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Vehicle Routing Problem in Under Deadlines: A Systematic Literature Review

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ABSTRACT

Transportation is one of key areas in supply chain management. EVPs or emergency vehicles, firefighters, and ambulances are one of 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. This research will use a systematic literature review method to identify variables, methods, and theories. From the analysis that has been carried out, the results are obtained in the form of journals that are most suitable for the topic of discussion, which methods are most suitable for solving problems, and which variables are most suitable for the existing topic of discussion. 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 Exact Algorithm. And eight types of variables are by the existing discussion.

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Firefighters,
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1. INTRODUCTION

Transportation is one of key areas of efficiency and effectiveness in supply chain management, and a difficult problem in the field of 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 & Ramser (1959) is a figure who 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 that have been published from 2019 to 2021 with total 88 journals (Tan & 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 one of the mobility settlements 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 both the lives and property of residents. Therefore, the timeliness of handling a case that occurs 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 according to the type of priority vehicle is emergency vehicle, fire fighting vehicles and ambulance vehicles.

The main contribution to this research is mapping related to VRP research by considering under-deadline conditions which can be used by further research to obtain a relevant and actual literature review with a comprehensive classification. Another aim of this research is to provide an overview of the latest research trends and positions carried out by researchers in the next period. The general overview of this research is divided into several parts. The next section will describe the method of this research. The result of the systematic literature review is presented in Section 4. The last section presents the conclusions of this paper and the proposed model for the next research.

2. RESEARCH METHODS

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 include focused research questions, appropriate methodology, and specific exclusion and inclusion criteria (Smith et al., 2011).

To make an analysis, steps are needed in using the systematic literature review method, which is to create a research question, conduct a literature review, select relevant journals, analyse the results of categorizing relevant journals, and make conclusions from the results that have been carried out (Luckyardi et al., 2022).

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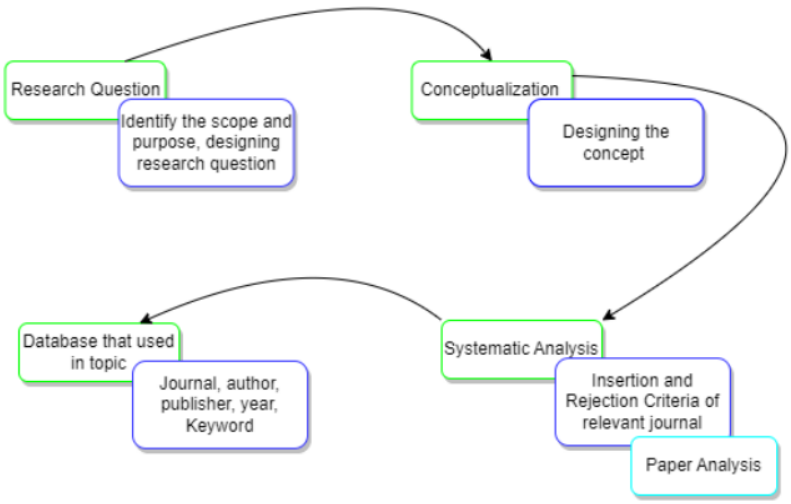

Figure 1. Schematic Review Planning Flow

2.1. Research Question

In accordance with the Schematic Review Planning Flow that has been displayed in **Figure 1.** the first step that will be taken is to determine the research question as a formulation of research problems that will be answered based on the research results.

The purpose of this research is to determine and identify the variables, methods, and trends that are most suitable for the topic to be discussed Designing research questions is one of the ways that can be used in identifying variables, methods, and trends that are suitable for the topic to be discussed designing research questions, it must be adjusted to the accuracy of developing 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 and ambulances as well as 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 best route in route optimization for emergency vehicles such as firefighters and ambulances as well as vehicles needed in evacuating goods and people using the VRP method.
Context	Studies related to route determination using the VRP method which is used to determine the best route for firefighters and ambulances as well as the vehicles that are needed in evacuating goods and people.

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In **Table 1.** It summarizes the question structure using the PICOC system which has five components that can be considered such as population, intervention, comparison, outcomes, and context. The aim of creating this PICOC system is to make it easier for the author to determine what research questions are suitable for the topic to be discussed. After designing using PICOC, the next step can 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	The most variables are often used on the topic of best route optimization for emergency vehicle types.	Identify variables that are often used on the topic of best route optimization for critical vehicle types.

In **Table 2.** Explain the research questions that are needed and the appropriate way to solve these questions.

2.2 Conceptualization

In the conceptualization section, the strategy, and steps for searching the most relevant journals to the topic are described. This search strategy aims to identify journal articles and summarize them that are only related to route optimization problems in priority vehicles, especially ambulance, and fire fighting 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" or can use "Vehicle" AND "Routing" AND "Problem" AND "In Firefighter" or can also use "Vehicle" AND "Routing" AND "Problem" AND "In Ambulance". The following is an illustration of the main study search strategy.

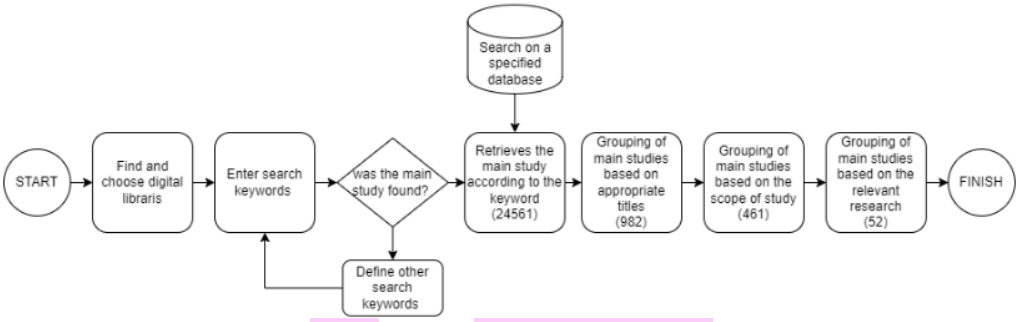

Figure 2. Main Study Search Strategy

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In **Figure 2.** Explains the flow of the series of concepts that will be implemented. Starting from searching the journal platform in the digital librarian, determining the online database platform, and which keywords will be used 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 that correspond to the relevant system will be narrower.

2.3 Systematic Analysis

This research uses Mendeley software as a tool to assist in storing and organizing references that will be used during this research until achieving research results. 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 that will be 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 which are the types of attributes that are by the topic discussed and are important to be taken, while the unacceptable criteria have attributes that are incompatible with the discussion and must be excluded. The inclusion and rejection criteria will be explained in **Table 3.** as follows.

Table 3. Insertion & Rejection Criteria

Insertion Criteria	Research or studies that address route optimization for emergency vehicles, firefighters, and ambulances.
	For research and studies that have conference and journal versions.
	Duplicate publications of the same research and study, only the most complete and recent publications will be included.
	For research and studies published between 2013 and 2023.
Rejection Criteria	For research and studies that discuss 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 by using the Boolean AND system in the online database. Another purpose of using the determination of acceptable and unacceptable criteria on relevant journals is to narrow down the search for relevant journals so that it 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.

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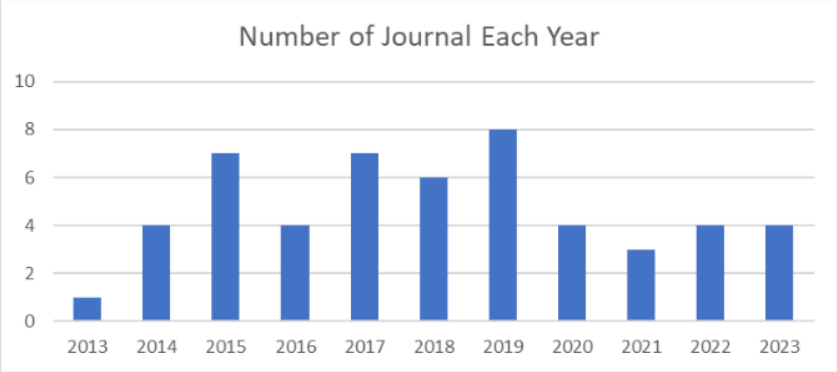

Figure 3. Number of Journals in the Last 10 Years

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

2.4 Database

The database in this study uses four types of databases such as Emerald, IEEE Express, Taylor & Francis, and ScienceDirect which are based on online databases. The amount of data obtained from the four types of databases that 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 shown in **Table 4.** with a final total of 52 journals.

Table 4. The final main study journal besides one relevant research

Keyword	Emerald	IEEE	Taylor&Francis	ScienceDirect
Vehicle Routing Problem in Emergency Vehicle	3	7	3	17
Vehicle Routing Problem in Firefighter	1	2	0	6
Vehicle Routing Problem in Ambulance	1	2	1	9
TOTAL	5	11	4	32

The results presented in **Table 4.** show that the number of journals that match the relevant system from each category is different. The largest number of relevant journals is in the keyword vehicle route problems in emergency vehicles, also the online database has the most relevant journals in the ScienceDirect database which has the largest database results, namely 32 journals. The relevant journals have different types of journal publications, the top eight journal publications are shown in **Figure 4.**

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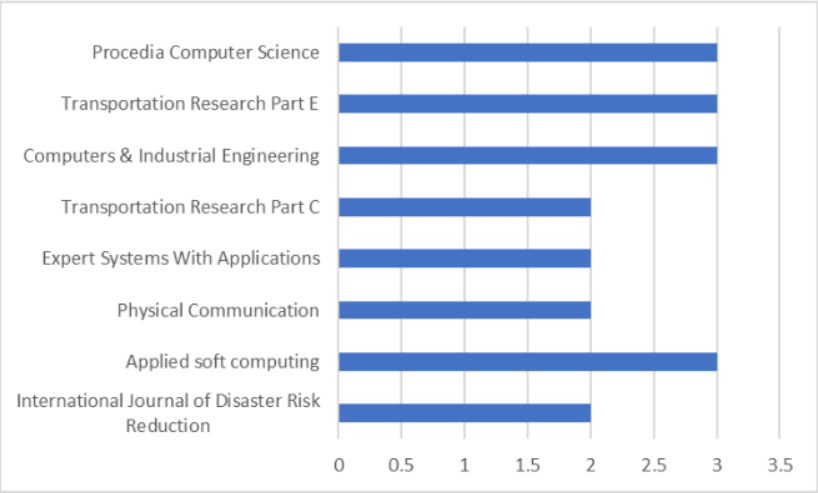

Figure 4. TOP 8 categories of publications of VRP

From the results in **Figure 4.** Four types of publication categories have the highest number of journals. Based on the category of the number of journals contained in each online database used and the number of journal publication types, the results of the database used can also determine the number of citations contained in each related journal. The top five citation based on tittle are shown in **Table 5.**

Tabel 5. TOP 5 Citation of Tittle Journals Relevant

Tittle	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 floods 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

From the top results in Table 5. The highest number of citations from 2013 to 2023 amounted to 151 (Chang et al., 2014) form Taiwan. The data was taken on November 28, 2023, at 1:00 PM to 6:00 PM GMT+7.

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3. RESULTS AND DISCUSSION

3.1 Objective Function

The objective function is one of the steps in making scientific papers that must be considered after knowing what problems will be analysed and providing a solution to these problems. The categories of optimization algorithm methods that are a reference for the categorization of methods from relevant systems are Exact, Heuristic, Metaheuristic, Simulation and Combination methods (Suyanto, 2010) and are shown in **Figure 5.** which presents the percentage of each category from the optimization algorithm methods that used.

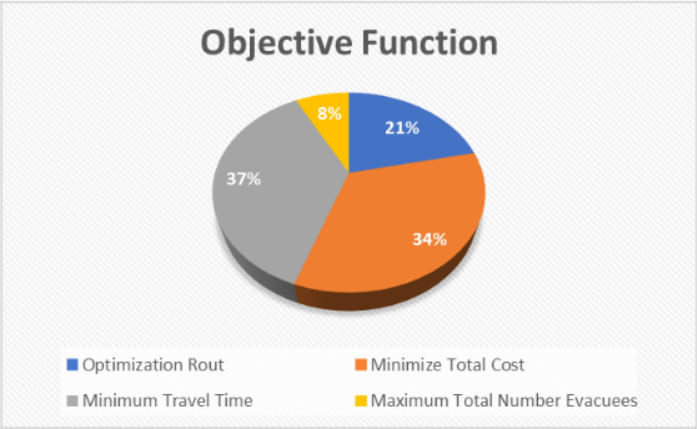

Figure 5. Percentage of Journal Categorization Based on Purpose Function

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%, which is the largest category among other types of categories.

3.2 Distribution of Method

The method that will be used by a writer to find a solution to the existing problem objectives, is very 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).

Problems related to vehicle routes in emergency conditions have been addressed in many previous studies. Various approaches have been taken to find the optimal solution. An exact algorithm is a type of algorithm that is able to find the optimal solution to any problem. It is known as an exact algorithm. For all those problems, where it is not possible to find the most optimal solution, approximation algorithms are used. 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 which is a method or rule of thumb used to find a good or adequate solution in a reasonable time, although it does not guarantee an optimal solution. The characteristics of heuristic algorithms do not guarantee the best solution, but rather focus on providing a good enough solution in a limited time. Examples of heuristic

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algorithms used in related research are nearest neighbor and djikstra.

The third type of algorithm is metaheuristic which is 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. Examples of heuristic algorithms used in related research are genetic algorithms and tabu search.

The next type of solution is simulation which can be used when there are limitations to solving problems in mathematical models. Another approach used can be a combination that integrates optimization and simulation models in solving route problems in emergency conditions. The distribution of method use in solving route problems in emergency conditions is shown in **Figure 6.**

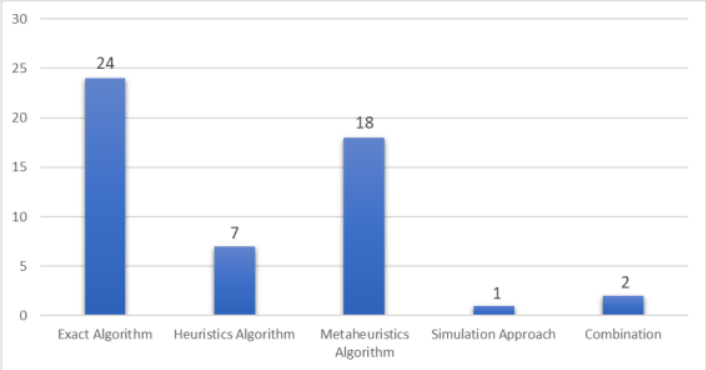

Figure 6. Distribution of the most frequently used methods

3.3 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 can be shown in **Table 6.** as follows.

Table 6. 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, n.d.)	✓			✓		✓			✓	✓			✓		✓		✓		✓

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	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix
(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 & Ji, 2019)	✓			✓	✓		✓			✓			✓			✓			✓
(Zahedi et al., 2020)		✓		✓		✓	✓				✓		✓		✓			✓	
(Zhang & Xiong, 2018)	✓			✓	✓		✓			✓			✓			✓			✓
(Qi & Hu, 2020)	✓			✓	✓		✓			✓		✓				✓			✓
(Edelmann-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, 2019)	✓		✓			✓			✓	✓			✓		✓				✓
(Chang et al., 2014)		✓		✓	✓				✓		✓	✓				✓	✓	✓	
(J. Liu et al., 2021)		✓		✓		✓	✓				✓		✓		✓			✓	
(Chai et al., 2018)		✓		✓		✓	✓	✓		✓			✓		✓	✓			✓
(Garrido et al., 2015)		✓		✓		✓	✓			✓			✓			✓		✓	
(Yan et al., 2014)		✓		✓	✓		✓	✓			✓	✓	✓		✓				✓

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	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix
(Brachman et al., 2020)	✓			✓	✓		✓			✓		✓			✓				✓
(Shahparvari & Abbasi, 2017)		✓		✓		✓	✓	✓		✓			✓		✓		✓		✓
(Dubois et al., 2019)	✓			✓	✓				✓	✓			✓		✓			✓	
(Krasko & Rebennack, 2017)	✓			✓		✓	✓			✓			✓		✓				✓
(Shahparvari & Abbasi, 2017)	✓			✓	✓			✓		✓			✓				✓		✓
(Shahparvari et al., 2019)		✓		✓		✓		✓		✓			✓				✓		✓
(Shahparvari 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 al., 2023)		✓	✓		✓		✓			✓		✓				✓			✓
(Knyazkov et al., 2015)	✓			✓	✓		✓			✓			✓		✓		✓		✓
(Acuna et al., 2020)	✓			✓	✓		✓	✓		✓			✓		✓				✓
(Zhen et al., 2015)	✓			✓		✓	✓				✓		✓		✓			✓	
(Zhen et al., 2014)		✓		✓	✓		✓			✓			✓		✓				✓
(Hannoun & Menéndez, 2022)		✓		✓		✓	✓				✓		✓		✓				✓
TOTAL	25	27	6	46	31	22	34	14	11	40	12	12	40	1	33	23	9	18	34

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	SO	MO	SD	MD	EV	Up to	UR	RU	UN	SV	HV	DE	ST	UN	TTD	DD	VD	RD	Mix

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**).

3.3.1 Point of Origin (PO)

Point of Origin in the context of a vehicle emergency is a point from which an incident occurs that can be used by emergency responders to get to the scene of the incident (Nicholas J, n.d.). Point of Origin is divided into 2 types of single and multiple characteristics (Tan & Yeh, 2021).

3.3.2 Type of Depot (TD)

The type of Depot in the context of 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).

3.3.3 Vehicle Number (VN)

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.

3.3.4 Geographic (GEO)

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.

3.3.5 Vehicle (VH)

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).

3.3.6 Approach Method (AP)

The approach Method is one of the methods used to perform an approach in analysis and modelling. Approach Method is divided into 3 types Deterministic, stochastic, and Unknown which means it is not clear what approach should be used (Tan & Yeh, 2021).

3.3.7 Transportation (TP)

Transportation in this context can be categorized into 3 types, which are Travel Time-Dependent, distance-dependent and vehicle-dependent (Tan & Yeh, 2021) which have their meaning according to the parameters used in the journal discussed.

3.3.8 Data Used (DU)

Data Used is a categorization section that can be used as a problem analysis by adjusting to the usage of the data. Used data is divided into 2 types such as synthetic, real data and data that combines 2 types of data. (Tan & Yeh, 2021).

4. 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 results of the systematic literature review is to determine which types of journals are suitable for problems in emergency vehicles that use the

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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. The journals that are most suitable for the main topic of the problem in the period of 2013 to 2023 are in **Figure 8.** The journals are mostly obtained in four publication locations which are 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 6**. namely in the type of Exact Algorithm.
3. The most frequently used variables in the process of solving a problem can be seen in **Table 6.** Based on the category of relevant systems, namely Multiple Origin, Multiple Depots, Exact Vehicle, Geographical in Urban, Similar Vehicle, Using Stochastic, Travel Time-Dependent, mixed usage of real and synthetic data.

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6. AUTHORS' NOTE

The authors have declared that there is no conflict of interest regarding the publication of this article. The authors confirmed that the data and this paper are free of plagiarism.

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