The vehicle routing problem

by Abdul Wahid

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The vehicle routing problem for perishable goods: A systematic review

Dana Marsetiya Utama[1]*, Shanty Kusuma Dewi[1], Abdul Wahid[2] and Imam Santoso[3]

Abstract: Vehicle Routing Problem (VRP) is the problem for finding optimal routes in the distribution system, and this problem needs attention because it can improve distribution performance. One of the problems in VRP is the Vehicle Routing Problem for Perishable Goods (VRPfPG). This issue addresses VRP for products that are rapidly losing quality and perishable. This paper attempts to review the Vehicle Routing Problem for Perishable Goods (VRPfPG). A systematic review has been carried out on fifty-nine (59) published papers from 2001 to March 2020. The optimization methods in this review were classified into single and multi-objective problems. In addition, the review was also conducted based on the objective function. The results show the metaheuristic algorithm to be a popular optimization method for solving single and multi-objective problems. Further, the results also show that minimizing the total cost distribution to be the objective function that was often used by researchers. Finally, future studies are suggested to explore a more comprehensive investigation in the VRPfPG.

Subjects: Algorithms & Complexity; Computer Engineering; Supply Chain Management

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Dana Marsetiya Utama

PUBLIC INTEREST STATEMENT

The Vehicle Routing Problem (VRP) is a matter of determining the optimal routes carried out by vehicles to serve a particular set of customers. One of some problem in VRP is the Vehicle Routing Problem for Perishable Goods (VRPfPG) that address for products that are rapidly losing quality and perishable. In this paper, a systematic literature review is carried out on the single and multiple-objective problem-solving. These problems are classified based on optimization methods and objective functions. Most of the reviewed papers above consider a single-objective problem, while some focus on multi-objective problems. Moreover, an analysis based on the optimization method, and the objective function is presented completely in single and multiple-objective problems. Finally, future studies are suggested to explore comprehensive studies in the VRPfPG problem.

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Keywords: optimization; perishable goods; routing; VRP

1. Introduction

Recently, the logistics industry has been increasing significantly, and it is expected to continue to develop over the next few years (Chen & Shi, 2019). In the United States, the logistics industry has developed for more than 12.7% (Damicis, 2018). This industry generates more than 400,000 new jobs and is projected to continue to grow until 2022 (Huang et al., 2019). In China, the logistics industry has shown significant growth in recent years, and it ranks first place among forty-five developing industries worldwide (Yao et al., 2019). One of the problems in the logistics industry is the Vehicle Routing Problem (VRP) (Putri, 2016). The VRP is a determining problem of the optimal routes that carried out by a fleet of vehicles to serve a particular set of customers (Masudin et al., 2019; Mohammed et al., 2017; Zhang et al., 2019). This problem is one of the essential combinatorial optimization issues to investigate in the logistics sector (Eshtehadi et al., 2020; Garside et al., 2016; Xu et al., 2019). The VRP problems were first investigated by Tarantilis and Kiranoudis (2001), Hsu et al. (2007), and Kang and Lee (2007). The route determination becomes a complex problem in perishable products because the products can quickly get damaged or decreasing quality (Sinha & Anand, 2020). Some products that are classified as perishable goods include food, fruit, and vegetable products (agricultural products). This problem has received considerable critical attention from many researchers.

Many researchers are enthusiastic about investigating the Vehicle Routing Problem for Perishable Goods (VRPfPG). However, there have not been any researchers reviewing literature papers on the VRPfPG that facilitate future research. Some reviews of VRP have been found in various scientific paper databases. Euchi (2017) analysis the metaheuristic approach to Vehicle Routing Problems with a Private fleet and Common Carrier. Koç and Laporte (2018) examine VRP with backhauls. Meanwhile, Gayialis et al. (2019) and Konstantakopoulos et al. (2017) investigate VRP for urban freight transportation. In addition, Ritzinger et al. (2016), Oyola et al. (2017), and Oyola et al. (2018) observe dynamic and stochastic VRP. Braekers et al. (2016) examined articles about the classification of VRP. Toro et al. (2016) review the VRP papers in the green transportation context. Meanwhile, Lahyani et al. (2015) overview research articles on taxonomy and the definition of VRP. Vidal et al. (2019) discuss the variants of existing problems in VRP. Lastly, Goel and Bansal (2020) assess papers about the hybrid approach to VRP.

The VRPfPG problems are more challenging and complex than the classic VRP. Since Tarantilis and Kiranoudis (2001) introduced the VRPfPG problem, several studies in the form of journals and conference papers in the VRPfPG problem have been published. In the VRPfPG problem, the best solution can be achieved with the optimization process, and the decision-maker makes a decision based on the maximum or minimum value. Some decision problems of VRPfPG involve one goal, which is classified as a single objective problem. Decision problems also consist of several conflicting objectives called multi-objective problems. In a single objective problem, one of the strengths of this problem is the aspect of excellent solution stability. However, the main weakness is the optimality aspect because it only considers one goal.

Conversely, multi-problems have strengths in the optimality aspect because they consider multiple decision objectives. However, the weakness in this problem is the aspect of the stability of the solution (Pies et al., 2019). Although many research papers have been published, there is no systematic review focused on the VRPfPG issue. Therefore, the motive for this review is to present a comprehensive idea of the scientific literature by presenting a classification of optimization methods from the VRPfPG paper based on the single and multi-objective problem.

This paper aims to provide an in-depth analysis of single and multi-objective problems in the VRPfPG. A systematic review for the VRPfPG was based on the optimization methods and objective function in the single and multi-objective problems. Most of the reviewed papers consider a single-

objective problem, while some focus on multi-objective problems. The researchers collected fifty-nine papers from accessible databases. It was projected that this paper would give a contribution to provide new insight into the VRPfPG, especially in the aspects of the optimization methods and objective function in the single and multi-objective problems. It was also expected that this review contributes to a deeper understanding of the VRPfPG. The organization of the paper was presented as follows: Section 2 presents the method of literature review; section 3 displays the results, analysis, and future work; and the last part projects the conclusion.

2. Methods

A literature review is a comprehensive study that is used to investigate research in emerging fields and to guide future research with the existing studies. The researchers employed several literature review stages as follows: Step 1: setting the keywords and collecting data; Step 2: development of the VRPfPG classification schema; Step 3: reviewing the collected literature; Step 4: separating and tabulating the literature according to the classification schema; Step 5: presenting the literature reviews using the classification schema, and Step 6: analyzing the reviews and presenting suggestions for future work. Some of the abbreviations used in this paper are described as follows.

2.1. Keywords and data collection

To achieve the objectives of the study, the researchers collected the VRPfPG papers using the keywords based on the Boolean method. The keyword used is "vehicle routing problem" and "perishable". The data collection was carried out by thoroughly examining some accessible popular databases such as Elsevier, IEEE, Springer, Taylor & Francis, MDPI, as well as Hindawi. Moreover, to search for papers in other databases, Google Scholar was used as a search engine. Fifty-nine papers were collected from the year 2001 to March 2020. Paper distribution is shown in Figure 1, and the classification of Type of Publication papers of the VRPfPG can be seen in Figure 2. Most papers were obtained 46 papers from journals (78%), and the rest was 13 papers from the conference paper (22%).

2.2. Classification schema of literature review

Classifying of the papers are based on by year, country, as well as optimization methods and objective function in the single and multi-objective problem. Categories single and multi-objective problems were chosen because these problems are the decision problem VRPfPG that can be chosen by decision-makers. A complete descriptive analysis is presented in Section 3, and the paper review framework can be seen in Figure 3. This paper reviewed the VRPfPG based on single and multi-objective optimization methods. Fifty-eight papers in English were successfully collected, and one article was a paper in Spanish. In paper non-English, we used a translation engine to make it easier to review. The collected papers were read and examined in-depth according to the classification schema.

Figure 1. Paper distribution based on publisher.
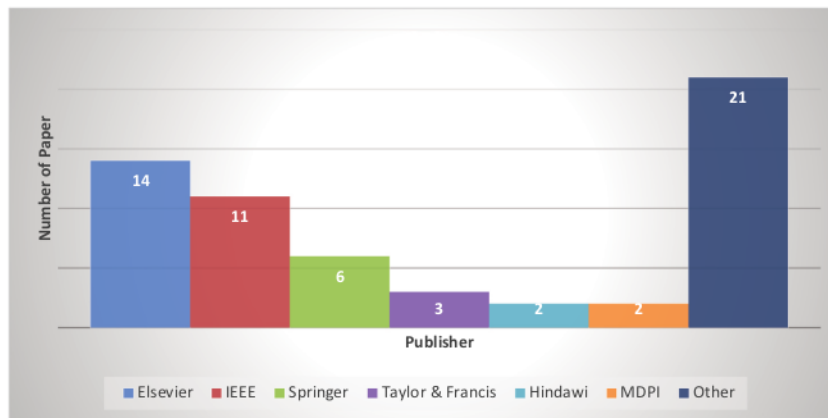
Figure 2. Number and type of publication.
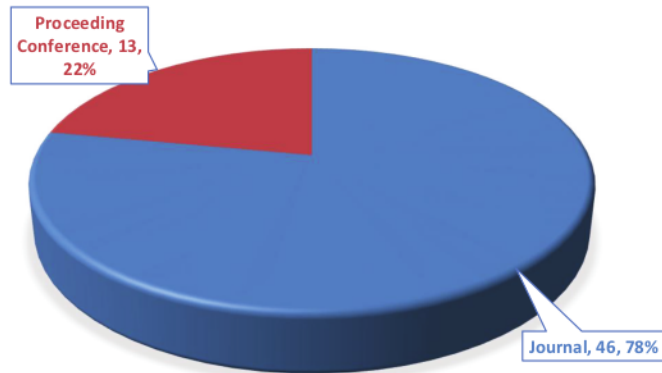
Figure 3. Literature review classification schema on the VRPfPG.
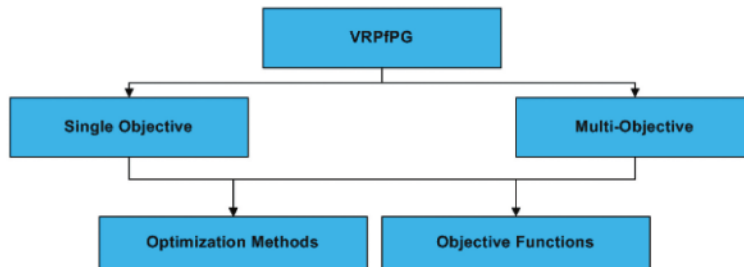
3. Results, analysis, and future work

3.1. Paper distribution based on year and country of publication

VRP is a problem that has developed rapidly over the last few decades. However, increasing literature on VRPfPG has also been significant. As can be seen in Figure 4, it shows an increasing interest in the studies of the VRPfPG. Most papers were published from 2014 to 2019. Even in early

Figure 4. Paper distribution based on year of publication.
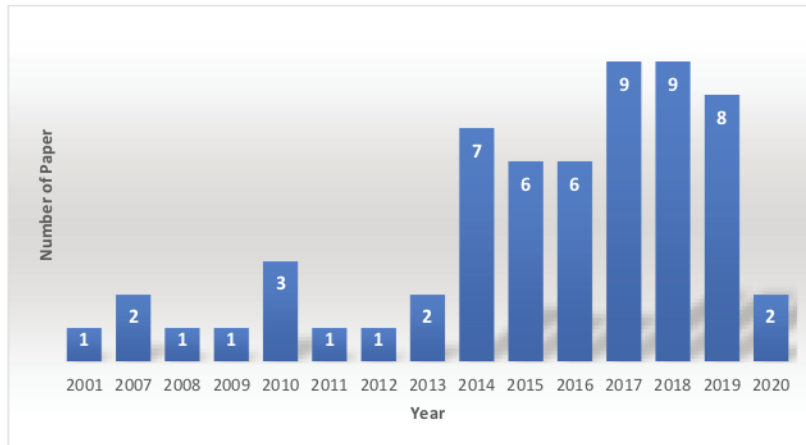
2020, two papers have been published by researchers. However, there was not any similarity in the topic of papers published each year.

As mentioned earlier, the researchers reviewed papers issued between 2001 to March 2020. There Fifty-nine papers were successfully collected on this issue published in scientific papers. Papers distribution based on year is shown in Figure 4. It shows that very few papers were published between 2001 and 2013. Only one publication was produced in 2001, 2008 to 2009, two papers in 2007, three papers in 2010, one article in 2011 and 2012 respectively, and two papers in 2013. Between 2014 and March 2020, there was an increase in the number of publications about the VRPfPG. It gave a total of forty-seven (47) publications by March 2020. The most significant increase in the published papers occurred in 2017 to March 2020.

Based on the country of publication, the topic of VRPfPG attracted the attention of many researchers around the world. Figure 5 shows that China was the country with the highest number of articles about the VRPfPG problem (sixteen papers). Iran followed it in second place, and Indonesia was in third place. Iran and Indonesia have contributed thirteen and four papers, respectively. It can be assumed that the research on this issue has been appealing in several countries.

3.2. Single-objective VRPfPG
This section presents a literature review in a single objective problem that is classified toward optimization methods for solving VRPfPG. Forty-two papers (71%) were collected, and the summarizing of papers can be seen in Table 1. The classifying of the optimization method in solving the VRPfPG is divided into five approaches, such as heuristic, metaheuristic, exact, hybridization, and simulation. A full review of this problem is presented in the next section.

3.2.1. Heuristics
This section summarized the studies on the VRPfPG problems with heuristic optimization methods. As Non-Polynomial Hard (NP-Hard) problems, some researchers have proposed heuristic methods to solve VRPfPG issues. Hsu et al. (2007) were the first researchers to overcome the VRPfPG problem with a heuristic solution. They used the Time-Oriented Nearest-Neighbour Heuristic algorithm for minimizing the total cost distribution. At the same time, Kang and Lee (2007) proposed the set partitioning problem to decrease the total distribution time.

On the other hand, Osvald and Stirn (2008) developed the heuristic algorithm to minimize the cost of delivery. The Nelder-Mead heuristic method was then proposed by Chen et al. (2009) to

Figure 5. Paper distribution based on the country of publication.
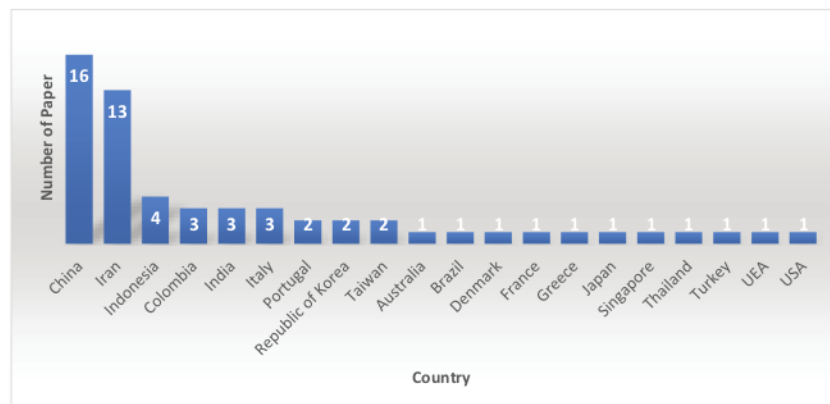
Table 1. Reviewed papers about single-objective in the VRPFPG

Year	Authors	Objective Function							Optimization Methods				
		Min TCD	Min FC	Max TLCS	Min TTD	Max FSDP	Max P	Min TDT	Metahe uristic	Heuristic	Exact	Simula tion	Hybridi zation
2001	Tarantilis and Kiranoudis (2001)				>				>				
2007	Hsu et al. (2007)	>								>			
	Kang and Lee (2007)							>		>			
2008	Osvald and Stirn (2008)	>								>			
2009	Chen et al. (2009)						>			>			
2010	Xunyu and Tomohiro (2010)	>							>				
	Tunjong sirigul and Pongch airerks (2010)	>							>				
2011	Keskinturk and Yildirim (2011)	>							>				
2012	Abraham et al. (2012)	>							>				

(Continued)

Table 1. (Continued)

Year	Authors	Objective Function							Optimization Methods				
		Min TCD	Min FC	Max TLCS	Min TTD	Max FSDP	Max P	Min TDT	Metahe uristic	Heuristic	Exact	Simula tion	Hybridi zation
2013	L. Li et al. (2013)	✓							✓				
	Shukla and Jharkharia (2013)	✓							✓				
2014	Amorim et al. (2014)	✓								✓			
	Seyedho sseini and Ghoreyshi (2014)	✓											✓
	Zhang and Chen (2014)	✓							✓				
	Rong and Sha (2014)	✓							✓				
	Agustina et al. (2014)	✓									✓		

Table 1. (Continued)

Year	Authors	Objective Function							Optimization Methods				
		Min TCD	Min FC	Max TLCS	Min TTD	Max FSDP	Max P	Min TDT	Metaheuristic	Heuristic	Exact	Simulation	Hybridization
2015	P. Li et al. (2015)	✓							✓				
	Seyedhosseini and Ghoreyshi (2015)	✓									✓		
	Adarme-Jaimes and Orjuela-Castro (2015)	✓										✓	
	Belo-Filho et al. (2015)	✓								✓			
	Zheng (2015)	✓							✓				
2016	Song and Ko (2016)			✓						✓			
	Rabbani et al. (2016)	✓							✓				
	Diabat et al. (2016)	✓								✓			
	Nair et al. (2016)	✓									✓		
	Bortolini et al. (2016)	✓									✓		

(Continued)

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Table 1. (Continued)

Year	Authors	Objective Function								Optimization Methods				
		Min TCD	Min FC	Max TLCS	Min TTD	Max FSDP	Max P	Min TDT	Metaheuristic	Heuristic	Exact	Simulation	Hybridization
2017	Tirkolaee et al. (2017) [8]				∨						∨		
	Ma et al. (2017)						∨						∨
	Haerani et al. (2017)	∨							∨				
	Komijan and Delavari (2017)	∨									∨		
	Devapriya et al. (2017) [36]	∨									∨		
	Marandi and Zegordi (2017)	∨							∨				

(Continued)

Table 1. (Continued)

Year	Authors	Objective Function							Optimization Methods				
		Min TCD	Min FC	Max TLCS	Min TTD	Max FSDP	Max P	Min TDT	Metahe uristic	Heuristic	Exact	Simula tion	Hybridi zation
2018	Lacomme et al. (2018)[13]	✓											✓
	Noguera et al. (2018)					✓							✓
	Salam et al. (2018)	✓							✓				
	Nadhori and Ahsan (2018)[18]	✓								✓			
	Patidar et al. (2018)	✓							✓				
2019	Lin et al. (2019)	✓											✓
	Chen et al. (2019)	✓							✓				
	Meneghetti and Ceschia (2019)		✓								✓		
	Y. Wang et al. (2019)[13]	✓							✓				
2020	Tirkolaee et al. (2020)	✓									✓		

maximize the expected total profits, integrated production, and route decisions by considering time windows. Moreover, the Neighborhood Search (NS) procedure has been used by Amorim et al. (2014), and Belo-Filho et al. (2015) to suppress the total cost distribution. To maximize the total level of customer satisfaction, Song and Ko (2016) implemented the Priority-based Heuristic Algorithm. Another emerging idea was that the *Tabu* search algorithm had been used by Diabat et al. (2016) and Nadhori and Ahsan (2018) to minimize the total cost distribution.

3.2.2. Metaheuristics

As mentioned in the previous section, the VRPfPG is an NP-hard combinatorial problem. Researchers have also used some metaheuristics algorithms for optimizing the single-objective VRPfPG problem. The first metaheuristics algorithm in the VRPfPG was proposed by Tarantilis and Kiranoudis (2001). They suggested the Backtracking Adaptive Threshold Accepting for reducing the total traveled distance. Moreover, Xunyu and Tomohiro (2010) were the first to propose the Genetic Algorithm (GA) to solve the VRPfPG. The GA was used to minimize the distribution cost by considering the time window. The GA has also been exercised by Tunjongsirigul and Pongchairerks (2010), Keskinturk and Yildirim (2011), Abraham et al. (2012), Zhang and Chen (2014), Rong and Sha (2014), P. Li et al. (2015), and Salam et al. (2018) to reduce the cost of delivery. Meanwhile, Zheng (2015) improved the GA for minimizing the total transportation cost, and Rabbani et al. (2016) utilized the GA to decrease the total cost delivery by considering multi-middle depots. The GA was studied by Haerani et al. (2017) to optimize multiple depots VRPfPG problems. They used the objective function to reduce the delivery cost, while Patidar et al. (2018) implemented the GA to minimize the total cost distribution by considering sustainable aspects.

A differential evolution-artificial bee colony algorithm was suggested by L. Li et al. (2013) for decreasing transportation costs. Meanwhile, Shukla and Jharkharia (2013) used an Artificial Immune System to reduce the total cost delivery with time window constraints. In addition, the Particle Swarm Optimization (PSO) was considered to minimize the total cost distribution by considering production decisions (Lu & Wang, 2017). Recently, Chen et al. (2019) proposed the Improved Ant Colony Optimization (ACO) Algorithm Based on *Tabu* Search (TS) algorithm to perform similar distribution costs cut out. Furthermore, the sophisticated whale optimization algorithm was also performed by Y. Wang et al. (2019) for minimizing the total cost distribution.

3.2.3. Exact methods

In 2014–2020, several researchers used the exact method to solve the VRPfPG problem. Agustina et al. (2014) developed the model to solve the VRPfPG problem with a cross-docking using Mixed-Integer Linear Programming (MILP). They implemented it to minimize the total cost distribution. MILP was also used by Seyedhosseini and Ghoreyshi (2015), who integrated production decisions to minimize the total cost distribution. The VRPfPG problems with pick-up and delivery were proposed by Nair et al. (2016) using MILP to minimize the total cost distribution.

Bortolini et al. (2016) developed a MILP model to minimize the total cost of delivery by considering the distribution cost, delivery time, and carbon footprint cost. Meanwhile, Tirkolaee et al. (2017) found a similar MILP model for multi-trip with intermediate depots and time windows that reduced the total traveled distance. To solve multi-period, multi-perishable product systems with time windows, Komijan and Delavari (2017) offered a MILP model. Devapriya et al. (2017) generated the MILP to decrease the total cost distribution by considering production decisions. Recently, Meneghetti and Ceschia (2019) also implemented the MILP model for reducing fuel consumption. In the following year, Tirkolaee et al. (2020) also constructed the MILP model for minimizing the total cost distribution by considering several environmental aspects.

3.2.4. Hybridizations and simulation

In this section, five papers on the Hybridizations method, and one paper on the simulation method were examined. Seyedhosseini and Ghoreyshi (2014) used a Linear Programming Model and PSO to

minimize the total cost distribution. Meanwhile, Ma et al. (2017) developed the Ant colony algorithm-neighborhood hybrid algorithm to solve combined order selection and time-dependent problems with time windows. They suggested the objective function of maximizing profit. Greedy Randomized Adaptive Search Procedure (GRASP) algorithm-neighborhood search developed by Lacomme et al. (2018) was exemplified for minimizing the total cost distribution. In addition, Noguera et al. (2018) engineered the PSO-TS algorithm to maximize the freshness state of the delivered products, while recently, Lin et al. (2019) integrated GA-TS to minimize the total cost distribution. Meanwhile, Adarme-Jaimes and Orjuela-Castro (2015) were the only researchers who proposed the *Monte Carlo* simulation to minimize the total cost distribution.

Some researchers also compared hybridization procedures with classic heuristic and metaheuristic procedures. Some hybridization procedures proposed by the researchers resulted in more efficient solutions compared to classic heuristic and standard metaheuristic procedures.

3.3. Multi objectives VRPfPG
In the VRPfPG problem, some researchers consider multi-objective to optimize problem-solving. Seventeen articles (28%) of the total papers collected are multi-objective issues. One instance of an objective function in the case of multi-objectives is to minimize the total cost distribution and maximize the freshness of the state of the delivered products. In this paper, a few issues consider multi-objective on the VRPfPG problem. Seventeen papers collected can be seen in Table 2.

3.3.1. Metaheuristics
In the multi-objective problem, Gong and Fu (2010) were the first researchers to propose metaheuristic procedures to solve the VRPfPG problem. They argued that an ACO algorithm was able minimize the total cost distribution and maximize the freshness of the delivered products. To minimize the total cost distribution and the total cost of environmental impact, the PSO algorithm was implemented by Govindan et al. (2014). They considered two-echelon multiple-vehicles with time windows and sustainable aspects. Meanwhile, Amorim and Almada-Lobo (2014) proposed an evolutionary algorithm to minimize the total cost distribution and maximize the freshness of the state of the delivered products. The problem to minimize the total cost of transportation and increase the freshness of the state of the delivered products was proposed by Khalili-Damghani et al. (2015) using the GA.

Meanwhile, Kuo and Nugroho (2017) solved the problem of multi-objective balance cargo with time windows and time-dependent using the Gradient Evolution (GE) algorithm. The problem of multi-commodities for minimizing the total cost distribution and reducing the weighted deterioration ratio was pinpointed by Lu and Wang (2017). They used Improved Harmony Search to optimize the problem.

Recently, Sahraeian and Esmaeili (2018) proposed the GA to reduce the total cost of distribution and reduce the total cost of environmental impact on a two-echelon capacitated vehicle routing problem. Some sophisticated metaheuristic algorithms have also been offered in the multi-objective problems. A biogeography-based optimization algorithm was suggested by Fatemi Ghomi and Asgarian (2019) to overcome the high cost of distribution and product freshness issues. The problem also involved lost sale products in the case. Furthermore, to minimize the total cost distribution and maximize the freshness of the state of the delivered products considering decaying factors, S. Li et al. (2019b) claimed that the use of ACO was useful in solving this problem. Even the GE algorithm was implemented by Zulvia et al. (2020) to solve four objective functions at once. These objective functions were minimizing the total cost distribution, reducing the total cost of environmental impact, maximizing the total level of customer satisfaction, and minimizing the damage. Their research is classified as the green VRPfPG with time windows and time dependencies.

3.3.2. Heuristics, exact, and hybridization
This section described several multi-objective studies on the classification of heuristic, exact, and hybridization optimization solutions. In the heuristics optimization solution, Esmaili and Sahraeian

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Table 2. Reviewed papers about multi-objective VRPFPG

Year	Author	Objective Function											Optimization Methods			
		BL	Min TCD	Min FC	Min TCEI	Max TLCS	Min TTD	Max FSDP	Min CWT	Min D	Min TDT	Min WDR	Metahe uristic	Heuri stic	Exact	Hybridi zation
2010	Gong and Fu (2010)		✓					✓					✓			
2014	Govin dan et al. (2014)		✓		✓								✓			
	Amorim and Almada-Lobo (2014)		✓					✓					✓			
2015	Khalili-Damgh ani et al. (2015)		✓					✓					✓			
2016	Wang et al. (2016)		✓					✓								✓
2017	Esmaili and Sahrae ian (2017)		✓						✓					✓		
	Kuo and Nug roho (2017)	✓	✓										✓			
	Lu and Wang (2017)		✓									✓	✓			

(Continued)

Table 2. (Continued)

Year	Author	Objective Function											Optimization Methods			
		BL	Min TCD	Min FC	Min TCEI	Max TLCS	Min TTD	Max FSDP	Min CWT	Min D	Min TDT	Min WDR	Metaheuristic	Heuristic	Exact	Hybridization
2018	Buelvas Padilla et al. (2018)						✓			✓				✓		
	Sahraeian and Esmaeili (2018) [8]		✓		✓								✓			
	Wang et al. (2018)		✓	✓		✓		✓								✓
	Navazi et al. (2018)		✓		✓			✓						✓		
2019	Rahbari et al. (2019)		✓					✓					✓		✓	
	Fatemi Ghomi and Asgarian (2019)		✓					✓								
	S. Li et al. (2019b) [23]		✓		✓	✓		✓					✓			
	P. Li et al. (2019a)		✓								✓				✓	
2020	(Zulvia et al. (2020))		✓		✓	✓				✓			✓			

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(2017) implemented a mathematical model based on a simple additive weighting method for minimizing the total cost distribution and minimizing the total customer's waiting time. Pareto front heuristic was studied by Buelvas Padilla et al. (2018). This algorithm considered road conditions for minimizing the total traveled distance and minimizing the damage. A new algorithm based on the Torabi-Hassini method was proposed by Navazi et al. (2018) to reduce the total cost distribution, limit the fuel consumption, minimize the total cost of environmental impact, and maximize the total level of customer satisfaction.

In the exact optimization solution, Rahbari et al. (2019) developed the MILP model to minimize the total cost distribution and maximize the freshness of the state of the delivered products. They considered cross-docking under uncertainty. The MILP model was also developed by P. Li et al. (2019a) for minimizing the total cost distribution and minimizing the total distribution time. They solved the problem of capacitated routing problems for multiple commodities. In the hybridization optimization solution, Wang et al. (2016) considered the temporal-spatial distance to minimize the total cost distribution and maximize the freshness of the state of the delivered products. Wang et al. (2018) used GA to minimize the total cost distribution and maximize the freshness of the state of the delivered products by considering mixed time windows.

3.4. Analysis and future research

3.4.1. Analysis

Based on Figure 4, There was an increasing trend in the growing interest in the VRPfPG problem. Figure 5 shows the distribution of papers by country based on the first author's affiliation account. It illustrates that the popularity of this topic is spreading in several countries. Based on the review, Figure 6 shows the classification of the optimization methods for the VRPfPGin the single-objective problem. It is clear from this figure that a huge of researchers use metaheuristic procedures to solve VFPfPG on single-objective problems. However, measly researchers use a simulation approach. 45.3% (19 papers) used a metaheuristic approach to resolve this problem. Nine papers (21.4%) implemented the exact approach, and eight papers (19%) used a heuristic approach. The hybridization approach (heuristic-metaheuristics and exact-metaheuristics) is five papers (11.9%). Only one researcher implemented a simulation approach (2.4%). In the multi-objectives problem, the paper distribution based on the classification of optimization methods can be seen in Figure 7. From the figure, it can be seen that the metaheuristic procedure is a popular procedure used by researchers. Metaheuristics procedure was the most popular procedure used for problem-solving. Researchers used 58.8% (10 papers) of the total multi-objective papers. The exact, heuristic and hybridization procedures did not attract the attention of most of the researchers.

Optimization methods distribution of single-objective problems based on year of publication can be seen in Figure 8. From this data, we can see that the heuristic method was a popular method

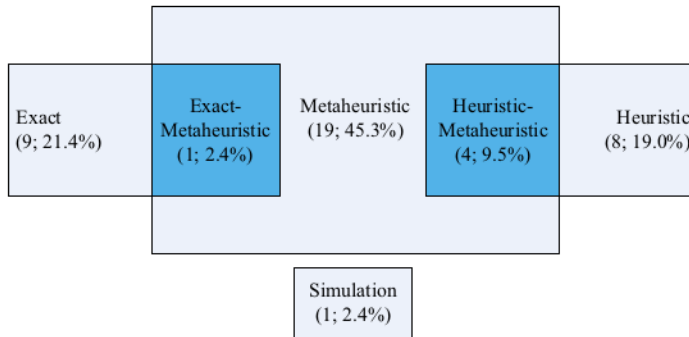**Figure 6. Paper distribution on the single-objective based on the classification of optimization methods.**

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Figure 7. Paper distribution on the multi-objective based on classification of optimization methods.
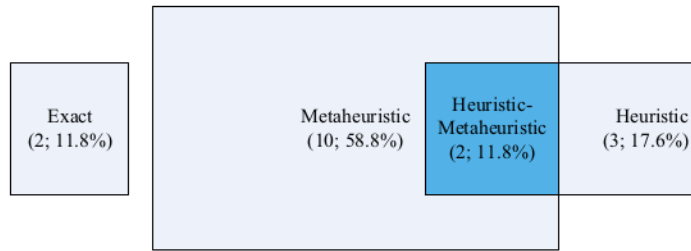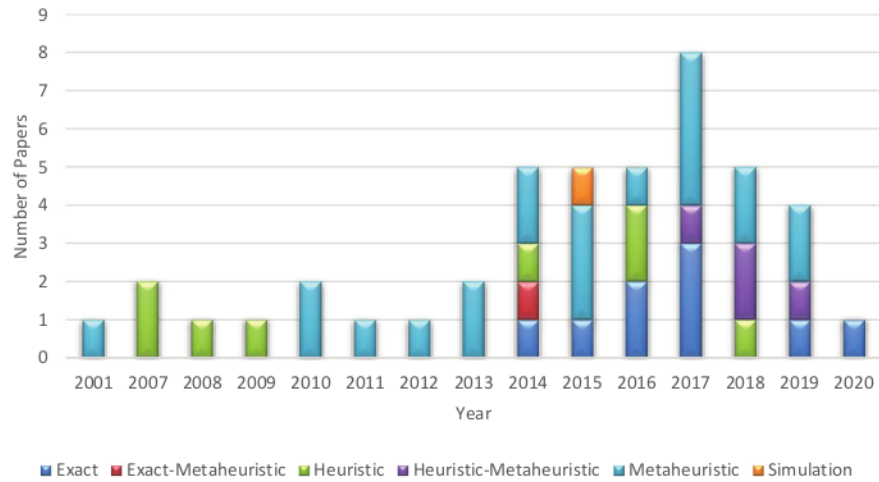

Figure 8. Optimization methods distribution of single-objective problem based on year of publication.

used in 2007–2009. Currently, the metaheuristic method is increasingly popular to solve single-objective problems, and increased interest has occurred from 2013-present. Researchers also combine heuristic-metaheuristic methods to solve problems. It was carried out in 2017–2019. The exact method is also of interest to researchers even though it requires a significant time to solve the problem. Unfortunately, the simulation method is less attractive to researchers. Figure 9 shows the optimization methods distribution of multi-objective problems based on the year of publication. As in the single-objective problem, the metaheuristic method has been improving since 2013-present.

In a single-objective problem, GA was the most popular algorithm used by the researchers. Twelve papers implemented GA to optimize the VRPfPG. The second position was NS with six papers. This approach is broadly used due to its practicality by merely swapping neighboring positions. The objective function for the single-objective problem is shown a pie chart in Figure 10. The results show that thirty-four papers (82%) applied the Minimized-Total Cost Distribution (Min-TCD) objective function. The purpose of the researchers in using this objective function is that it is easy to apply and serves a significant factor in the distribution. Unfortunately, the research for maximizing the total level of customer satisfaction, minimizing fuel consumption, maximizing the freshness state of the delivered products, and minimizing the total distribution time received less attention from researchers. Each of them was only found in 1 paper.

In a multi-objective problem, four (4) papers utilized GA to optimize the VRPfPG. GA is widely used as this approach is the first metaheuristic approach popularly employed in many studies. GA has the main framework, such as mutation and crossover. The next metaheuristic approach

Figure 9. Optimization methods distribution of multi-objective problem based on year of publication.
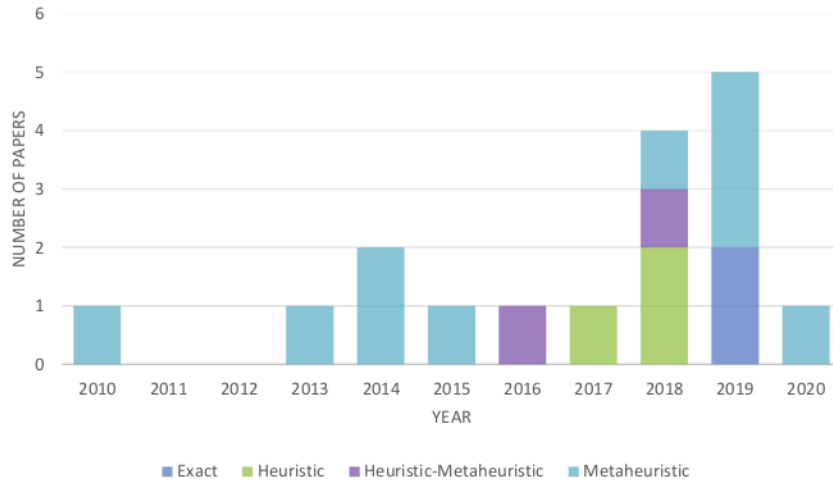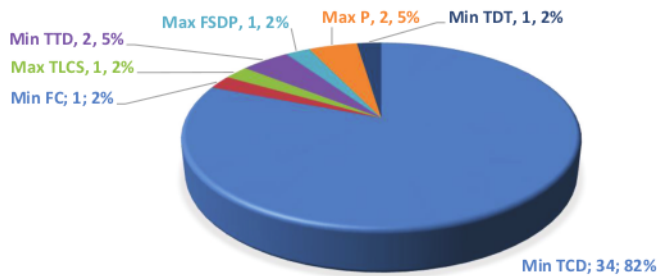

Figure 10. The pie chart of the objective functions in the single-objective VRPfPG.

is ACO, which is used by researchers to solve two VRPfPG problems. Furthermore, the objective function of the multi-objective problem is presented in Figure 11. The paper observation results indicate that sixteen papers utilized the Minimized-Total Cost Distribution objective function. The researchers argued that this objective function is selected as it is practical, and at the same time, plays a significant factor in the distribution of goods. Another popular objective function was maximizing the freshness state of the delivered products. The objective function was to maximize the freshness of the products being sent. This objective function is essential as the products dispatched are classified as perishable goods. Bi-objective for minimizing the total cost distribution and maximizing the freshness of the state of the delivered is a famous problem studied. Eight articles have been studied in this objective function. However, the problems of balancing the load in each vehicle, minimizing fuel consumption, minimizing the total distribution time, minimizing the total customers' waiting time, minimizing the total traveled distance, and minimizing the weighted deterioration ratio have received very little attention from researchers.

In the VRPfPG research, there is an increase in research interest in this issue (Figure 4). Meanwhile, a comparison of the number of publications each year for single and multi-objective problems can be observed in Figure 12. For the past six years (2014- March 2020), the publication of single-objective problems displays quite stagnant data. However, the publication of multi-objective issues has increased significantly. These results pinpoint that the multi-objective problem research trend is more popular than the single-objective problem.

Figure 11. Pie chart of the objective function for the multi-objective VRPfPG.

Min D, 2, 5% Min TDT, 1, 3% Min WDR, 1, 3% BL, 1, 2%
Min CWT, 1, 3%
Max FSDP, 8, 21%
Min TCD, 16, 42%
Min TTD, 1, 3%
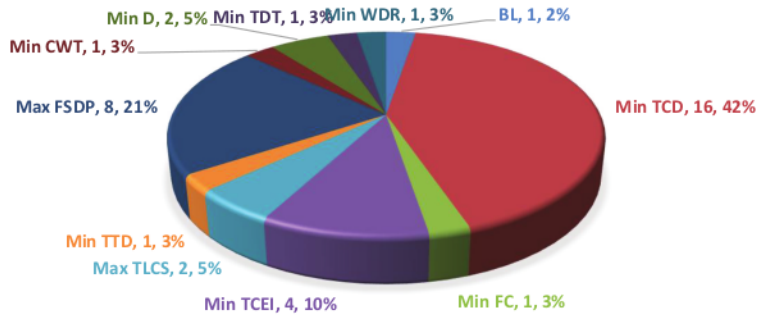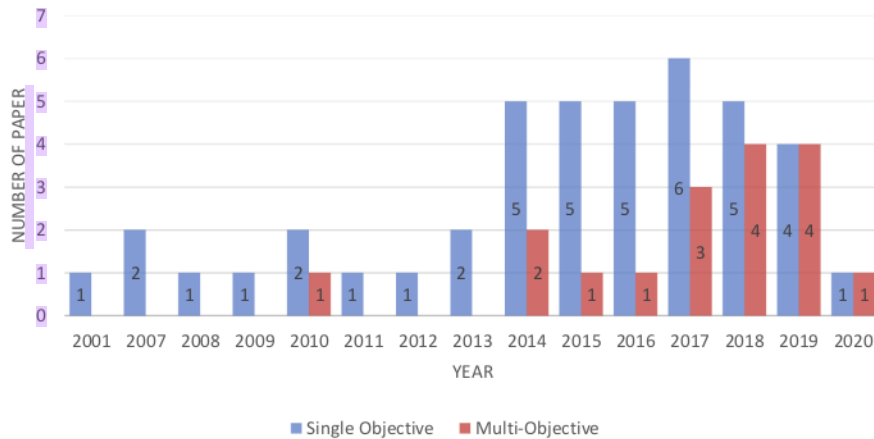Max TLCS, 2, 5%
Min TCEI, 4, 10%
Min FC, 1, 3%

Figure 12. Distribution of single and multi-objective functions based on year of publication.

Many researchers used heuristic and metaheuristic functions to solve the VRPfPG. These procedures were selected because they can produce better results with a relatively short computational time. Some researchers implemented an exact procedure to solve the VRPfPG, as this procedure has gained optimal results. However, it requires a relatively large amount of computing time. Therefore, as an NP-hard problem, researchers claim that metaheuristic and heuristic approaches are beneficial for VRPfPG problems. Advanced heuristic and metaheuristic algorithms are useful for optimizing VRPfPG problems.

3.4.2. Future research

Based on the analysis of figures and tables in the previous subsection, some insights and research directions are described as follows:

Only 17 of 59 publications address multi-objective problems. However, on single-objective problems, 42 papers have been published. Therefore, future research needs to focus on multi-objective problems considering that this problem has been developing rapidly in the last five years. 59 Published papers focus on developing new VRPfPG models and solution methods for real-world applications. In addition, the majority of VRPfPG research is aimed at pure investigations, not applications. Several other studies have concentrated on developing new algorithms and the performance of their procedures. Therefore, several applications of VRPfPG problems need to be investigated in the fields of food, fruit, vegetable products (agricultural products), and agroindustry.

In a single-objective problem, most VRPfPG problems are acquainted with minimizing the total cost distribution objective function. On the other hand, very few papers are used to investigate nontraditional goals in a single-objective problem such as the objective function of maximizing the freshness of the state of the delivered products, reducing the total cost of environmental impact, as well as minimizing the damage of the delivered products. Therefore, this study proposes that future researchers should focus on developing optimization for the nontraditional objectives in a single-objective problem such as the objective function of maximizing the freshness of the state of the delivered products, minimizing the damage of the delivered products, as well as reducing the total cost of environmental impact.

Very few published articles investigated multi-objective problems. One significant problem in multi-objectives is the Bi-objective of minimizing the total cost distribution and maximizing the freshness of the state of the delivered products. A clear gap occurred in this study, as many other objective functions have industrial relevance. In the multi-objective problems, which means that the objective function considers several criteria, the number of the reviewed papers was found to be inadequate. Therefore, this study proposes that future researchers focus on broadening the observation of optimization methods for multi-objective papers. Future researchers also need to consider more than two objectives to optimize the objective function (e.g., minimizing the total cost distribution, maximizing the freshness of the state of the delivered products, minimizing the total cost of environmental impact, and minimizing the damage). Such investigations are implemented to find non-dominant solutions. Furthermore, with the current trend, aspects of sustainability need to be considered. Lastly, the gap in this study can be bridged by proposing an efficient and effective solution for multi-objective problems.

Moreover, in the single objective and multi-objective problem, realistic complex VRPG issues need to be considered for future research because it has not been considered in previous research. Some additional obstacles are urged to be investigated, such as the pick-up and delivery processes, time windows, and dynamic vehicle speeds for the VRPfPG problems. In addition, some features that are not and are less considered in VRPfPG problems include variations in vehicle speed and variations in demand. Generally, the problems investigated use the assumption of deterministic and constant vehicle speed and demand. However, this assumption is sometimes unrealistic to real problems. There is only 1 study that used simulation, taking into account uncertainty. Future studies can develop a VRPfPG model that is appropriate by considering variations in vehicle speed and variations in demand, even considering uncertainty vehicle speed and demand.

One of the complex problems in the field of logistics distribution is determining the optimal vehicle route. Early VRPfPG studies focused on proposing efficient algorithms. With the development of computer technology, many researchers preferred heuristic and metaheuristic procedures as the VRPfPG was classified as an NP-Hard problem. 45.3 % (nineteen papers) used the metaheuristic in the single-objective problem, and 58.8 % (ten papers) utilized the metaheuristic in the multi-objective problem-solving. Some widely-used algorithms, including the GA, ACO, and PSO, were exercised as well. Furthermore, Neighborhood Search (NS) is considered as a popular heuristic procedure used by researchers. Currently, very few advanced metaheuristics algorithms used to solve the VRPfPG problem. Only one paper proposes an advanced algorithm using a whale optimization algorithm to minimize total distribution cost (Y. Wang et al., 2019). Therefore, we suggest developing advanced metaheuristic algorithms to solve this problem. Moreover, a few heuristics algorithms and hybridization procedures are proposed, as their effectiveness has been well-proven. It should be noted that some heuristic and hybridization of heuristic-metaheuristic procedures can also be developed to solve VRPfPG problems. Additionally, we did not find any VRPfPG studies comparing the performance of the algorithms. Therefore, there is potential for research comparing algorithm performance.

On the other hand, in the exact method, MILP is a popular procedure for single and multi-objective problems. In single-objective problems, research generally uses the objective function of minimizing the total cost of distribution. There is an opportunity for further research to examine the objective function to maximize the total level of customer satisfaction, reducing fuel consumption, maximizing the freshness state of the delivered products, and minimizing the total distribution time received less attention from researchers. In multi-objective problems, previous research generally used two objective functions. There is a research gap that uses the objective function for more than two purposes. Therefore, in further investigation, it is necessary to study using > 2 objective functions in decision making.

4. Conclusion

In the Logistics system, determining the optimal route for transporting products to customers is one of the main functions. This paper focused on reviewing the optimization method and objective function from the VRPfPG problem based on single and multi-objective problems. This study presented a complete analysis of the scientific literature of the VRPfPG problem. This article successfully classified optimization methods based on a heuristic, metaheuristic, exact, hybridization, and simulation methods. In developing the VRPfPG model, researchers ignore realistic assumptions on real problems. By considering realistic assumptions, future research will produce a model for VRPfPG solutions that is more practical to apply. Some of the assumptions that need to be considered are varying vehicle speeds and uncertain demand.

Detailed insights and research directions can be found in future research in section 3. This review shows that the metaheuristic algorithm is the most widely used algorithm for solving VRPfPG. This procedure has flexibility in finding solutions to NP-Hard problems. In single and multi-objective problems, some popular metaheuristic algorithms of the VRPfPG were introduced, including GA and ACO, and several integrated procedures heuristics-metaheuristics were also suggested. Further research is expected to develop advanced metaheuristic algorithms that are proven to be useful for the single and multi-objective problems in the VRPfPG problem. Future research needs to conduct a more in-depth investigation to compare the performance of the metaheuristic algorithm.

In a single-objective, minimizing distribution costs was most of the papers about the VRPfPG implemented the objective function. Minimizing the total cost distribution and maximizing the freshness of the state of the delivered products were a significant problem in multi-objective problems. This study suggests focusing on developing objective function for a nontraditional in a single-objective problem. Meanwhile, in a multi-objective problem, future work needs to consider more than two objectives to optimize the objective function simultaneously. Aspect sustainability, including carbon emission and consumption energy, can be explored in the VRPfPG problem because it came to the attention of the world.

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