] and the DVRP which is VRP with time dependent travel times [20].

8.3.2 Problem Specific

These category of problems are the RVRPs, which reflect the nature of real life operations. Not all papers we review in this chapter specifically state that the problem at hand is a 'rich' or a 'real life' problem, but they are inspired by industry operations and accommodate unique aspects and constraints. Martins et al. [21] introduce a Multi-compartment VRP, which has product-oriented time windows. This is relevant in the grocery industry, where the delivery time windows depend on the product type, whether it is fresh or frozen. Ren et al. [22] discuss the multishift VRP with overtime, which emphasizes on the drivers considerations and constraints, where [23] analyse the VRP with deadlines and travel/demand time, which is consumer centred. Archetti et al. [24] introduce a real life VRP with occasional drivers and solve it with a multi-start heuristic, while [25] introduce a RVRP with desynchronized arrivals to depot. Battarra et al. [26] solve the Multiple Minimum Trip VRP (MMTVRP), which is also industry inspired and assumes that one vehicle can be assigned to more than one route. Seixas and Mendes [27] incorporate drivers working hours into a Multiple Trip VRP with Heterogeneous Fleet. Franca et al. [28] consider a problem motivated by the selective waste collection of recyclables in Rio de Janeiro. The authors use the ORTEC routing software to test different scenarios for waste collection, where they explore the trade-offs between selective and non-selective waste collection. They found that even though some additional routes were generated and the total mileage increased, the cost of serving a client decreased by 28%, as well as the total overall cost. This is a very important finding, which can be used as a baseline for research in other countries.

Kramer et al. [29] consider a problem applied to the pharmaceutical distribution in Tuscany with auxiliary depots and anticipated deliveries. It is an interesting problem with various features such as incompatibilities between customers and routes and a maximum number of customers serviced. The authors solved this problem by a multi-start Iterated Local Search (ILS). Alcazar et al. [30] consider a rich VRP with last mile outsourcing decisions, driver hour regulations, incompatibility among goods, etc. The authors design a hybrid heuristic consisting of elements from Tabu Search (TS), Simulated Annealing (SA) and Variable Neighbourhood

Search (VNS), where they are specifically adapted to deal with the multiple real life constraints of the problem. Bianchessi et al. [31] consider a VRP with split delivery and time windows, where one of the aims is to limit customer inconvenience.

Tarantilis [32] uses a hybrid metaheuristic method based on TS, VNS and Guided Local Search (GLS) for the VRP with intermediate replenishment facilities. Liu and Jiang [33] use a memetic algorithm to solve the Closed-Open VRP, while [34] adopts a Column Generation based heuristic and a Greedy Randomized Adaptive Search Procedure (GRASP) for the min-max selective VRP. Benjamin and Beasley [35] propose a waste collection VRPTW with driver's rest period and multiple disposal facilities. They develop a hybrid metaheuristic method using TS and VNS, which performed well on selected benchmark problems. It is a common practice that authors often create or adapt methodologies to fit the richness of the problem they are investigating. For instance, [22] solved the VRP with multi shift and overtime and introduced a shift-dependant heuristic to tackle the problem. Some problems are motivated by urban logistics and are greatly applicable in a city setting. For instance, recently [36] propose a complex 2E-VRP with multi-objective function, vehicle synchronization and the notion of grey zone customers. It examines the assignment of those customers which are at the boundary of the two echelons and explores different city layouts. Bevilaqua et al. [37] also discuss a 2E-VRP, with heterogeneous fleet and real life constraints, motivated by Brasilian wholesale companies.

Simeonova et al. [38] introduce a RVRP with heterogeneous fleet, light load customers and overtime, motivated by the gas delivery industry. The authors solve the problem using a Population VNS with Adaptive Memory. Mancini [39] introduces and formalizes a problem with multi depot, multi period and heterogeneous fleet and solved it using an Adaptive Large Neighbourhood Search (ALNS) heuristic. Though it is not specifically applied to a given company, it is a problem that can arise in industry. Both papers provide a MIP formulation and a heuristic method to solve the problem, as well as a comparison of the exact method to the performance of the heuristic algorithm. This is a very good practice when it comes to RVRPs, because there are no available literature benchmark instances for RVRPs.

8.3.3 Problems with Alternative Objective Function

Some problems have objective function alternative to minimize cost, such as minimize carbon emissions or maximize value. Other problems can be multi-objective, where there is multiple criteria for decision making. The objectives can also be conflicting and there is no single solution which simultaneously optimizes all criteria. Therefore, we look for Pareto optimal solutions (also known as non-dominated solutions) and analyse the trade-offs between the different criteria. Spliet and Gabor [40] address a problem where the objective is to have consistent time windows which are assigned to customers before their demand is known. Kovac et al. [41] solve the Consistent VRP (ConVRP) where customers should be visited by the same driver and deviations from a given arrival time are penalized. Papers with similar objective show the clear trade-off between routing cost and service consistency, and propose ways on how to improve customer service at a minimum increase in cost. The authors have estimated that the service consistency can be improved by 70% with only 4% increase in cost.

Rodriguez-Martin et al. [42] also consider driver consistency in a context of Periodic VRP, which is aimed at improving customer service. Similarly to [41], the authors report that the cost of consistency is 4% on average. There are examples in industry where this is required, because it improves the driver's learning. In some cases drivers also do other activities such as special loading requirements, shelf replenishment, etc. However, having the same driver visit the same customers also contributes to other aspects which are not greatly discussed in the literature. Drivers prefer to have the same delivery areas every day, because they feel more comfortable with getting to the customer's locations and are familiar with the nature of the delivery. This helps them to be more efficient and could contribute to reducing the service time and the driving time to the customer. Hoogeboom and Dullaert [43] solve the VRP with arrival time diversification. This is a very interesting problem, which is relevant for the Cash-in-Transit (CIT) companies, which deliver valuable goods. The objective here is not only to minimize cost but also to create an unpredictable route, with alternating arrival times at the customers, which is important for security reasons.

We mentioned in the introduction that the development of the VRP field is greatly inspired by changes in industry and policy. Companies and governments are investing in more environmentally friendly vehicles because of the increased global awareness and necessity to lower our carbon footprint. Therefore, there is emerging research around Green VRPs and Electric VRPs, where the aim is to minimize carbon emissions and environmental footprint. The literature on the green road transportation has mainly concentrated on the issue of emissions and [44] were one of the first to highlight it. Bektas and Laporte [14] presented a study based on the classical Vehicle Routing Problem (VRP), called Pollution-Routing Problem (PRP) optimizing travel distance and greenhouse emissions. Wassan et al. [45] provide an extensive summary on Green Reverse logistics, which shows the benefit of incorporating green aspects in delivery and collection problems. Poonthalir and Nadarajan [46] conducted research on fuel consumption and concluded that greater efficiency can be achieved under varying speed limit. Fathollahi-Fard et al. [47] address a Green Home Health Care (GHHC) Supply chain problem, as a bi-objective location-allocation-routing problem with the aim of achieving sustainability for HHC.

Electric vehicles (EVs) are by definition more energy efficient, but they come with different constraints such as their range is limited by the battery life. The objective function is typically to minimize distance or cost, but also to optimize the battery life, as well as the optimal location for the recharging facilities. Some studies consider hybrid vehicles, where the battery life is firstly used up, and then the vehicle switches to regular fuel. Badin et al. [48] presented a study that quantifies the influence on energy consumption of different factors such as driving conditions, auxiliaries' impact, driver's aggressiveness and braking energy recovery strategy on an electric vehicle. Wua et al. [49] proposed an analytical electric vehicle power estimation, which concludes that EVs are more efficient when driving on in-city routes rather than motorway routes. Lin et al. [50] studied a general Electric Vehicle Routing Problem (EVRP) which considers the load effect on battery consumption. Hiermann et al. [51] introduce an Electric Fleet Size and Mix Vehicle Routing Problem with Time Windows and Recharging Stations (E-FSMFTW), where they optimize the minimum cost routing and fleet composition (a mix of electric and conventional vehicles), but also the recharging times and locations. Macrina et al. [52] introduce a complex energy-efficient Green VRP, with a mix of conventional and electric vehicles, partial battery recharging and incorporating the effect of the braking regenerating system. All these studies can help society and businesses with the global transition to more energy-efficient travel and highlight any possible issues and ways to overcome them.

8.3.4 Integrated Problems

The integrated problems are another interesting area with real life application. Recently there is an increasing number of publications which tackle VRPs in combination with other aspects such as loading, inventory, machine scheduling, etc. These problems are quite important as they show the potential savings and improvement in operations and supply chain, when we approach problems in an integrated manner rather than sequentially. Van Gils et al. [53] formulate and solve a complex integrated problem, which includes order batching and picker routing and scheduling. The problem also has real life aspects such as high-level locations, order due times and limited availability of pickers, where the objective is to increase order picking efficiency. The authors used ILS to solve the problem and found substantial savings of 16.9% from using this integrated approach, applied to a real case study. Hoogeboom and Dullaert [43] research a deteriorating inventory routing problem applied in the liquefied natural gas distribution network. The authors use ALSN and provide managerial insights regarding alternative replenishment strategies, some interesting trade-offs and observations, and different effects on the problem such as gas evaporation rates. Bertazzi et al. [54] also consider inventory routing, but with multiple depots and solves the problem using a three-phase matheuristic method, consisting of clustering, routing and optimization phase. Liu et al. [55] also examine an interesting real life inventory routing problem, which also has an alternative objective function which relates to the maximization of the service levels under budget limitations.

Integrating routing with location is also an important problem with application in real life. Darvish et al. [56] solve the flexible two-echelon location-routing problem and the authors find average savings from the integration of up to 30% for businesses. Ghaderi and Burdett [57] consider location routing for hazardous materials in a bi-modal transportation network, which aims to minimize cost and risk. Zheng et al. [58] integrate routing, location and inventory aspects in a supply chain network design with real life constraints, which they solve with an exact method. It is worth noting that there is practical and controversial issue in combining these two problems as these have different time frame, where location is usually a strategic problem, whereas routing is operational. This issue was firstly investigated by Salhi and Nagy [59]. The reader is referred to [60] and [61] for surveys on location-routing problems. Routing can also be integrated with machine scheduling, which can assist companies with supply chain flow optimization and management. For instance, [62] aim to minimize carbon emissions for an integrated routing and machine scheduling problem, which can provide a greener approach to manufacturing practices.

8.4 Methodological Considerations

The papers we evaluated in this chapter are examples on the need to adjust, extend and be creative with existing methodologies in order to make them applicable to real life problems and address their special features. All those real life aspects that can be added to a VRP problem and provide that extra richness contribute to making RVRP research very flexible and a fertile area for ideas and novel developments. However, there is an issue which has not been specifically addressed in the literature, which relates to the solution methodologies. In the VRP family, a contribution to the literature is mainly considered if a new interesting problem is introduced, which is different from previous research or a new methodology, which is powerful and relevant in terms of performance and novelty. However, given the fact that RVRPs are so different from other variants and from each other, it poses a challenge for proving algorithmic efficiency compared to other methods in the literature. Table 8.1 shows a summary of the most recent applications reviewed in the chapter so far, outlining their methodological choices. We present papers from each of the problem categories discussed earlier, the nature of the data used in the paper, whether there is comparability of the results and whether the method has been implemented in a real life setting with real savings estimation. Column 3 in the table refers to datasets which are either randomly generated or hypothetical, which simulate real life operations. Column 4 refers to adaptations from literature benchmark instances, where column 5 shows if the research is tested on data provided by industry. Comparability includes any approach to results validation, such as comparing against Best Known Solutions (BKS), against results from an exact method (or the main methodology of the paper is exact), or against baseline results generated by a company.

Looking at Table 8.1, we can make a few observations. There are very few applications, which are compared against BKS or extend their methodologies to other problems. Forty-five percent of the cited papers test their real life problems on actual data provided by businesses, but none is implemented and used by those businesses. Even though the authors make highly relevant and useful recommendations and provide managerial insight, actual implementation can help understand the true value of optimization and how much of the projected benefits can be materialized.

Table 8.1 Methodological review of recent real life applications

Paper	Category	Generated dataset	Adapted dataset	Real dataset	Comparability	Implementation
Alcazar et al. [30]	Problem specific	✗	✓	✓	✗	✗
Anderluh et al. [36]	Alternative objective	✓	✓	✓	✗	✗
Archetti et al. [24]	Problem specific	✓	✗	✗	✗	✗
Badin et al. [48][a]	Integrated problem	✗	✓	✓	✓	✗
Bertazzi et al. [54][b]	Problem specific	✗	✓	✓	✓	✗
Bevilaqua et al. [37]	Integrated problem	✓	✗	✗	✗	✗
Darvish et al. [56][c]	Problem specific	✗	✗	✓	✗	✗
Franca et al. [28]	Integrated problem	✓	✗	✗	✗	✗
Ghaderi and Burdett [57][a]	Integrated problem	✗	✓	✗	✗	✗
Ghiami et al. [63][b]	Problem specific	✗	✓	✓	✓	✗
Hoogeboom and Dullaert [43]	Problem specific	✗	✓	✗	✗	✗
Kovac et al. [41]	Problem specific	✗	✓	✓	✗	✗
Kramer et al. [29]	Problem specific	✗	✓	✓	✗	✗
Lee and Lee [23][a]	Mixed problem	✗	✓	✗	✓	✗
Mancini [39]	Mixed problem	✗	✓	✗	✓	✗
Martins et al. [21]	Problem specific	✗	✗	✓	✓	✗
Naji-Azimi et al. [25]	Problem specific	✗	✓	✗	✓	✗
Rodriguez-Martin et al. [42]	Problem specific	✗	✓	✗	✓	✗
Simeonova et al. [38][d]	Integrated problem	✗	✗	✓	✓	✗
Van Gils et al. [53]	Mixed problem	✗	✓	✗	✓	✗
Wassan et al. [18]	Integrated problem	✗	✗	✓	✓	✗
Zheng et al. [58]	Alternative objective	✗	✓	✗	✓	✗
Fathollahi-Fard et al. [47]	Alternative objective	✓	✗	✗	✗	✗
Macrina et al. [52]	Alternative objective	✗	✓	✗	✗	✗
Bianchessi et al. [31]	Problem specific	✓	✗	✗	✗	✗

[a] Compared against exact method
[b] Compared against BKS
[c] The authors used routing software to solve the problem
[d] Compared against real operations

8.4.1 Methodological Comparability

Real life problems have unique characteristics and additional requirements, which lead to extra restrictions. If we consider a classical mathematical formulation (ILP), exact methods generally find it hard to solve RVRPs, as the problem becomes too large and very small instances are solved to optimality. Column generation, however, seems to perform better on RVRPs, because the extra constraints allow for the elimination of columns, which can decrease the complexity. This could be one of the reasons why most exact methods for RVRPs focus on CG and Branch-Cut-Price. For instance, [4] used Branch-and-Cut for Rich VRP with docking constraints. Dayarian et al. [64] developed a Column Generation (CG) method for a real life case inspired by milk collection, where [65] applied CG to the livestock collection problem.

Heuristic methods are more flexible and adaptive in their design, therefore adding special features can actually speed up their performance. This makes them a preferred option when solving RVRPs, but they also have some limitations. They are generally problem specific and cannot guarantee optimality. Coupled up with the problem-specific nature of the RVRPs it may raise a question for methodological justification. This is the main reason why we need consistent and reliable approach to show the algorithmic strength and adaptability of the methods we create in the RVRP domain, which would strengthen their contribution. In fact, researching a real life variant can act as an inspiration to adapt and adjust well known methods and provide an opportunity to extend those methods to other problems and ideally make them more generalizable across VRP problems.

We already mentioned an example of good practice when it comes to demonstrating algorithmic efficiency, namely generating optimal solutions and LB/UB where possible and compare against the heuristic solution using commercial solvers such as CPLEX and Gurobi. The larger the instances are, the gap between the bounds is more likely to increase, though not always the case. However, having the heuristic solution within those bounds could be a good indication for the quality and appropriateness of the heuristic method.

Another suggestion is to reduce the RVRP to a well known and researched VRP variant, which has publicly available benchmark instance sets. If the RVRP is quite unique, most likely it could be reduced to the capacitated VRP (CVRP) or some of the most common problems such as VRPTW, VRPPD and FSMVRP. In this scenario the method is not expected to outperform existing BKS, because it is created for a real life problem with unique constrains. However, if the method performs reasonably well and fast on the standard benchmark instances, with relatively small gaps from BKS, it is an indication that the methods are powerful. One of the trends in the literature is to design more generalizable algorithms, which can be applied to a range of VRPs. Testing an algorithm which is specifically designed for a given RVRP on different instance sets shows not only algorithmic efficiency but also generalizability and adaptability.

Regarding preferred methods in the literature for RVRPs, there is no one best method, because different aspects of the heuristic methods fit different RVRPs.

However, it seems that the ILS and ALNS are getting more attention, especially when it comes to problems with real life constraints. One of the main reasons could be that ALNS is equipped with destroy and repair mechanisms which can be adapted to fit special features. For instance, [21] recently use daily and weekly operators within their method to reflect the nature of their RVRP.

8.4.2 Data Considerations

Following the methodological discussion, there is also the question on what data we should use when we address RVRPs, as algorithm testing and data are closely related. There are a few good practices regarding data which we would like to outline. Some papers on RVRPs are case studies, based on real company data. Using a real dataset, which is also used by the company in question, is a good way of showing algorithmic efficiency by directly comparing the results from the study to the actual practices of the company. By doing this, the impact of the study can be measured and recommendations can be made on how to improve the routing practice. Moreover, using real data can impact the behaviour of the algorithm and lead to very interesting practical insights, which is very important when addressing RVRPs.

In other cases, the datasets used for the RVRPs can be either random or generated in a way to simulate real operations. In these cases the issue of comparability is more critical. Therefore, it is important that some form of comparison or test of algorithmic merits is adopted, or some practical applicability is demonstrated when the algorithm is used by the business which motivated the research. Some authors test their methodology on adapted benchmark instances from the literature, which are well known and available. In this case we suggest that the authors run their algorithms on the original instances they were adapted from, to demonstrate their flexibility and capability to address similar problems.

It has to be noted here that some papers propose algorithms for RVRPs which aim to be all-encompassing rich solvers, rather than single methodologies for one particular problem. An example of this is the Genetic Algorithm based rich solver proposed by Vidal et al. [5]. In their paper many aspects of the VRP, including various rich elements can be addressed by the proposed methodology, hence the results can be tested on many literature benchmarks. However, the purpose of the method is to be all-encompassing and able to accommodate VRPs across the different variant classes.

8.4.3 Implementation considerations

As demonstrated in Table 8.1, not all research in the RVRP domain is tested on datasets provided by industry. This leads to a very interesting question of practical applicability, implementation and the real use of real life routing methodologies in practice. Recently there have been some discussions on international forums and conferences about the implementation issues of OR models and methods in business operations [66], and a realisation that very often the methodologies developed to improve company operations do not result in the desired and estimated benefits. There are many barriers to implementation and adoption of new methodologies, such as resistance to change, long standing perceptions, even personal preferences of drivers and other personnel. We suggest that authors aim to incorporate their findings and recommendations into the daily decision making of the companies the research is motivated by. By doing so, we can observe the true impact of optimization and how much of the savings we compute are actually realized. Moreover, we can discover how well our methodologies fit into the daily decision making routines and if there are any aspects of the organisational structure which can strengthen or compromise the desired results. For instance, [67] state that visual attractiveness of the vehicle routes can assist implementation, because they appear more user-friendly to the scheduling staff. Therefore, generating routing schedules which are compact, not overlapping and not complex can increase the adoption of routing algorithms in practice. Academics should recognise the issue of implementation, especially in the face of current literature trends to bring academia closer to industry. Moreover, there are numerous relevant and important real life applications which we discussed throughout the chapter and if they are properly implemented by businesses and governments can result in significant financial, social and environmental gains.

8.5 Conclusion

In this chapter, we presented the recent developments and applications of real life vehicle routing problems. We discussed the origins and definition of RVRPs and how they differ from the other problems in the VRP domain. In particular, we reviewed Mixed VRPs, Problem-Specific VRPs with unique real life features, Integrated problems and those with Alternative objectives, including green and sustainable practices. We also discussed some important methodological considerations regarding algorithm comparability and generalizability. Some important data-related challenges are outlined when dealing with RVRPs, alongside suggestions on how to overcome them and make a stronger contribution to the literature and routing practice. Lastly, we touched on the importance of implementation when it comes to RVRPs. By definition they are motivated by real operations and should result in practical implications and managerial insight. If we ensure the successful implementation of VRPs in general, we can see the full potential of optimization and the actual benefit realisation for businesses. More importantly, a lot of the RVRP research is aimed not only to achieve economic gains but also to reduce the carbon footprint of routing operations, to maximize the added value for customers and improved experience for the society. Benefit actualisation through implementation of real life problems can achieve our quest for minimizing the gap between academia and industry, which will make our findings not only academically viable but also an important tool for business and governments to build a more efficient and greener economy.

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