Application of Genetic Algorithms to Optimize Distribution in Food Transport Companies: A Systematic Literature Review

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Abstract

The article applies genetic algorithms as a tool of artificial intelligence that provides optimal solutions to the problem of vehicle routing in the distribution chain by transport companies. The main problem in the food sector is transporting perishable goods with low life expectancy. The methodology used for the present work was a systematic literature review focused on applying genetic algorithms in transport companies. To achieve this goal, a massive search was made in Scopus, Web of Science, and Proquest databases. A total of 60 articles were compiled for this document. For the study of the extracted articles, they were categorized into three factors: total costs in distribution, profitability, and delivery times. For the findings section, the use of Vosviewer software was used. The use of this software allowed us to demonstrate that genetic algorithms would have a positive influence on each of the factors mentioned.

Keywords
Genetic Algorithm, Vehicle Routing Problem, Optimization, Routing

1. Introduction
This article focuses on analyzing and applying the algorithm in supply chain management. Likewise, it has become an indispensable resource for the optimization of distribution routes to the final customer, as a consequence of which the increase in profitability in transport companies has been highlighted, especially in the food sector, in recent years. According to the Food and Agriculture Organization of the United Nations (FAO 2021), they highlight "Solutions to stop food loss and waste include: good data to know where in the value chain the main food loss and waste hotspots; apply innovation, for example, e-commerce platforms for merchandising or mobile shrink-wrap food processing systems; government incentives to strengthen private sector action against food loss and waste and collaboration in supply chains; investments in training, technology, and innovation, even for small producers."

Distribution is directly linked to the transportation sector, which assumes an important role in the flow of products from a distributor supply chain. But activities such as the distribution of perishable foods are often very limited by the life expectancy of the products and the possibility that they are affected on the way to the final customer. This is due to the distance between the distributor and the last customer, which cause high transportation costs and risk to the quality of the distributed merchandise, especially when transporting perishable products (Haerani et al. 2017). This is how the efficiency of distribution networks in a logistics system will determine the speed of response to rapid changes in market demands in this era of economic globalization, worldwide supply, and mass customization (Wang & Lu 2009). The vehicle routing problem (VRP) must be addressed to achieve this efficiency. Tasan and Gen (2012) describe delivering goods to customers with known demands through vehicle routes that begin and end in the deposit with a minimum cost. For this (Ting & Liao 2013; Derbel et al. 2012) agree that the objective of efficiency should be focused on finding the shortest route and providing an efficient service in such a way that the requirement of each client can be satisfied. It is on time and within the capacity and travel time of the vehicles. The approach to obtaining the best approximate solution is essential for efficiency in logistics activity, environmental conservation, and energy savings (Okude & Taniguchi 2014).

The vehicle routing problem (VRP) is, mathematically, a combinatorial optimization problem (Wang & Lu 2009). The problem is complex and highly restricted, as it involves many different and interconnected decisions (service

options, facility location, and two levels of vehicle routing) (Zhou et al. 2018). High-performance approximate solution methods that can change the delivery schedule quickly are required, in addition to obtaining a more accurate approximate solution that considers travel time fluctuation (Okude & Taniguchi 2014). The problem is of interest due to its theoretical complexity and important applications in industry (Liu et al., 2013). VRP models are applied in a wide area of transport and distribution, such as the transport of people and goods, transport service, and waste collection (Mohammed et al. 2017).

1.1 Objectives

This document aims to give a greater scope of the application of genetic algorithms in different countries and future research through the application of this algorithm in transport companies. For this, the following research question is formulated: How can genetic algorithms contribute to optimizing distribution in transport companies?

2. Methods

The methodology in the present investigation is oriented to a systematic literature review using genetic algorithms and supply chain management. The main reason why this methodology is being worked on is due to the vehicle routing problem that various transport companies are going through in the distribution. Transport companies still need detailed information on the application of this resource and the positive results that can be obtained by applying this technology, focused on the food sector. The following figure will describe the process of the applied methodology.

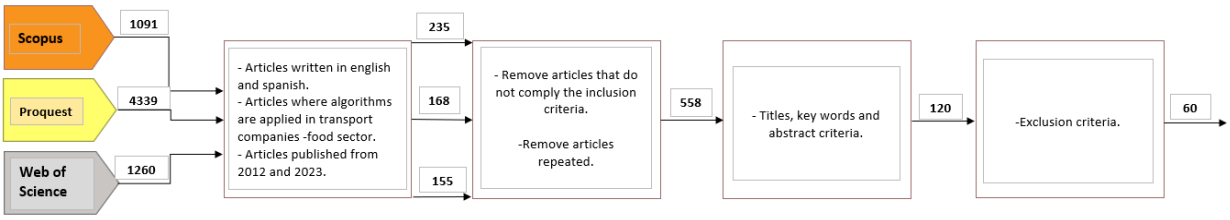

Figure 1. Systematic mapping sequence

The first stage of the process was to find various sources of research related to the application of algorithms in transport companies, which used three search criteria to obtain the greatest amount of information; the search criteria used and that were applied in the databases will be mentioned in detail in Table 1.

In the second stage of the process, certain databases were used to search for research sources; among the most prominent were: Scopus, Proquest, and Web of Science. Likewise, it was possible to extract a total of 6690 results; however, when applying the inclusion criteria: articles in English and Spanish, articles involved in the transport companies-food sector, articles published between the years 2012-2023, articles where evidence of the use of genetic algorithms, articles that are repeated in the three databases used, after having applied the inclusion criteria and the exclusion criteria detailed in Table 2, a total of 60 articles were obtained, and they are directly related to the three factors that were segmented as follows for the present investigation: Components of the supply chain of the food sector, technological resources and alignments in the final distribution.

Table 1. Search Criteria

N°	Search Criteria
1	("genetic algorithm" AND "vehicle routing problem") OR ("genetic algorithm" AND "optimization") OR ("genetic algorithm" AND "routing")
2	("vehicle routing problem" AND "optimization" AND "routing")
3	("genetic algorithm" AND "routing problem" AND “food sector”)

Table 2. Exclusion criteria

N°	Exclusion criteria
1	Articles that do not show the use of genetic algorithms for route optimization.
2	Articles that need to provide solutions to the problem of vehicle routing.
3	Articles that do not show the use of genetic algorithms in transport companies.

The following paragraphs will detail the description of the factors that were taken into consideration for this investigation.

Components of the supply chain of the food sector
The factor considers the life expectancy of perishable products in last-mile logistics and supply chain management; among the main elements, we have inventory control, profitability, and delivery time management. Inventory control is based on registering and differentiating perishable and non-perishable products. As perishable products have a short expiration date and the environmental risks they entail, they are managed as first deliveries in distribution. Profitability has become a requirement in companies in the food sector because transporting perishable products and the possibility of them suffering physical damage and decomposition results in large losses that the companies assume; therefore, they choose to apply new technologies to reduce losses and optimize resources. Finally, transport companies use time windows for distribution in managing delivery times, which the end customer establishes. Conversely, evaluating if companies in other sectors handle the same delivery flow is necessary. by time windows to provide the user with an excellent shopping experience.

Technological resources
The following factor was considered because it is essential to understand the use of technological resources in supply chain management and how the genetic algorithm is developed and influenced in route optimization. Next, the three dimensions considered will be explained: Artificial Intelligence, Environmental Management, and Last Mile Logistics. The first item is related to applying genetic algorithms as the main tool to address the vehicle routing problem (VRP) that allows companies to optimize their distribution process. The second item is involved in determining the positive consequences after the implementation of the new technologies in the final distribution, which leads to the reduction of the fleet of vehicles for each organization for the final distribution, reduction of maintenance costs, and reduction of the use of fuel (gasoline, oil), as a whole, bring benefits to the environment. Finally, last-mile logistics is the last step in the distribution to the end customer because by applying genetic algorithms and transporting perishable products, the rate of return or replacement of merchandise is considerably reduced, and the rate of complaints is reduced. by users (end customers) by not receiving their products in optimal conditions and reducing delivery times (time windows).

Alignments in the final distribution
This factor describes the alignments in the final distribution in supply chain management, which is divided into three dimensions: business economic resources, the final application of the genetic algorithm, and efficiency in logistics activity. The first item is the primary mechanism and investment that transportation companies should consider when implementing new technologies (genetic algorithms) in their lines and acquiring new warehouses and vehicle equipment. As a second item, we have the management of the implementation, positive results, and the influence when applying genetic algorithms for the distribution to the final client. As a last item, it is worth highlighting the efficiency in the logistics activity, which is of vital importance because it is possible to reflect in the result a reduction in the total distance traveled and an increase in profitability, reduction of distribution costs, inventory, and maintenance, reduction in distribution delivery time, reduction in the number of vehicles used.

3. Findings
Next, the list of journals with the greatest scope in the present investigation will be shown. According to the search carried out in the SCImago Journal Rank (SJR), the International Journal of Production Economics obtained a score of 3.03, located in the highest rank quartile (Q1); the Hirsch index received by the journal above addresses the amount

of 214 and the average number of citations obtained in the last four years was 13,176, which is interpreted as the journal achieving a high average number of citations per article published between 2019 and 2022.

Table 3. Highest impact journals included in the article

N°	Journal	SJR	Best quartile	H-index	Cites / Doc. (4 years)
1	International Journal of Production Economics	3.03	Q1	214	13.176
2	Journal of Manufacturing Systems	2.74	Q1	92	14.036
3	Journal of Manufacturing Systems	2.74	Q1	92	14.036
4	Journal of Industrial Information Integration	2.72	Q1	42	17.41
5	European Journal of Operational Research	2.37	Q1	288	7.481
6	Journal of Cleaner Production	1.98	Q1	268	12.385
7	Applied Soft Computing Journal	1.88	Q1	171	9.842
8	Expert Systems with Applications	1.87	Q1	249	10.497
9	Computers and Industrial Engineering	1.76	Q1	148	8.842
10	Computers and Operations Research	1.72	Q1	170	5.893
11	Alexandria Engineering Journal	0.93	Q1	81	7.531
12	Sustainability	0.66	Q1	136	4.649

Figures 2 and 3 show greater emphasis and search criteria for the 60 articles considered for this research.

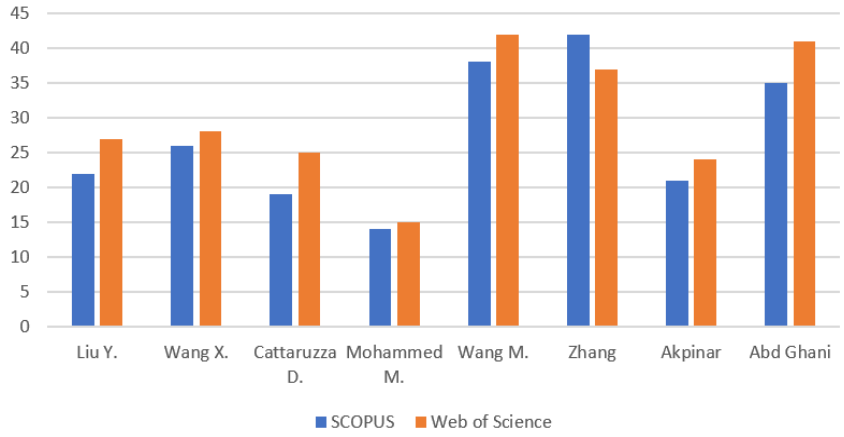

Figure 2. Several citations from authors with more presence in the databases were used.

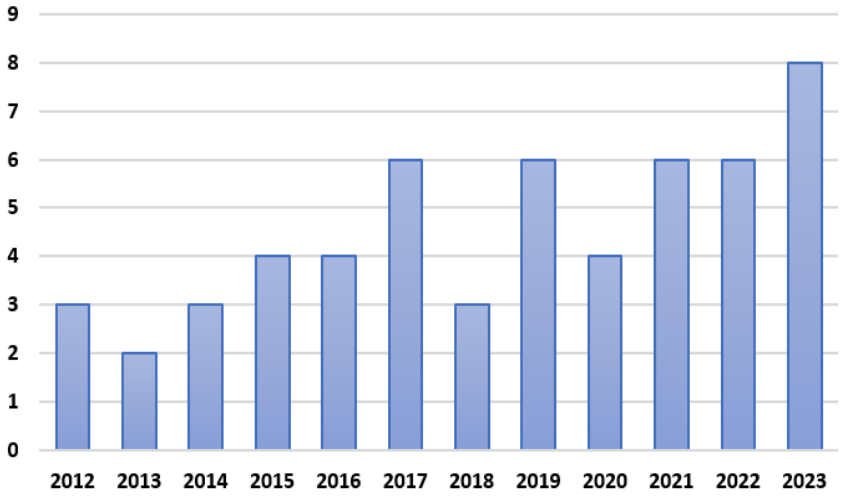

Figure 3. Articles published for each year

By applying the Vosviewer software as part of the analysis of the present investigation, we could visualize in detail the main thematic axes obtained from the 60 articles collected. First, the software used was the main tool that allowed us to get greater detail on the relationship between the thematic axes and the keywords that can be displayed in the scheme represented in Figure 4. Second, we have genetic algorithms, supply chain, and vehicle routing problems between the thematic axes most prominent. According to the scheme shown, it is concluded that the mentioned thematic axes are linked sequentially with the routing of vehicles in the distribution. Finally, the main thematic axes are related to the cost of transportation, time windows, optimization, route time, inventory control, logistics, supply chain management, inventory routing problem, sales, and location. and combinatorial optimization.

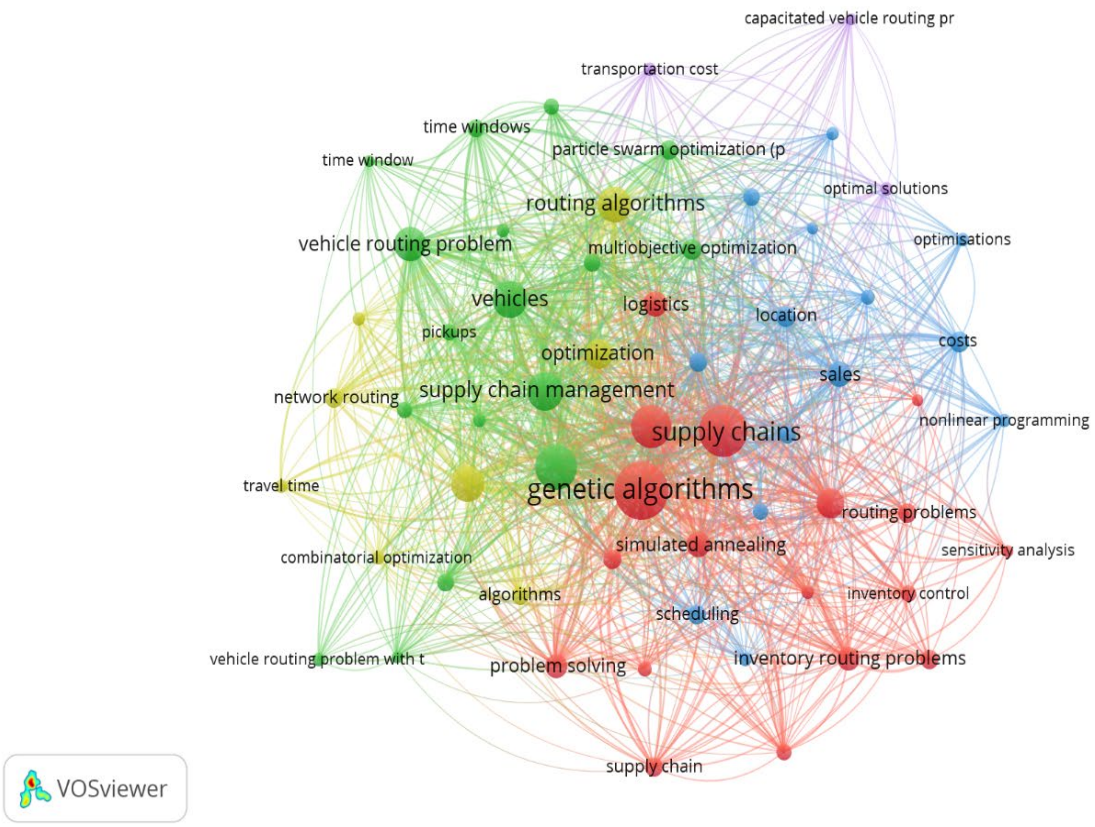

Figure 4. VosViewer for keywords

Next, the consolidated findings obtained from the bibliographic review of the 60 articles compiled for the present investigation will be detailed in Table 4. In addition, the results have been divided according to factor and dimension where the contributions of each can be viewed—author for the present study.

Table 4. Findings obtained by each author.

Factor	Dimension	Authors	Findings
Components of the supply chain of the food sector	Inventory control	(Ganji et al. 2020); (Haerani et al. 2017); (Mahmud and Haque 2019); (Zhang et al. 2013); (Zhu et al. 2023)	• Maintain safety stock. • Determine selection based on purchase history. • Reports in real-time with the VRP. • The implementation of a just-in-time inventory policy reduces time delays in and within each stage of the supply chain.
	Cost-effectiveness	(Fitriana et al. 2019); (Akpinar 2021); (Mohammed et al. 2017); (Zhou et al. 2018); (Zhang et al. 2013); (Ganji et al. 2020); (Li et al. 2023); (Miranda-Ackerman et al. 2019); (Tangour et al. 2021)	• Alignment of the warehouse, with priority given to high turnover items. • Ensure safety stock with order history. • Definition of optimal layout to reduce times. • Order planning based on customer history and preferences. • A multi-level trained joint inventory-location model will be developed, whereby a single product is distributed from a manufacturer to retailers through a set of warehouses, whose locations will be determined by the model.
	Delivery time management	(Jalalian and Defersha 2019); (Zhou et al. 2018); (Mohammed et al. 2017); (Haerani et al. 2017); (Okude and Taniguchi 2014); (Mahmud and Haque 2019) ;(Zhang et al. 2013); (Jeshvaghani et al. 2023); (Gomes et al. 2021); (Pasha et al. 2020); (Pratiwi et al. 2018); (Qiu et al. 2023)	• Reduction of the total distance traveled. • Optimal delivery planning. • Route optimization by applying genetic algorithms. • Direct contact with carriers and locations in real-time.

Factor	Dimension	Authors	Findings
Technological resources	Artificial intelligence	(Sharma and Tripathi, 2022); (He 2022); (Zhang et al. 2022); (Zhang et al. 2015)	• IoT-based systems provide an intelligent framework for making effective decisions and automating various tasks to make human life easier. • It is proposed to combine computer science to study the optimization model system and combine information management and other disciplines to develop and apply research on dynamic logistics system management software. • The concept of a comprehensive service platform is realized through RFID technology.
	Last mile logistics	(Mohammed et al. 2017); (Liu et al. 2013); (Tasan and Gen 2012); (Zhou et al. 2018); (Mahmud and Haque 2019) (Zhang 2023); (Zhang et al. 2013); (Cattaruzza et al. 2014); (Gomes et al. 2021); (Nazif and Lee 2012); (Zulvia et al. 2020)	• With the development of technology, constructing a new wireless sensor network and intelligent communication transmission system can promote further upgrading and improvement of the industry. • It is considered to reduce the order delivery time and improve customer satisfaction through optimal scheduling. • A seamless collaboration could provide faster customer responsiveness, greater flexibility to changing market conditions, improved service, customer satisfaction, and customer retention.
	Environmental management	(Wang et al. 2016); (Ganji et al. 2020); (Okude and Taniguchi 2014); (Chen et al. 2023); (Abdulaal et al. 2016); (Gomes et al. 2021); (Govindan et al. 2014); (Kumari et al. 2023); (Miranda-Ackerman et al. 2017); (Miranda-Ackerman et al. 2019); (Wang et al. 2017); (Zhu et al. 2023); (Zulvia et al. 2020)	• Reduction of the vehicle fleet. • Reduction in the use of raw material (fuel). • Companies must reduce distribution costs by minimizing the contamination generated during distribution. For the current multi-depot problem, a mixed-integer programming model is proposed in this paper to minimize all expenses incurred in the entire transportation process. • Gasoline vehicles will be replaced by electric cars to save energy and reduce carbon emissions.

Factor	Dimension	Authors	Findings
Alignments in the final distribution	Business economic resources	(Karakatic and Podgorelec 2015); (Rybickova et al. 2019); (Hou et al. 2023); (Fahimnia et al. 2012); (Diabat and Deskoores 2016); (Gomes et al. 2021); (Nazif and Lee 2012); (Rabbani et al. 2016); (Vidal et al. 2012); (Zhu et al. 2023)	• Extends the problem by entering vehicle capacity and customer demand and adding multiple depots. • The continuous location and routing problem allows the location of an infinite number of sites in a given region. • In the field of application of the distribution of fresh products, it is necessary to use vehicles capable of distribution due to their particular temperature demands. • Enterprise resource allocation involves managing warehouse storage allocations, transportation routes, and inventory management issues.
	Final application of the Genetic Algorithm	(Hiassat et al. 2017); (Utama et al. 2020); (Azadeh et al. 2017); (Ibrahim et al. 2021); (Vidal et al. 2012); (Liu et al., 2013); (Tasan and Gen 2012); (Govindan et al. 2014); (Jalalian and Defersha 2019); (XueJing and Xu 2019); (Derbel et al. 2012); (Kumari et al. 2023); (Jin et al. 2022); (Akpunar and Akpinar 2021); (Cardozo et al.2016); (Cattaruzza et al. 2014); (De Araujo et al. 2018); (Zheng 2015)	• Numerical experiments show that the hybrid algorithm improves, for all instances, the best-known solutions previously obtained by the tabu search heuristic. • The experimental results show that the developed algorithm can help decision-makers to obtain high-quality solutions compared to classical algorithms. • A new hybrid metaheuristic algorithm is proposed that is composed of the Adaptive Large Neighborhood (ALNS) and Variable Neighborhood Search (VNS) algorithms to address the Location Routing Problem (LRP) with capacity constraints.
	Efficiency in logistics activity	(Ting and Liao 2013); (Derbel et al. 2012); (Okude and Taniguchi 2014); (Liu et al. 2013); (Li et al. 2015); (XueJing and Xu 2019); (Xin et al. 2022); (Zhou et al. 2018); (Afra and Behnamian 2021); (Cui et al. 2023); (Diabat and Deskoores 2016); (Li et al. 2023); (Lin et al. 2022); (Nazif and Lee 2012); (Rybickova et al. 2019); (Wang et al. 2017); (Zheng 2015)	• The focus of the fulfillment center distribution operation is how to use the vehicle effectively and determine its most economical driving route map so that the products can be delivered to customers in the shortest possible time. • A route design is required for a fleet of depot vehicles to transport customer demands to a subset of the satellites. The second level refers to routing a fleet of cars from the satellites to serve all customers. • Due to increased competition in the market, the integration of production and distribution decisions in the supply chain leads to improvements in efficiency. Therefore, production routing models have been developed to optimize production and distribution.

4. Discussion

The proposed research question can be answered by discovering the sources collected in the present study. Our analysis of the results is based on the three factors mentioned previously in Chapter 3.

Having analyzed the information on the components of the supply chain of the food sector, there is a deficit in the collection of data; in this way, it is essential to apply new technologies as part of Industry 4.0 to have an optimal entry record. and departure of perishable foods. On the other hand, large companies must use their transit warehouses as the first instance for products such as dairy products, fresh meats, fruits and vegetables, desserts and pastries, sausages, and food to be consumed with a short expiration date, among others. Likewise, applying these new tools to optimize inventory control through the management of indicators allows us to give a greater visualization of which end customers most request perishable products. Finally, carry out a final mapping of the products that have obtained the greatest economic losses to implement the new management in delivery times through time windows and increase the profitability of companies in the food sector.

Having analyzed the information on technological resources, it is demonstrated that genetic algorithms are a multifunctional tool because it involves collecting a large amount of data to optimize distribution routes for the end customer. Likewise, obtaining optimal routes involves a large percentage of reduction in different aspects, such as the vehicle fleet, maintenance, and fuel costs. On the other hand, companies must focus on implementing and making an intelligent investment in their fleet of vehicles for the correct transport of perishable foods such as refrigerated vans, guaranteeing that all the merchandise transported is at room temperature and can arrive in optimum conditions to the destination. end customer beyond inconveniences or fluctuations in travel time. In this way, they would reduce the indicator for replenishment of merchandise for food that suffered physical or room temperature damage. This involves transportation companies from different sectors, such as health, manufacturing, and transportation of people, so they can implement new technologies, such as genetic algorithms, in their distribution.

Having analyzed the information on the alignments in the final distribution, the genetic algorithm contributes to the efficiency of the distribution channels in the logistics activity of supply chain management in the present economic globalization and the emergence of Industry 4.0 in the last years. In the same way, the algorithms offer a greater global reach, such as the follow-up of orders in real-time towards the final customer in the distribution. In the same way, there is a gap in the distance between the distributor and the end customer; as a solution proposal, we would focus on associating with other companies that belong to the food sector to share distribution warehouses to have more presence in the market and considerably reduce the distance traveled between the distributor and the final customer. Finally, considering the difficulties and obstacles that may arise along the way, the recruitment of highly qualified personnel for the use and application of the genetic algorithm is vital for the distribution to be carried out successfully and for companies to achieve excellent results.

Limitations and Future Research

For the present investigation, certain limitations were presented when conducting this systematic literature review. Accessing all the full-text academic articles was impossible since they were not updated in Scopus, Proquest, and Web of Science databases. The limitations that could be observed in the database were incomplete-text academic articles; this is because certain articles contain confidential data from companies that cannot be shared or that require certain registration and prior payment.

Finally, for future research, it is recommended to include the application of genetic algorithms for other sectors that require long delivery routes, last-mile logistics, and E-commerce, among others. Likewise, some recommendations for small and medium business people searching for new technologies, such as the application of the genetic algorithm in the distribution and increase the profitability of their company, is the hiring of highly qualified personnel with previous experience regarding the use and application of the Genetic algorithm. There are also certain issues to be investigated and further deepened in the application of genetic algorithms, such as the implementation of time windows, multiple depots, capacitated vehicles, dynamic vehicle routing problems considering variations in demand, time-dependent vehicle routing problems involving fluctuations in the travel time under the influence of vehicular traffic, products with variable shelf lives, implementation of restrictions related to the costs of carbon emissions and irregularities in the route related to damage to perishable foods.

5. Conclusion

The objective of this research is to give greater visibility to the results obtained by implementing genetic algorithms in transport companies in the food sector and how these can achieve great changes both in the logistics activity and in the profitability of the company. To carry out the structure of this research, three factors with their dimensions have been determined, which allowed us to explore the contributions obtained by the authors of the 60 articles collected. Compared to other studies on genetic algorithms, this one focuses on quantitatively demonstrating the results obtained before and after implementation.

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