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Vehicle Routing Problem in Under Deadlines: A Systematic Literature Review

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Abstract

Transportation is one of the key areas in supply chain management. Emergency vehicles, firefighters, and ambulances are among the priorities needed in densely populated settlements to reduce casualties from an incident. This study aims to map VRP research by considering under-deadline conditions and provide an overview of current trends and positions for future research. A systematic literature review is necessary to connect studies, investigations, and decision-making. It can be validated with databases that need to be reviewed using a systematic search, including research questions, methodology, and specific exclusion and inclusion criteria. Based on the results of the analysis that has been carried out, the results of the most suitable journals were published in Applied Soft Computing, Procedia Computer Science, Computers & Industrial Engineering, and Transportation Research Part E. The most frequently used method is the Exact Algorithm. Eight types of variables are included in the existing discussion.

Keywords
Vehicle Routing Problem, Systematic Literature Review, Emergency Vehicle, Firefighters, Ambulance

1. Introduction

Transportation is one of the key areas of efficiency and effectiveness in supply chain management, and a difficult problem in transportation is the vehicle routing problem (VRP) (Kumari et al. 2023). Solving transportation problems using this technology can provide appropriate and rapid progress in reducing travel time, reducing congestion, shortening the distance from the origin location to the destination location, etc. (Al-Khassawneh, 2023). Dantzig and Ramser (1959) introduced and defined VRP as a problem in scheduling vehicle depots to customers by minimizing the distance of the vehicle's travel. Objectives and model categories about VRP have been published from 2019 to 2021 in 88 journals (Tan and Yeh 2021). Several types of VRP can be categorized based on objectives and constraining factors. Types of VRP based on constraining factors include Multiple Trips Vehicle Routing Problem (MTVRP), Vehicle Routing Problem with Time Windows (VRPTW), Pickup and Delivery Vehicle Routing Problem (PDVRP), Capacities Vehicle Routing Problem (CVRP), VRP with Multiple Products, Multiple Depots Vehicle Routing Problem (MDVRP), Periodic Vehicle Routing Problem, VRP with Heterogeneous Fleet of Vehicles.

EVP, or emergency vehicle priority, is a mobility settlement that gives a green signal to ambulance vehicles and fire trucks (Rosayyan et al. 2023). EVP in a settlement is key to the safety and security of residents' lives and property. Therefore, the timeliness of handling a case at the scene is an important factor in saving human lives in an urgent situation.Regulations regarding EVP vehicles or emergency vehicle priorities are regulated in the traffic law in Article 134 of the Road Traffic and Transportation Law (UU LLAJ), which states that 7 types of vehicles get priority on the road, including fire fighting vehicles, ambulance vehicles, vehicles to assist traffic accidents, vehicles of state institution leaders, vehicles of foreign leaders and dignitaries as international guests, funeral escort vehicles, and certain convoy vehicles according to the consideration of the police. Therefore, the discussion that will be the focus of this research regarding the type of priority vehicles are emergency vehicles, fire fighting vehicles, and ambulance vehicles.

2. Research Method

A systematic literature review is necessary to link studies, investigations, and decision-making prepared and written by "reputable researchers" and "experienced authors" (Zibaei 2018). Systematic literature reviews can be validated with databases that need to be reviewed using systematic searches, including focused research questions, appropriate methodology, and specific exclusion and inclusion criteria (V. Smith et al. 2011).
The systematic literature review method requires steps to analyze: Creating a research question, conducting a literature review, selecting relevant journals, analyzing the results of categorizing relevant journals, and drawing conclusions from the results (Luckyardi et al. 2022).

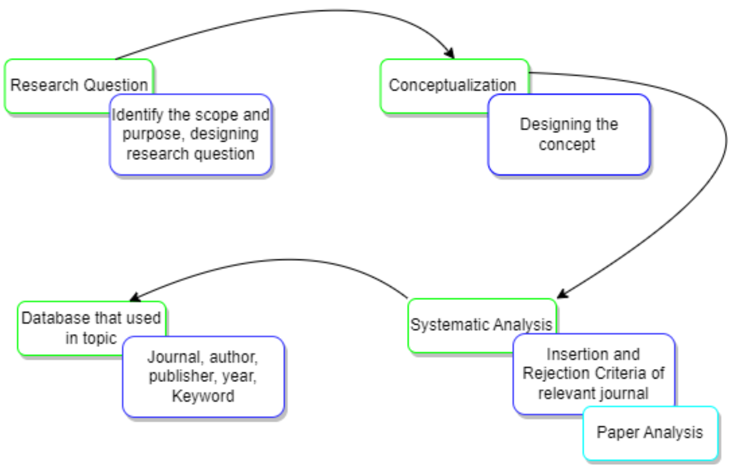

Figure 1. Schematic Review Planning Flow

2.1 Research Questions

Following the Schematic Review Planning Flow displayed in Figure 1, the first step is to determine the research question, which is a formulation of research problems that will be answered based on the research results. This research aims to determine and identify the variables, methods, and trends most suitable for discussing the topic. Designing research questions is one of the ways that can be used to identify variables, methods, and trends that are suitable for the topic to be discussed. It must be adjusted to the accuracy of developing research questions when designing research questions. One of the ways that can be used to design research questions is by using the PICOC system to consider the components that are important in the criteria.

Table 1. Summary of PICOC

Population	Route optimization for emergency vehicles such as fire engines, ambulances, and vehicles needed to evacuate goods and people.
Intervention	Optimizing the best route to minimize emergency vehicle handling time by considering several determinant factors.
Comparison	n/a
Outcomes	The VRP method optimizes the best route for emergency vehicles such as firefighters, ambulances, and vehicles needed to evacuate goods and people.
Context	Studies related to route determination using the VRP method, which determines the best route for firefighters, ambulances, and other vehicles needed to evacuate goods and people.

Table 1 summarizes the question structure using the PICOC system, which has five components: population, intervention, comparison, outcomes, and context. This PICOC system makes it easier for the author to determine the research questions suitable for discussing the topic. After designing using PICOC, the next step is to determine the research questions.

Table 2. Research Question

RQ_n	**Research Question (RQ)**	**Scientific Rational**
RQ1	The most suitable journal with the best route optimization for the emergency vehicle type.	Identify the most suitable journal with the best route optimization for critical vehicle types.
RQ2	The most frequently used method concerning best route optimization for critical vehicle types.	Identify the trend of the method used by the research journal with the best route optimization for critical vehicle types.
RQ3	Most variables are often used to optimize the best route for emergency vehicle types.	Identify variables often used to optimize the best route for critical vehicle types.

Table 2. Explain the needed research questions and the appropriate way to solve these questions.

2.2 Conceptualization

The conceptualization section describes the strategy and steps for searching the most relevant journals to the topic. This search strategy aims to identify journal articles and summarize them related to route optimization problems in priority vehicles, especially ambulances, firefighting vehicles, and vehicles used to assist in handling an emergency event. The discussion will focus on the variables and methods discussed in the journal. The search is performed using the Boolean AND system in the sentence “Vehicle” AND “Routing” AND “Problem” AND “In Emergency” AND “Vehicle.” You can also use “Vehicle” AND “Routing” AND “Problem” AND “In Firefighter” or “Vehicle” AND “Routing” AND “Problem” AND “In Ambulance.” The following is an illustration of the main study search strategy.

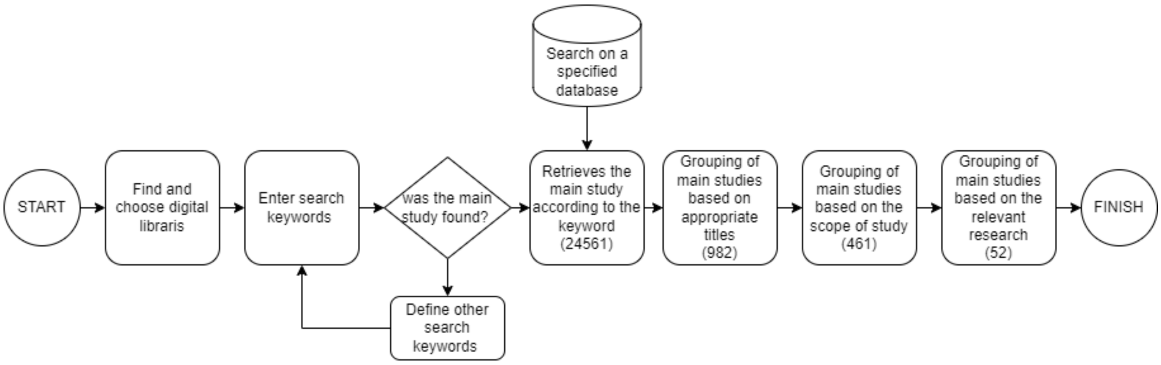

Figure 2. Main Study Search Strategy

Figure 2 explains the flow of the series of concepts that will be implemented. It starts with searching the journal platform in the digital librarian, determining the online database platform, and using keywords to group journals that have the main study discussion by relevant research. The strategy in making the main study search concept aims to facilitate the categorization of relevant journals. This is because the scope of journals corresponding to the relevant system will narrow.

2.3 Systematic Analysis

This research uses Mendeley software to assist in storing and organizing references that will be used during this research until research results are achieved. The final list of the first stage of the main study search was 52 main studies using the insertion and rejection criteria. The determination of accepted and unaccepted criteria is adjusted to the criteria used. The first step that can be done is to search for journals needed during the research process by focusing on the criteria of journals that have been published from 2013 to 2023 and the acceptance string that will be retrieved from the title, abstract, and content of the research discussed in online databases such as data science or Scopus. The next step is to determine what criteria are acceptable. The acceptable criteria are attributes related to the topic discussed and essential to consider. In contrast, the unacceptable criteria are attributes incompatible with the discussion and must be excluded. The inclusion and rejection criteria will be explained in Table 3.

Table 3. Insertion & Rejection Criteria

Insertion Criteria	Research or studies address route optimization for emergency vehicles, firefighters, and ambulances.
	This is for research and studies that have conference and journal versions.
	Only duplicate publications of the same research and study and the most complete and recent publications will be included.
	For research and studies published between 2013 and 2023.
Rejection Criteria	This is for research and studies that discuss things other than route optimization.
	For research and journals in languages other than English.

Determining the criteria for acceptable and unacceptable journal categories is aimed at categorizing specifically from journal searches that are only initiated using the Boolean AND system in the online database. Another purpose of using the determination of acceptable and unacceptable criteria in relevant journals is to narrow the search for relevant journals so that they can be more specific to the topic of the problem.

By applying the criteria of acceptable and unacceptable journals to the relevant search system, the categorization of the final list of major studies obtained from the last 10 years, from 2013 to 2023, can be seen in Figure 3. below.

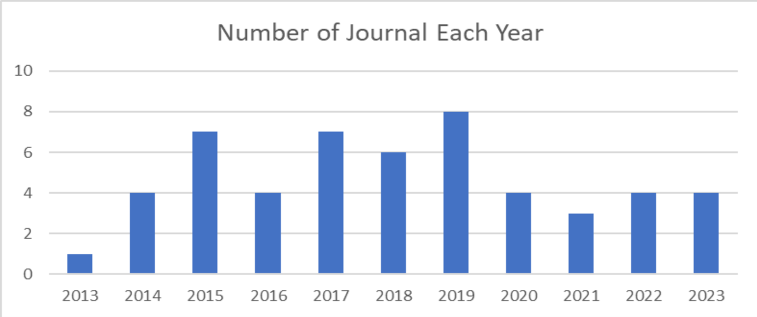

Figure 3. Number of Journals in the Last 10 Years

The results are shown in Figure 3. It shows that the number of journals published in the last 10 years has fluctuated yearly, with the highest number uploaded in 2019, with 8 journals related to the topic discussed. However, the journals listed by the relevant system each year have experienced ups and downs.

3. Database

This study uses four types of databases: Emerald, IEEE Express, Taylor & Francis, and ScienceDirect, which are based on online databases. The amount of data obtained from the four types of databases will be used based on the type of keywords from the search for journals, which are divided into three categories, including vehicle route problems in emergency vehicles, fire fighting vehicles, and ambulance vehicles. There will be a final total of 52 journals. The most relevant journals are in the keyword vehicle route problems in emergency vehicles.

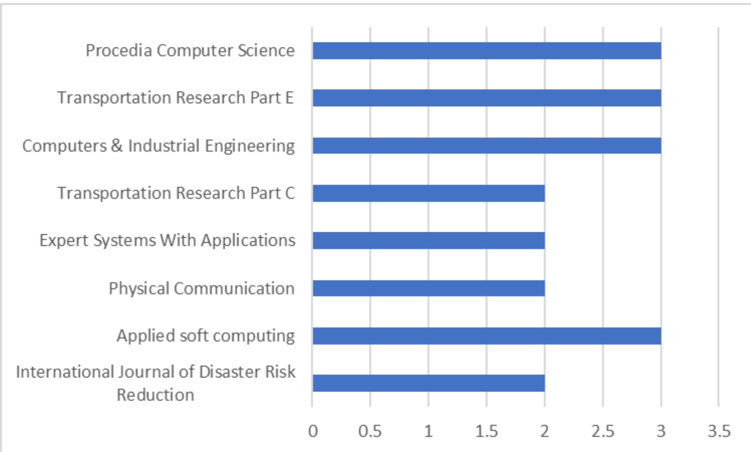

Figure 4. TOP 8 categories of publications of VRP

Table 4. TOP 5 Citation of Tittle Journals Relevant

Title	Citation	Country	University
Greedy-search-based multi-objective genetic algorithm for emergency logistics scheduling	151	Taiwan	National Sun Yat-sen University dan I-Shou University
A stochastic programming approach for flood emergency logistics	94	Chile	Universidad Diego Portales
A simulation-optimization framework for ambulance deployment and relocation problems	74	China	Shanghai University
Emergency transportation network design problem: Identification and evaluation of disaster response routes	50	Iran	Iran University of Science and Technology dan Bu-Ali Sina University
Optimization of vehicle routing problem for emergency cold chain logistics based on minimum loss	46	China	Beijing Union University

The results in Figure 4 show that the four types of publication categories have the highest number of journals. The database results can also determine the number of citations in each related journal based on the category of the number of journals in each online database and the number of journal publication types. Table 5 shows the top five citations based on the title, from the top results in Table 5. The highest number of citations from 2013 to 2023 amounted to 151 (Chang et al., 2014) from Taiwan. The data was taken on November 28, 2023, from 1:00 PM to 6:00 PM GMT+7.

4. Result and Discussion

Objective Function

The objective function is one of the steps in making scientific papers that must be considered after knowing what problems will be analyzed and provide a solution to these problems. The categories of optimization algorithm methods that are a reference for categorizing methods from relevant systems are Exact, Heuristic, Metaheuristic, Simulation, and Combination (Suyanto 2010). The percentage results of journal categorization based on the objective function of the relevant journals show that the objective function category "Minimum Travel Time" has a result of 37%, the largest category among other categories.

Distribution of Method

The method that a writer will use to find a solution to the existing problem objectives is necessary to determine which is by the problem objectives. An optimization algorithm is a numerical algorithm that can be used as a problem solver by involving the value of a scale or vector that aims to minimize or maximize the objective function of the problem (Suyanto 2010).Many previous studies have addressed problems related to vehicle routes in emergency conditions. Various approaches have been taken to find the optimal solution. An exact algorithm is a type of algorithm that can find the optimal solution to any problem. It is known as an exact algorithm. Approximation algorithms are used for all those problems where finding the most optimal solution is impossible. An approximate algorithm is a type of algorithm that finds a result as the average result of sub-results for a problem. Examples of exact algorithms used in related research are mixed integer linear programming and dynamic programming.

The second type of algorithm is a heuristic algorithm, a method or rule of thumb used to find a good or adequate solution within a reasonable time. However, it does not guarantee an optimal solution. The characteristics of heuristic algorithms do not guarantee the best solution; rather, they focus on providing a good enough solution in a limited time. Examples of heuristic algorithms used in related research are nearest neighbor and Dijkstra.The third type of algorithm is metaheuristic, a general approach to designing heuristic algorithms that can be applied to various optimization problems without having to be specifically adapted for each problem. The characteristics of metaheuristic algorithms are more general and flexible than conventional heuristics because they can be adapted to various optimization problems. It is usually iterative, improving the solution gradually through a series of search steps. Genetic algorithms and tabu search are heuristic algorithms used in related research.

The next type of solution is simulation, which can be used when solving problems in limited mathematical models. Another approach is a combination that integrates optimization and simulation models to solve route problems in emergency conditions. The distribution of methods used in solving route problems in emergency conditions is shown in Figure 5.

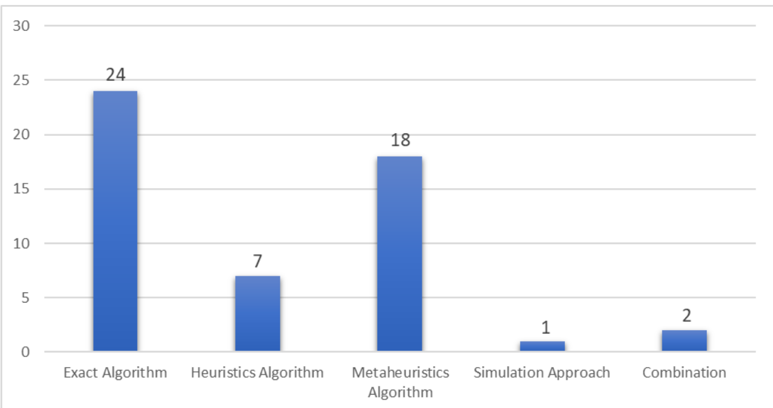

Figure 5. Distribution of the most frequently used methods

5. Categorization

After determining the most categories of objective functions of relevant journals, the next step is to determine the journals based on the categories that have been prepared. These categories include Point of Origin, Type of Depot, Vehicle Number, Geographic, Vehicle, Travel Time, Transportation, and Data Type. The categories are shown in (Appendix A)

5.1.1 Point of Origin (PO) and Type of Depot (TD)

Point of Origin in the context of a vehicle emergency is a point from which an incident occurs that emergency responders can use to get to the scene of the incident (N. Smith et al., 2010). Point of Origin is divided into 2 types of single and multiple characteristics (Tan & Yeh 2021). The type of Depot in a vehicle emergency is the destination point of an incident location, such as evacuation sites, hospitals, etc. Depots can also be defined as emergency vehicle locations for storage and maintenance. Depot types are divided into 2 types: Single and Multiple (Tan & Yeh 2021).

5.1.2 Vehicle Number (VN) and Data Used (DU)

Vehicle Number is divided into 2 types: Exact vehicle and Up-to-vehicle (Tan & Yeh 2021). Exact means that the vehicle with the load must maximize the vehicle capacity, and the route taken must go through the starting point to the end, while Up to the Vehicle, the vehicle with the load does not have to maximize the vehicle capacity and the route taken does not have to be one way. Data Used is a categorization section that can be used as a problem analysis by adjusting to the data usage. Used data is divided into 2 types: synthetic, real, and data that combines 2 types of data (Tan & Yeh 2021).

5.1.3 Geographic (GEO) and Vehicle (VH)

Geographic is divided into 2 types: urban and rural (Tan & Yeh 2021). Urban means a settled area (big city), while rural is a village area. The context of this vehicle is the type of vehicle that will be used in handling an incident. Vehicles are divided into 2 types: similar and heterogeneous (Tan & Yeh 2021).

5.1.4 Approach Method (AP) and Transportation (TP)

The approach Method is one of the methods used to perform an approach in analysis and modelling. The Approach Method is divided into three types: Deterministic, stochastic, and Unknown, which means it is unclear what approach should be used (Tan & Yeh 2021). Transportation in this context can be categorized into three types: Travel Time-Dependent, distance-dependent, and vehicle-dependent (Tan & Yeh 2021), which have meaning according to the parameters used in the journal discussed.

Conclusion

This article presents a systematic literature review on the Vehicle Routing Problem under Deadline. This study aims to determine the research GAP and research opportunities that can be used for further research. The analysis of the systematic literature review results is to determine which types of journals are suitable for problems in emergency vehicles and which use the most suitable methods and variables for solving these problems.
Based on the systematic literature review stage, we obtained 52 journals on the main study discussion, which then obtained answers to research questions based on the results of the analysis that had been carried out, including:

1. Figure 4 shows the journals that were most suitable for the main topic of the problem from 2013 to 2023. The journals are primarily obtained in four publications: Applied Soft Computing, Procedia Computer Science, Computers & Industrial Engineering, and Transportation Research Part E.
2. The method most often used in solving the problem and the objective function can be seen in Figure 5, namely in the type of Exact Algorithm.
3. Appendix A shows the most frequently used variables in solving a problem. It is based on the categories of relevant systems: Multiple origin, multiple depots, exact vehicle, geographic location in urban areas, similar vehicle, using stochastic, travel time-dependent, and mixed usage of natural and synthetic data.

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APPENDIX -A: Author and categories of relevant system

Author	PO		TD		VN		GEO			VH		AP			TP			DU	
	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix
(J. Liu & Xie, 2017)		✓		✓		✓		✓		✓			✓		✓				✓
(Babaei et al., 2019)		✓		✓	✓		✓			✓			✓		✓	✓		✓	
(Hong et al., 2015)	✓			✓		✓	✓				✓	✓				✓			✓
(Chen, 2014)	✓			✓		✓			✓	✓			✓		✓		✓		✓
(Rathore et al., 2018)		✓		✓		✓	✓			✓			✓		✓			✓	
(Mizuno & Takahashi, 2016)	✓			✓		✓		✓		✓			✓			✓		✓	
(He et al., 2016)	✓			✓	✓				✓	✓				✓		✓			✓
(Xu et al., 2022)		✓		✓		✓	✓				✓		✓				✓	✓	
(Yang et al., 2015)	✓			✓		✓			✓	✓			✓		✓	✓			✓
(Hu et al., 2016)		✓		✓	✓				✓		✓		✓		✓	✓			✓
(Xia et al., 2023)		✓		✓		✓	✓				✓		✓		✓	✓			✓
(Bu et al., 2019)		✓		✓	✓		✓			✓			✓			✓			✓
(D. Liu &	✓			✓	✓		✓			✓			✓			✓			✓

Author	**PO**		**TD**		**VN**		**GEO**			**VH**		**AP**			**TP**			**DU**	
	SO	**MO**	**SD**	**MD**	**EV**	**Up to**	**UR**	**RU**	**UN**	**SV**	**HV**	**DE**	**ST**	**UN**	**TTD**	**DD**	**VD**	**RD**	**Mix**
Ji, 2019)																			
(Zahedi et al., 2020)		✓		✓		✓	✓				✓		✓		✓			✓	
(Zhang & Xiong, 2018)	✓			✓	✓		✓			✓			✓			✓			✓
(Qi & Hu, 2020)	✓			✓	✓		✓			✓		✓				✓			✓
(Giedelmann-L et al., 2022)	✓		✓		✓				✓	✓		✓				✓		✓	
(Nikoo et al., 2018)		✓		✓	✓	✓	✓			✓			✓		✓	✓			✓
(Wang et al., 2021)		✓		✓	✓		✓			✓			✓		✓			✓	
(Wang et al., 2023)	✓			✓	✓		✓	✓		✓		✓				✓		✓	
(Park et al., 2019)		✓		✓		✓	✓			✓			✓		✓	✓			✓
(Jiang et al., 2021)	✓			✓	✓		✓	✓		✓		✓				✓		✓	
(Zhao et al., 2022)	✓			✓	✓		✓			✓			✓		✓				✓
(Musolino et al., 2013)	✓			✓	✓		✓			✓		✓			✓				✓
(Huang & Rafiei	✓		✓			✓			✓	✓			✓		✓				✓

Author	PO		TD		VN		GEO			VH		AP			TP			DU	
	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix
, 2019)																			
(Chang et al., 2014)		✓		✓	✓				✓		✓	✓				✓	✓	✓	
(J. Liu et al., 2021)		✓		✓		✓	✓				✓		✓		✓			✓	
(Chai et al., 2018)		✓		✓		✓	✓	✓		✓			✓		✓	✓			✓
(Garrido et al., 2015)		✓		✓		✓	✓			✓			✓			✓		✓	
(Yan et al., 2014)		✓		✓	✓		✓	✓			✓	✓	✓		✓				✓
(Brachman et al., 2020)	✓			✓	✓		✓			✓		✓			✓				✓
(Shahparvari & Abbasi, 2017)		✓		✓		✓	✓	✓		✓			✓		✓		✓		✓
(Dubois et al., 2019)	✓			✓	✓				✓	✓			✓		✓			✓	
(Krasko & Rebennack, 2017)	✓			✓		✓	✓			✓			✓		✓				✓
(Shahparvari et al., 2019)		✓		✓		✓		✓		✓			✓				✓		✓
(Shahparva		✓		✓		✓		✓		✓			✓		✓		✓		✓

Author	PO		TD		VN		GEO			VH		AP			TP			DU	
	SO	**MO**	**SD**	**MD**	**EV**	**Up to**	**UR**	**RU**	**UN**	**SV**	**HV**	**DE**	**ST**	**UN**	**TTD**	**DD**	**VD**	**RD**	**Mix**
ri et al., 2017)																			
(Bodaghi et al., 2020)		✓		✓	✓			✓		✓			✓		✓	✓			✓
(Shahparvari et al., 2016)		✓		✓	✓			✓			✓		✓				✓		✓
(Kamireddy et al., 2016)	✓		✓		✓		✓			✓		✓				✓		✓	
(Yu et al., 2020)	✓		✓		✓		✓			✓			✓		✓				✓
(El Fallahi & Sefrioui, 2019)		✓		✓	✓				✓	✓			✓		✓				✓
(Caliskan & Altintas, 2020)		✓		✓		✓	✓				✓		✓		✓			✓	
(Sutherland & Chakrabortty, 2023)		✓	✓		✓		✓	✓		✓			✓		✓				✓
(Tlili et al., 2017)	✓			✓	✓				✓	✓		✓				✓		✓	
(ZIDI et al., 2019)	✓			✓	✓				✓	✓			✓		✓			✓	
(Hemici et		✓	✓		✓		✓			✓		✓				✓			✓

Author	PO		TD		VN		GEO			VH		AP			TP			DU	
	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix
al., 2023)																			
(Knyazkov et al., 2015)	✓			✓	✓		✓			✓			✓		✓		✓		✓
(Acuna et al., 2020)	✓			✓	✓		✓	✓		✓			✓		✓				✓
(Zhen et al., 2014)	✓			✓		✓	✓				✓		✓		✓			✓	
(Zhen et al., 2015)		✓		✓	✓		✓			✓			✓		✓				✓
(Hannoun & Menéndez, 2022)		✓		✓		✓	✓				✓		✓		✓				✓
TOTAL	24	27	6	45	30	22	34	13	11	39	12	12	39	1	33	23	8	18	33

Annotation:

- Point of Origin (**PO**), Type of Depot (**TD**), Vehicle Number (**VN**), Geographic (**GEO**), Vehicle (**VH**), Approach Method (AP), Transportation (**TP**), and Data Used (**DU**).
- Single Origin (**SO**), Multiple Origin (**MO**), Multiple Depot (**MD**), Exactly Vehicle (**EV**), Up to Vehicle (**Up To**), Urban (**UR**), Rural (**RU**), Similar Vehicle (**SV**), Heterogenous Vehicle (**HV**), Deterministic (**DE**), Stochastic (**ST**), Unknown (**UN**), Travel Time-Dependent (**TTD**), Distance Dependent (**DD**), Vehicle Dependent (**VD**), Real-World Data (**RD**) and Synthetic Data (**SC**).