Article

Analysis of Decision Parameters for Route Plans and Their Importance for Sustainability: An Exploratory Study Using the TOPSIS Technique

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Abstract: *Background:* This study aimed to identify the most widespread performance objectives for the vehicle routing problem, the degree of comparative importance attributed to each of these performance objectives in the opinion of professionals in the logistics area working in Brazil and also relate them to aspects of sustainability considering environmental, economic and social issues. *Methods:* To this end, a literature review was carried out in the area and a survey was developed with professionals through a structured questionnaire. The collected data were treated using the TOPSIS multi-criteria technique. *Results:* The results indicate that the performance objectives in route plans "level of service", "total number of vehicles" and "total distance travelled" are the ones that, in the opinion of the professionals participating in the research, have greater importance in the planning and elaboration of plan routes and that such objectives directly impact the sustainable results of a given organization. *Conclusions:* The results can serve as a basis for researchers in the area who aim to broaden the debates on this topic and for logistics operations managers who work directly with planning and elaboration of route plans and who aim to make their operations more sustainable. Therefore, this research addresses the literature gap by identifying which performance objectives should be considered in the elaboration of route plans and how they relate to sustainability guidelines. It is noteworthy that no other study with a similar objective was identified in the literature.

Keywords: vehicle routing problem; sustainability; TOPSIS

1. Introduction

The vehicle routing problem has been discussed in the literature and according to [1], in a simplified way, the problem consists of resources that are available and need to be transported to different locations where they are needed; and in the course of this movement, there is an associated cost. Additionally, according to these authors, the first formulation for the problem dates back to the 1940s; currently, the problem is well known as the vehicle routing problem (VRP).

The VRP solution revolves around finding a route plan, that is, a set of routes associated with a fleet of vehicles, which implies low costs associated with time, fuel, total distance traveled, and labor charges. These solutions are obtained through optimization problems

that may not result in optimal solutions. In recent decades, different variations of the VRP can lead to different optimization goals. The authors of [2] developed a review study on solutions that simultaneously consider more than one optimization objective.

In addition to the cost context, other perspectives have been associated with a good route plan, such as the level of customer service [3–6] expressed by objectives such as waiting time, average delay and number of customers served per route, and have been considered in optimization problems. Objectives related to environmental issues [2,7] and risks have also been observed in the literature [8].

In this sense, it is worth highlighting the perspective of the impact of the route plan on sustainability issues. According to [9], the growth of scripting considering sustainable aspects requires cooperation between regional economic development and environmental conservation, representing a global concern for both developed and developing countries, as in the case of Brazil. Brazil is a developing economy that has technological and logistical infrastructure limitations, with road transport as the main mode of transport, so the country has difficulties in promoting the achievement of goals aligned with sustainable objectives, which justifies the development of studies that enhance the debate in the area. There are several operational restrictions to be considered in a route plan, such as transport capacity, demand, time available to operate, and the type of modal to be used. The authors of [10] argue that transport activity, which is included in the development of the route plan, directly influences the three dimensions of sustainability (environmental, economic and social) and therefore becomes an essential operation in contributing to the achievement of sustainable objectives.

Given the growing diversity of elements to be considered in the elaboration of a route plan, together with interest in the VRP and its variants, the definition of a route plan can result in different aspects of performance depending on the objectives considered in its definition. Therefore, an important question emerges: "Considering the objectives found in the literature, which ones should be considered in the vehicle routing problem, what is their degree of importance in the perception of professionals in the area and how do they relate to the sustainability guidelines?"

To answer this question, this study aimed to identify the most widespread performance objectives for the vehicle routing problem, and the degree of comparative importance attributed to each of these performance objectives in the opinion of professionals in the area of logistics working in Brazil and also relate them to aspects of sustainability considering environmental, economic and social issues. The collected data were analyzed using the TOPSIS technique. The authors of [11] argue that TOPSIS allows the ranking of alternatives considering different analysis criteria. Therefore, TOPSIS was utilized since it is possible to obtain a classification of the objectives of route plans considering different criteria and perceptions of different professionals with experience in the management of logistics activities.

In addition to this introductory section, there are four more sections to this article. Section 2 contains the systematic review of the literature on the VRP theme, where the different objectives are compiled. Section 3 presents the methodological procedures related to the methods used to execute this research. Then, in Section 4, the results and associated discussions are presented. Finally, the conclusions, research limitations, proposals for future studies and implications for theory and practice are found in Section 5.

2. Literature Review

The VRP can be interpreted as the definition of delivery routes assigned to a fleet of vehicles to obtain an optimal result in a given objective [1,12]. In the 1990s, the authors of [13,14] mathematically described the problem as a graph $G = (V, A)$, where $V = \{v1, v2,..., vn\}$ is a set of vertices or cities and A is a set of arcs such that $A = \{(vi, vj):i \neq j, vi, vj \in V\}$. Additionally, according to the same authors, for each arc "path" used in the route plan, there is a parameter cij that generally represents the costs involved in transporting from vi to vj, and in specific contexts can represent distances traveled or travel time.

The different sets of routes that meet the constraints of the problem can be indefinitely gridded, but the set that matters is the one that will lead to the lowest or lowest total cost obtained by $\sum c_{ij}$. The VRP problem is usually formulated as an optimization problem, where the objective function expresses which aspect of the route plan should be optimized. The definition of route plans as a VRP solution has been widely discussed in the literature and several exact and sub-optimal methods have been obtained over time [2,15]. The authors of [16] argue that vehicle routing and scheduling are fundamental problems, both in the context of primary and secondary distribution. For primary distribution purposes, the services of third-party logistics companies are usually purchased. On the other hand, secondary distribution is generally carried out through its fleet of vehicles. Optimizing distribution at both levels is challenging and realistic routing plans can often require considering multiple conflicting objectives and identifying an appropriate trade-off.

In parallel with developing these more efficient solutions to the problem, new variants emerged to make the problem closer to practical situations. The inclusion of time windows is an example. Each customer that must be visited informs a time interval [17] in which it is convenient to receive the requested service. Another classic variant of the VRP includes a restriction on the transport capacity of each vehicle belonging to the fleet [5,18]. These are well-established variants in the literature, but in recent decades new perspectives have been considered in the elaboration of a route plan, for example, quality of service and sustainability issues, especially taking into account the triple bottom line vision (social, economic, and environmental) [7,19]. Furthermore, new technologies such as drones [4] and the evolution of communication technologies have taken the optimization goals of VRP and variants far beyond direct cost, distance traveled and travel time.

Many performance objectives can be considered in the formulations of the VRP. Given the diversity of performance objectives, the literature sought to identify which performance objectives compose the solution proposals for the VRP and its variants. The articles that served as the basis for this survey are from the last 5 years, and all are literature review articles in which their authors mapped the different objective functions according to the scope of their research. It was then possible to group the different performance objectives into four dimensions: cost, productivity, quality and time (Table 1).

Table 1. Performance objectives have been identified in the literature.

Dimensions	Code	Performance Objectives	References
Cost	Cos_01	Number of stops and transported volume	[5,17]
	Cos_02	Fuel	[15,20,21]
	Cos_03	Labor	[20–25]
	Cos_04	Vehicle and machinery maintenance	[7,20]
	Cos_05	Unit of goods delivered	[24]
	Cos_06	Subcontracting	[7]
	Cos_07	Overtime worked cost	[17]
Productivity	Pro_01	Total number of vehicles	[2,6,8,17,19,22]
	Pro_02	Number of customers served	[3]
	Pro_03	As fast as possible	[4]
	Pro_04	Risks associated with the route	[2,7,8]
	Pro_05	total distance traveled	[3,4,6,8,19,22];
	Pro_06	Profit	[1,7,15,23]
Quality	Qua_01	Total delay in deliveries	[3,15,17,23]
	Qua_02	Total emissions of pollutants	[2,4,15,19,22]
	Qua_03	Service Level (fraction of customer demand met by the route plan)	[6,15,19]
	Qua_04	Product damage depending on the route	[23]

Table 1. *Cont.*

Dimensions	Code	Performance Objectives	References
Time	Tim_01	Customer wait	[2,4,15,23]
	Tim_02	Total congestion time	[23]
	Tim_03	Total service time	[1,3,18]
	Tim_04	Loading/unloading times	[19]
	Tim_05	Total empty truck time	[18]

As shown in Table 1, it is observed that the performance objectives are grouped by dimensions. The cost dimension refers to performance objectives that are directly related to the operation costing issues. In the productivity dimension, the related objectives are linked to the idea of production rate, which leads to more operational issues. In the quality dimension, aspects related to the customer's vision are observed. Finally, in the time dimension, performance objectives are related to the idea of time and can also be attributed to other dimensions directly or indirectly, as in the case of the customer's expectation objective, which can also be interpreted as an element of quality. For this study, the 22 performance objectives identified in the literature were considered in the survey carried out with professionals.

Given the context, it is also relevant to emphasize the importance of the route plan to achieve sustainable goals and objectives both in the environmental dimension and in issues related to economic and social aspects [26]. The elaboration of the route plan aligned with sustainable issues has been gradually increasing [26]. According to [27], a joint development of the routing plan, inventory management, and operational adjustments ensure good cost management and reduce polluting gas emissions from activities belonging to a supply chain network.

Since production and consumption generally occur in different locations and with considerable distances, issues of negative environmental impacts are recurrent in this context, caused mostly by polluting gas emissions from physical transport activities [26]. Regarding social aspects, it is highlighted that the generation of traffic congestion, the increase in the incidence of noise pollution, the occurrence of public health problems and the increase in the risk of traffic accidents are still neglected in the face of economic goals. Organizations [26]. Analyzing this scenario, it is possible to notice that some companies adopt several measures aiming to minimize their environmental impacts resulting from the development of their transport activities, in which the route plan is inserted [24]. Such adjustments are due to current legislation and pressures and customer demands for increasingly sustainable services and products [26].

In this context, it is still important to highlight some similar studies that also used multi-criteria analysis methods. In their study, the authors of [28] highlight the importance of using multi-criteria methods for quality assurance in decision making and the final decision when selecting viable alternatives in a given context. Further, [29] is another example of a developed study that concluded that decision-making processes increasingly use models based on various methods to ensure the professional analysis and evaluation of the considered alternatives. The authors of [30] used the Neuro-Fuzzy System to support decision making in the selection of construction machines. The authors of [31] analyzed criteria for selecting the position of the air traffic control radar.

Therefore, this study considers the importance of sustainability in the definition and elaboration of a route plan, in addition to the identification in the literature of the performance objectives and the analysis of the importance of each one by professionals in the logistics area working in Brazil, and also carries out an analysis of the relationship and impact of performance objectives considered the most important by professionals, making a parallel with the sustainability guidelines.

Considering the context presented, a multi-criteria analysis technique was employed, since it is understood that professionals in the area must analyze the objectives that include

route plans considering different criteria and perceptions. Therefore, techniques such as Gray Relational Analysis, TOPSIS and Fuzzy TOPSIS are some possible examples of applications to achieve the objectives proposed in this study. TOPSIS was used since it could be used to obtain a consistent ordering considering the amount of the sample obtained with the application of the survey. Details of using TOPSIS are presented in the next section.

3. Methodological Procedures

Four well-defined steps were developed for this study: (a) systematic review of the literature, (b) survey with professionals in the logistics area, (c) analysis of data collected via the TOPSIS technique, and (d) establishment of discussions and conclusions.

Initially, a systematic literature review was developed. This form of research uses the literature on a given topic as a data source. For this, the scientific databases of Web of Science, Scopus, Taylor and Francis, Science Direct and Springer were used. Searches were performed using the following string: "vehicle routing problem" AND "route management" AND "route plan". Articles published between the years 2015 and 2020 were considered. Inclusion criteria were: articles based on mathematical models and that had developed a literature review. The exclusion criteria were: articles that did not have at least one term of search in the title, abstract or keywords and did not address the vehicle routing problem. Thus, 1480 articles were identified, of which 160 were duplicates and, after the analysis and application of the exclusion criteria, a final collection of 33 publications considered in this study remained. The results of this step can be found in Section 2 of this article. So, in the first selection, only the title and abstract of each article found were read and all those that did not have any keywords contained in the search string were excluded from this study. Then, all articles accepted in the first selection were read in full. In this second selection, all those that did not have a basic mathematical model and that did not mention the route parameters considered were discarded. Additionally, it was decided to consider in this study only the articles that adopted the literature review strategy, since they presented the decision parameters for route plans in a more detailed way.

Once the literature review was carried out, the research instrument and development of the survey started with professionals in the logistics area. The research instrument (questionnaire) consisted of the objectives presented in Table 1. The questionnaire was built using the online Google Forms database. The first part of the questionnaire corresponded to the respondents' characterization questions (occupation, job location, professional training, and experience). The second part referred to the 22 decision objectives mapped in the literature review (Table 1). Respondents should assign a score from 0 to 10, considering the degree of importance of each objective for the elaboration of a route plan. A score of 0 indicates that the parameter is not important for the elaboration of the route plan and a score of 10 indicates that the objective is very important in the elaboration of the route plan. Intermediate grades could be freely assigned. It is noteworthy that this research was approved by the Research Ethics Committee of the Universidade do Estado do Pará and is registered under the number CAAE: 46833721.6.0000.8767.

The professionals invited to participate in this study were identified through searches on the Lattes platform (academic curriculum registration platform in Brazil) considering the following criteria: having a doctorate, having updated their curriculum on the platform during the last year and having at least 5 publications on the topic of "logistics routing". Additionally, the social network LinkedIn was used to search for professionals working in the logistics area. In all, a sample of 110 professionals was obtained and the questionnaire was sent to each one via e-mail. A return rate of 28.18% was obtained (31 respondents). A total of 48.38% of the professionals are professors and/or researchers; 32.25% are managers, coordinators or analysts of logistics companies; and 19.35% are consultants. Regarding experience in the area, 48.38% have up to 10 years of experience, 25.80% have between 11 and 20 years of experience and 25.82% have over 20 years of experience.

The collected data were treated using the TOPSIS multi-criteria analysis technique, following the recommendations of [32]. According to these authors, through TOPSIS, it is possible to classify variables (activities, items, objectives, challenges, among others) considering different analysis criteria. The criteria can assume different weights and, consequently, assume varying degrees of importance, basing decision making according to the weights assigned to each one. In this study, we chose to assign different weights to the answers for each performance objective analyzed considering the experience of each of the respondents, with 0.50 for those with more than 20 years of experience, 0.30 for those with between 11 and 20 years of experience and 0.20 for those with up to 10 years of experience.

According to the guidelines presented by [32], the first step in using TOPSIS is the structuring of the matrix D, where the elements (x_{ij}) are identified by an alternative (i) and by an analysis criterion (j). In this study, the alternatives corresponded to the 22 performance objectives considered in the questionnaire and the criteria corresponded to the three averages obtained from each group of respondents for each of the activities. Then, the normalization of matrix D is performed using Equation (1) presented in Figure 1, resulting in a matrix called Matrix R. Then, the values of Matrix R must be weighted using Equation (2) presented in Figure 1, obtaining a new matrix called Matrix V. Subsequently, positive (v_j^+) and negative (v_j^-) ideal solutions are defined. In this step, the maximum and minimum values existing in Matrix V are identified for each analysis criteria. Next, the positive and negative Euclidean distances for each alternative are calculated.

Matrix 1	$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix}$	Matrix 3	$V = \begin{bmatrix} v_{11} & v_{12} & \dots & v_{1n} \\ v_{21} & v_{22} & \dots & v_{2n} \\ \dots & \dots & \dots & \dots \\ v_{m1} & v_{m2} & \dots & v_{mn} \end{bmatrix}$
Equation (1)	$r_{ij} = x_{ij} / \sqrt{\sum_{i=1}^{n} x_{ij}^2}$	Equation (3)	$s_i^* = \left[\sum_j \left(v_{ij}^* - v_j^+ \right)^2 \right]^{1/2}$
Matrix 2	$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1n} \\ r_{21} & r_{22} & \dots & r_{2n} \\ \dots & \dots & \dots & \dots \\ r_{m1} & r_{m2} & \dots & r_{mn} \end{bmatrix}$	Equation (4)	$s_i' = \left[\sum_j \left(v_{ij}' - v_j^- \right)^2 \right]^{1/2}$
Equation (2)	$v_{ij} = w_j r_{ij}$	Equation (5)	$c_i^* = \dfrac{s_i'}{(s_i^* + s_i')}$

Figure 1. TOPSIS steps.

Finally, with the values of Euclidean distances, it was possible to calculate the C_{i*} indicator and classify the 22 performance objectives considered in this study according to the perception of different professionals in the logistics area. It is worth mentioning that the C_{i*} values must be between 0 and 1. The matrices mentioned above and equations are shown in Figure 1.

4. Results and Associated Discussions

This section presents the survey results developed by logistics professionals working in Brazil and the discussions of such results through an analysis of the literature in the area. As detailed in the methodological procedures section, the collected data were treated using the TOPSIS technique, considering the guidelines proposed by [32]. To begin the TOPSIS stages, the data collected were divided into three groups of respondents considering the length of experience of professionals in the logistics area divided into professionals with more than 20 years of experience, professionals with between 11 and 20 years of experience and professionals with up to 10 years of experience. Initially, the average (Table 2) of the scores attributed by each professional to each of the objectives considered in this study

(Table 1) was calculated and then they were normalized using Equation (1) presented in Figure 1, resulting in the Matrix R presented in Table 3.

Table 2. Averages are assigned to performance objectives. Source: authors.

Code	Performance Objectives	G1 (Over 20 Years)	G2 (between 11 and 20 Years)	G3 (Up to 10 Years)
Cos_01	Number of stops and transported volume	6.571	7.400	8.500
Cos_02	Fuel	8.429	8.000	9.000
Cos_03	Labor	6.857	7.100	7.357
Cos_04	Vehicle and machinery maintenance	7.143	6.600	7.214
Cos_05	Unit of goods delivered	7.000	8.500	7.000
Cos_06	subcontracting	7.143	8.000	6.429
Cos_07	Overtime worked cost	7.286	8.100	6.143
Pro_01	Total number of vehicles	8.571	9.900	9.286
Pro_02	Number of customers served	8.286	8.500	8.643
Pro_03	As fast as possible	7.429	8.800	8.429
Pro_04	Risks associated with the route	6.571	7.900	7.643
Pro_05	total distance traveled	8.143	8.900	9.214
Pro_06	Profit	8.714	7.200	8.929
Qua_01	Total delay in deliveries	8.000	8.500	8.500
Qua_02	Total emissions of pollutants	6.286	5.100	4.000
Qua_03	Service Level (fraction of customer demand met by the route plan)	9.286	9.400	9.071
Qua_04	Product damage depending on the route	7.000	8.100	7.857
Tim_01	Customer wait	7.286	8.700	8.429
Tim_02	Total congestion time	7.714	7.700	7.214
Tim_03	Total service time	8.143	8.700	8.786
Tim_04	Loading/unloading times	7.857	8.200	8.143
Tim_05	Total empty truck time	7.714	7.200	6.714

Table 3. R matrix with normalized values. Source: authors.

Code	r_{ij} (Over 20 Years)	r_{ij} (between 10 and 20 Years)	r_{ij} (Up to 10 Years)
Cos_01	0.18	0.20	0.23
Cos_02	0.23	0.21	0.24
Cos_03	0.19	0.19	0.20
Cos_04	0.20	0.17	0.19
Cos_05	0.20	0.22	0.19
Cos_06	0.20	0.21	0.17
Cos_07	0.20	0.21	0.16
Pro_01	0.24	0.26	0.25
Pro_02	0.23	0.22	0.23
Pro_03	0.21	0.23	0.23
Pro_04	0.18	0.21	0.21
Pro_05	0.23	0.23	0.25
Pro_06	0.24	0.19	0.24
Qua_01	0.22	0.22	0.23
Qua_02	0.18	0.13	0.11
Qua_03	0.26	0.25	0.24
Qua_04	0.20	0.21	0.21
Tim_01	0.20	0.23	0.23
Tim_02	0.22	0.20	0.19
Tim_03	0.23	0.23	0.24
Tim_04	0.22	0.22	0.22
Tim_05	0.22	0.19	0.18

Then, weights were assigned to each group of respondents, with professionals with more than 20 years of experience receiving a weight of 0.5, between 11 and 20 years of experience 0.3 and professionals with up to 10 years of experience a weight of 0.2. Then, it was possible to obtain Matrix V (Table 4).

Table 4. Matrix V weighted values. Source: authors.

Code	r_{ij} (Over 20 Years)*0.50	r_{ij} (between 11 and 20 Years)*0.30	r_{ij} (Up to 10 Years)*0.20
Cos_01	0.09	0.06	0.05
Cos_02	0.12	0.06	0.05
Cos_03	0.10	0.06	0.04
Cos_04	0.10	0.05	0.04
Cos_05	0.10	0.07	0.04
Cos_06	0.10	0.06	0.03
Cos_07	0.10	0.06	0.03
Pro_01	0.12	0.08	0.05
Pro_02	0.12	0.07	0.05
Pro_03	0.10	0.07	0.05
Pro_04	0.09	0.06	0.04
Pro_05	0.11	0.07	0.05
Pro_06	0.12	0.06	0.05
Qua_01	0.11	0.07	0.05
Qua_02	0.09	0.04	0.02
Qua_03	0.13	0.07	0.05
Qua_04	0.10	0.06	0.04
Tim_01	0.10	0.07	0.05
Tim_02	0.11	0.06	0.04
Tim_03	0.11	0.07	0.05
Tim_04	0.11	0.06	0.04
Tim_05	0.11	0.06	0.04

In Table 5, the positive and negative ideal solutions are presented. Through them, the calculation of the values in Table 5 is performed, where they correspond to the Euclidean distances of the positive and negative ideal solution. Using Equation (5) presented in Figure 1, it is possible to obtain the coefficient Ci* that is used to generate the ranking of the performance objectives considered in this study and used in the elaboration of route plans. This coefficient is also presented in Table 6.

Finally, by ordering the values of the Ci* coefficient, there is a comparative ranking of the route plan performance objectives considered in this study and analyzed by professionals in the logistics area of companies operating in Brazil. Table 7 presents the results of the referred ordering.

Table 5. Positive ideal solution and negative ideal solution for accessing the criteria. Source: authors.

Solution Criteria	Over 20 Years	between 11 and 20 Years	Up to 10 Years
Positive ideal solution (v_j^+)	0.13	0.08	0.05
Negative ideal solution (v_j^-)	0.09	0.04	0.02

Table 6. Distances from the positive ideal solution, distance from the negative ideal solution and C_{i*} coefficient. Source: authors.

Code	Distances from the Positive Ideal Solution (S_{i+})	Distances from the Negative Ideal Solution (S_{i-})	Coefficient (C_{i*})
Cos_01	0.04	0.03	0.416
Cos_02	0.02	0.05	0.706
Cos_03	0.04	0.03	0.377
Cos_04	0.04	0.02	0.369
Cos_05	0.04	0.03	0.478
Cos_06	0.04	0.03	0.441
Cos_07	0.04	0.03	0.456
Pro_01	0.01	0.06	0.852
Pro_02	0.02	0.05	0.718
Pro_03	0.03	0.04	0.597
Pro_04	0.04	0.03	0.416
Pro_05	0.02	0.05	0.732
Pro_06	0.02	0.05	0.668
Qua_01	0.02	0.04	0.669
Qua_02	0.06	0.00	0.000
Qua_03	0.00	0.06	0.936
Qua_04	0.04	0.03	0.480
Tim_01	0.03	0.04	0.571
Tim_02	0.03	0.03	0.526
Tim_03	0.02	0.05	0.712
Tim_04	0.02	0.04	0.616
Tim_05	0.03	0.03	0.470

Table 7. Ranking of the items: Source: authors.

Position	(C_{i*})	Code	Performance Objectives
1°	0.936	Qua_03	Service Level
2°	0.852	Pro_01	Total number of vehicles
3°	0.732	Pro_05	total distance traveled
4°	0.718	Pro_02	Number of customers served
5°	0.712	Tim_03	Total service time
6°	0.706	Cos_02	Fuel
7°	0.669	Qua_01	Total delay in deliveries
8°	0.668	Pro_06	Profit
9°	0.616	Tim_04	Loading/unloading times
10°	0.597	Pro_03	As fast as possible
11°	0.571	Tim_01	customer wait
12°	0.526	Tim_02	Total congestion time
13°	0.480	Qua_04	Product damage depending on the route
14°	0.478	Cos_05	Unit of goods delivered
15°	0.470	Tim_05	Total empty truck time
16°	0.456	Cos_07	Overtime worked cost
17°	0.441	Cos_06	subcontracting
18°	0.416	Cos_01	Number of stops and transported volume
19°	0.416	Pro_04	Risks associated with the route
20°	0.377	Cos_03	Labor
21°	0.369	Cos_04	Vehicle and machinery maintenance
22°	0.000	Qua_02	Total emissions of pollutants

Analyzing the first three performance objectives of the route plan in the generated planning, considering the opinion of professionals in the logistics area of companies operating in Brazil, who measured through a scale the degree of importance of each objective in the elaboration of the route plan, the "service level" is in the first position. This objective is associated with the "quality" dimension and refers to the fraction of customer demand served by the route plan. According to [4,5], the level of service is important because it is directly related to the waiting time, average delay and the number of customers served per route. Analyzing its importance for achieving sustainable goals, the authors of [33] state that when companies consider sustainable practices in their logistics activities (which is included in the route plan), they also tend to consider sustainable characteristics in the level of services offered to their customers, thus ensuring competitive advantages in matters related to sustainability.

Regarding the total number of vehicles (second in the ranking), which is directly linked to the productivity dimension, the authors of [17,26,34] draw attention to the importance of maintaining an operation of physical transport activities with the correct quantity required of vehicles according to demand. Negative economic, environmental and social impacts arise from poor planning of the number of vehicles required for a particular route plan elaboration [35]. Regarding environmental issues, we can highlight the issues related to the amount of pollutant gas emissions by vehicles used in such operations [11].

In the third position of the order appears the objective "total distance covered", also linked to the productivity dimension and with a considerable relationship with the aspects of sustainability. The VRP solution revolves around finding a route plan, that is, a set of routes associated with a fleet of vehicles, which implies low costs associated with the total distance traveled, directly impacting the economic aspects of a given organization [36]. In addition, as well as the total number of vehicles, the correct planning of the total distance to be covered also guarantees the achievement of sustainable goals since the shorter the distance traveled, the lower the emission of polluting gases and also the lower the social impact generated in large urban centers [4,8,19,25,36,37].

Analyzing the last three in the ranking, it can be seen that two of them are linked to the cost dimension (labor and maintenance of vehicles and machinery) and one to the quality dimension (total emissions of pollutants). It is noteworthy that the fact that they are in the last positions does not mean that they are not important in the elaboration and definition of a route plan and also for the achievement of sustainable goals concerning the best ranked, but that, in the opinion of the participating professionals of this research, when analyzing the degree of importance between them in a comparative way, they obtained only the lowest coefficients. Considering the results achieved, it is possible to perceive the importance of considering the opinion of professionals in the logistics area in the analysis of the objectives considered in the elaboration of route plans. A critical analysis of the literature enhances the expansion of debates in the area and a better alignment between theory and practice in this context; specifically, it is also possible to discuss and identify the relationship between the performance objectives of route plans and sustainable aspects presented in the literature.

5. Conclusions

According to the results achieved, it can be concluded that the objectives of this research were achieved. In other words, it was possible to identify the most widespread performance objectives for the vehicle routing problem, the degree of comparative importance attributed to each of these performance objectives in the opinion of professionals in the logistics area working in Brazil and also relate them to aspects of sustainability considering environmental, economic and social issues.

It is essential to highlight the impact of the results presented here for theory and practice in the area of logistics and specifically in the planning and elaboration of route plans. From a theoretical point of view and because it is an exploratory study, the results can serve as a basis for researchers in the area who aim to broaden the debates on this topic

through future research. From a practical point of view, the results can serve as a basis for logistics operations managers who work directly with planning and elaboration of route plans and who aim to make their operations more sustainable, thus defining priority, and assertive actions in line with such objectives. Therefore, as presented, it is important to highlight the vehicle routing problem's impact on issues related to achieving sustainable goals from both environmental and economic and social aspects.

As a research limitation, it is highlighted that this study has an exploratory character and that its results cannot be generalized to other contexts of which the sample used is not part. Further, another limitation is the use of only one criterion (experience in the area) in the process of assigning weights for each of the responding professionals participating in the research. Future studies from this can be developed, such as (a) elaboration and implantation in a company of a plan of routes considering the results presented here; (b) proposition of guidelines for the adoption of sustainable practices in operations related to the route plan; and (c) validation of specific indicators aligned with the operation of sustainable route plans.

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