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Factors Affecting the Choice of Urban Freight Vehicles: Issues Related to Brazilian Companies

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Abstract: In this paper, we present the attributes that influence the choice of an urban freight vehicle by using a systematic literature review and a survey conducted with logistics operators that perform urban deliveries in some of the biggest cities in Brazil. The results obtained facilitate the analysis and determination of the main attributes of vehicle selection in some cities of Brazil. Descriptive statistics are used to describe the characteristics of the companies, and a principal component analysis identifies the dependent variables, in order to evaluate the importance of each attribute. Also, an ordered logistic regression model is used to identify if the characteristics of the companies influence the choice of an urban freight vehicle. The results of this analysis indirectly indicate the dependence of the decision-making process on the logistics policies implemented in a given city. These attributes agree with those in the literature review. These results, despite of being evident, are different from the present selection criteria, which depend on local city policies.

Keywords: city logistics; urban freight transport; freight vehicles; attributes of choice; statistical analysis; ordered logistics regression model

1. Introduction and Background

Vehicles used for urban distribution are one of the main components of the freight transport system, as they play a vital role in the economic development of urban areas, besides being responsible for a large share of the logistics costs of a company [1]. Since goods are not normally consumed where they are produced, multiple interrelated decisions are made, in order to ensure that the cargo reaches its final destination. Choosing the proper mode of transportation is perhaps the most important factor in decisions regarding freight transport. Therefore, knowledge of the factors that affect this decision is essential [2].

There is a keen interest in understanding how freight operators make decisions about the type of vehicle that should be used for the distribution of goods [3]. The complexity of the urban freight transport process influences the type of freight vehicle chosen to perform urban deliveries. In this way, some attributes related to the different characteristics of the vehicle, product, and route influence this choice.

The ascertainment of relevant attributes for urban freight transport vehicle choice is essential to understand the studied phenomenon [4]. In order to identify these attributes, we carried out a systematic literature review. The research problem is “What are the attributes that influence the choice of an urban freight vehicle?” Considering this research question, the string “attributes in freight transport mode choice” was used for search papers in Emerald, Google Scholar, Science Direct, and

the Scopus database. Firstly, 54 papers were identified, of which 19 were selected to carry out an analysis in depth. Table 1 presents the attributes used to choose an urban freight vehicle identified in the literature review. These attributes are divided in three categories: vehicle, route, and commodity.

Table 1. Attributes used to choose an urban freight vehicle.

Category	Attributes	Reference
Vehicle attribute	Vehicle conditions	[5]
	Vehicle capacity	[3,6,7]
	Fleet (own or outsourced)	[3,8]
	Total Cost	[3,5,7–15]
	Customer requirement	[5,7,10,14,15]
	Operational cost per kilometre	[3,7,16]
	Mode of transportation	[8,17]
	Type of fuel	[3,16]
Age of vehicle	[3]	
Route attributes	Total distance	[1,3,9,10,12,18,19]
	Origin and destination	[5,9,20]
	Number of stops/tour	[1,19]
	Number of tours/day	[1]
	Diversity of regions (central area, historical, area, suburb)	[1,19]
	Accessibility	[20]
	Traffic restrictions	[19]
Load/unloading area	[19]	
Commodity attributes	Type of product	[1,10,12,19–21]
	Weight of products	[1,3,10,20,21]
	Diversity of products	[9,10,19,20]
	Volume of products	[10,18,20]
	Lot size	[10,19–21]
	Characteristics of the product	[18]

The attributes listed in Table 1 show that there is no common agreement on the most important factors that influence freight vehicle choice. Considering this, we used these attributes in a survey conducted with logistics operators that perform urban deliveries in some of the biggest cities in Brazil to (i) analyse the attributes that most influence the choice of an urban freight vehicle, and (ii) to identify the most important attributes and scale their relative importance.

Considering the challenge of transport companies to choose vehicles that meet both customer and public policy requirements while maximizing their activity and level of service, this paper contributes to the literature, consolidating this information and establishing the attributes that influence the decision-making process for urban freight vehicles to perform urban deliveries in Brazil.

2. Research Approach

A survey was conducted with logistics operators in Brazil, in order to obtain data to evaluate the selected attributes in the choice of urban freight vehicles. The questionnaire has two blocks, as presented in Table 2.

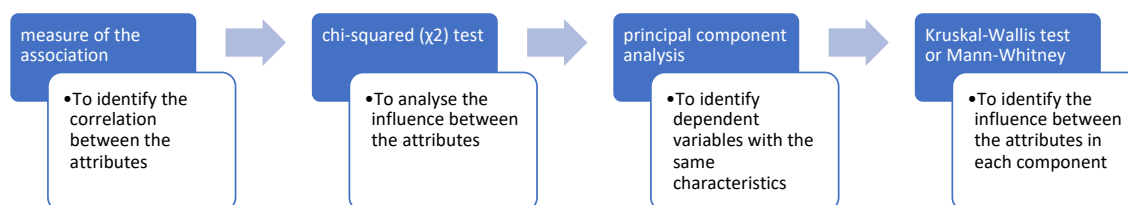
Descriptive statistics were used to show the characteristics of the companies. The internal consistency of these attributes, evaluated by the interview participants, was measured using Cronbach's alpha, expressed as a number between 0 and 1 [22]. Internal consistency "means that all items in a test measure the same concept" [22] (p 53). This interpretation of Cronbach's alpha uses a wide range of different qualitative descriptors [23]. We considered a Cronbach's alpha value above 0.7 as acceptable [24]. Also, the importance of the attributes was measured by their relative standing (minimum, first quartile, median, third quartile, and maximum).

Table 2. Survey questionnaire template.

Block	Theme	Variable	Response Type
Block 1	Company information	City/state	Text
		Gross sale	Categorical (10 classes)
		Number of employers	Continuous
		Main class of product delivered	Categorical (10 classes)
		Fleet class	Categorical (3 classes)
		Attendants' city	Categorical (19 classes)
Block 2	Attributes	Type of vehicles	Categorical (6 classes)
		(A1) Number of deliveries in one route	Likert Scale (1–5)
		(A2) Total distance in one route	
		(A3) Area of delivery (central area, historical, area, suburb)	
		(A4) Type of goods	
		(A5) Variety of goods in one route	
		(A6) Freight vehicle restriction	
		(A7) Conditions of on-street load/unload areas	
		(A8) Condition of the access of commercial establishments	
		(A9) Type of fuel	
		(A10) Capacity of vehicle (tons)	
		(A11) Capacity of vehicle (m ³)	
		(A12) Operational cost by kilometre	
(A13) Vehicle cost (in acquisition process)			

2.1. Evaluation of the Importance of Attributes

Figure 1 presents the statistical analysis carried out in this section. Considering the data from block 2, the measure of the association (Spearman correlation) was considered to identify the correlation between the attributes, using a correlogram to present the results [25].

**Figure 1.** Statistics analysis procedures.

The influence between the attributes was analysed using a chi-squared (χ^2) test. The null hypothesis is that “there is not an association between the attributes”. If χ^2 is calculated at $\geq \chi^2$ distribution with $k - 1$ degrees of freedom, then the null hypothesis (H_0) is rejected based on the value of alpha, obtained from the p -value [26].

If H_0 is rejected in the chi-squared test, we carried out a principal component analysis (PCA) to identify dependent variables with the same characteristics [27]. In this case, we first measured the suitability of the data sample for PCA using a Kaiser–Meyer–Olkin (KMO) test [28]. According to [29], a value above 0.7 is considered the median, and a value above 0.8 is considerable acceptable to the KMO test. If we identified attribute with value below 0.7, we removed this attribute from the sample, until obtaining a data sample suitable for the PCA.

The next step of the PCA is to obtain the eigenvalues to determine the number of principal components [29]. An eigenvalue greater than 1 indicates that the analysed component accounts for more variance than that accounted for by one of the original variables. This was used as a cut-off point to identify which components to retain. The total variance and analysis of the Scree Plot is another way to limit the number of components. A Scree Plot is a plot of eigenvalues ordered from the largest to the smallest. The number of components is determined by the cut-off point [30,31]. In this paper, we considered the ordered eigenvalues to determine the number of components. We used the circle of correlation to identify the correlation between a variable and a principal component (PC), using them as coordinates of the variable on the PC. We then presented these results using a correlation circle. The squared loading for variables is called \cos^2 , and measures the quality of the representation

of the variables. A high \cos^2 value indicates a good representation of the variable for the principal component, and in this case, the variables are positioned close to the centre of the correlation circle. The \cos^2 can be represented by the colours in the correlation circle: red represents a high value of \cos^2 , blue represents variables with a middle \cos^2 value, and white represents variables with a low \cos^2 value. Considering these steps, we identified the pattern of similarity between the attributes. We suggest reading [27] and [30] for more details about PCA.

We used the attributes identified as having similarities through PCA, to analyse if those attributes are homogeneous and have the same distribution (a null hypothesis), using a Kruskal–Wallis test [32,33]. If the null hypothesis (H_0) is rejected (p -value < 0.05), we can conclude that the attributes are heterogeneous.

2.2. The Influence of the Characteristics of the Companies on Choosing an Urban Freight Vehicle

The influence of the characteristics of a company on choosing an urban freight vehicle was identified using ordered logistic regression, which considers the dependent variable as an ordinal variable. The conceptual framework for this modelling process is presented in [34,35]. We used the proportional odds model to estimate these parameters, considering the attributes needed to choose an urban freight vehicle as the dependent variable and some companies' characteristics as the independent variable.

We performed this analysis using the software R, v.1.1.463 through the packages Corrgram [36], psych [37], MAAS [38], FactoMineR [39], and factoextra [40].

3. Results

We interviewed 202 logistics operators in Brazil between July and August 2018, using a web-based survey. The location of the company headquarters is presented in Figure 2. These companies deliver beverages, fresh food, clothing and shoes, electronics, hygiene and medical products, books, newspapers, furniture, and others goods to almost all metropolitan areas in Brazil. All surveyed companies perform urban deliveries in cities with high population density in Brazil; in general, the largest companies operating in cities with the largest concentrations of people were interviewed. The gross sales (in REAL) and number of employees are presented in Figure 3: 72% of the companies surveyed were large (over 100 employees) and have significant daily challenges to deliver goods.

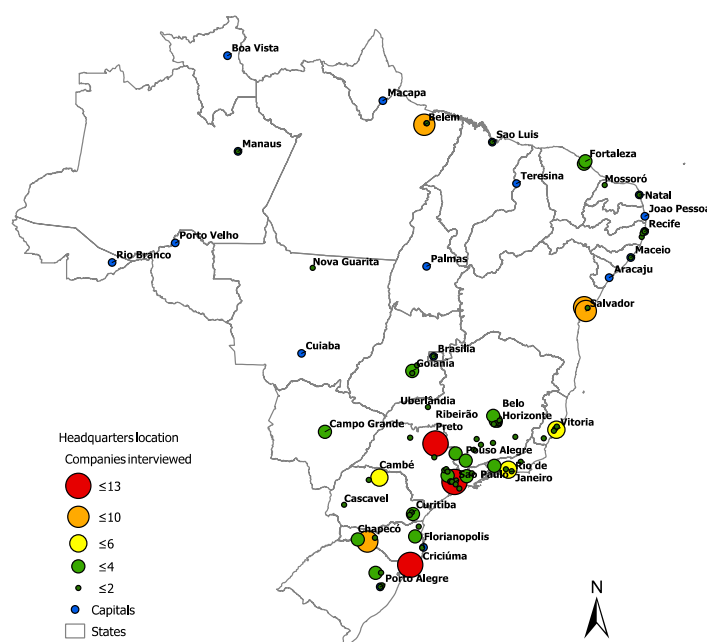


Figure 2. Location of the interviewed companies' headquarters.

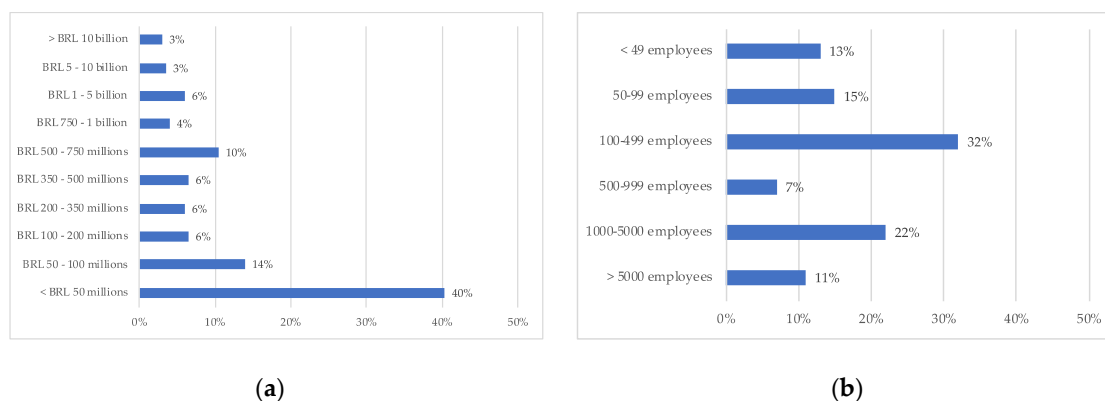


Figure 3. Characteristics of the companies: (a) gross sales (in REAL); (b) number of employees.

Table 3 presents the descriptive results for the importance of each attribute. It is possible to observe that the interviewees agree (“agree” or “totally agree”) with the impact of the importance of the attributes evaluated in urban freight vehicle choice. The first (representing 25% of respondents) and third quartile (representing 75% of respondents) responses in this category are 4 (agree) or 5 (totally agree). The reliability of the sample was evaluated using the Cronbach’s alpha; the results are acceptable (all are greater than 0.7) [25], and could be used to continue the analyses proposed in this paper.

Table 3. Descriptive results of the attributes.

Attribute	Cronbach’ Alpha	Minimum	1st Quartile	Median	3rd Quartile	Maximum
(A1) Number of deliveries in a route	0.79	1	4	4	5	5
(A2) Total distance in a route	0.79	1	4	4	4	5
(A3) Area of delivery	0.79	1	4	4	4	5
(A4) Type of goods	0.79	1	4	4	5	5
(A5) Variety of goods in a route	0.79	1	3	4	4	5
(A6) Freight vehicle restriction	0.79	1	4	4	5	5
(A7) Conditions of on-street load/unload areas	0.78	1	4	4	5	5
(A8) Condition of the access of establishments	0.78	1	4	4	5	5
(A9) Type of fuel	0.81	1	3	4	4	5
(A10) Capacity of vehicle (tons)	0.79	1	4	4	5	5
(A11) Capacity of vehicle (m ³)	0.78	1	4	4	5	5
(A12) Operational cost by kilometre	0.80	1	4	5	5	5
(A13) Vehicle cost (in the acquisition process)	0.82	1	4	5	5	5

3.1. Evaluation of the Importance of Attributes

Figure 4 presents a correlation matrix with the significance levels. The correlation is statistically significant (p -values < 0.05 are blank on the matrix). However, the correlation coefficient was poor or unacceptable (≤ 0.6), except for the following:

- The freight vehicle restriction (restriction) and conditions of the on-street loading/unloading area (On-streetLUArea) (0.67);
- Conditions of on-street loading/unloading area (on-street L/U area) and the condition of the access to commercial establishments (Access Establishments) (0.66);
- Capacity of vehicle (m³) and capacity of vehicle (tons) (0.69).

These results indicate a possible independence between these attributes (a low correlation). The result of the chi-squared test indicates that all combinations of these attributes resulted in a p -value of < 0.00 . Considering these results, we rejected the null hypothesis and concluded that there is an influence between these attributes.

Next, we proceed with the principal component analysis. First, the sampling adequacy (MSA) was measured using the KMO test presented in Table 4. Considering the 13 attributes, the overall value of the KMO test was 0.79, which is considered the median. The KMO test values of the attributes “type

of fuel” (A9) and “vehicle cost” (A13) are below the threshold of acceptability. Thus, these attributes were removed in order to perform the KMO test again (Table 4 indicates the second KMO, or KMO2), thereby obtaining an overall value of 0.82, which is considered acceptable. These 11 attributes were considered for the PCA.

Table 4. Measure of sampling adequacy of each attribute (KMO: Kaiser–Meyer–Olkin test).

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
KMO1	0.80	0.75	0.86	0.81	0.80	0.83	0.84	0.85	0.69	0.77	0.77	0.78	0.60
KMO2	0.86	0.78	0.87	0.83	0.72	0.86	0.83	0.85	-	0.78	0.77	0.79	-

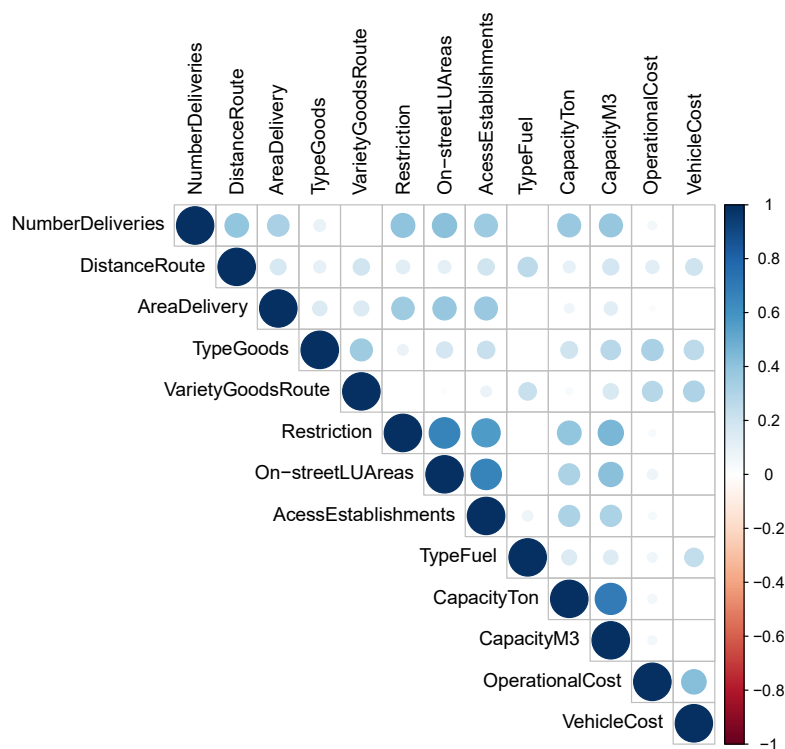


Figure 4. Correlation coefficients of the attributes (significance level < 0.05).

Table 5 shows the eigenvalue and variance of each principal component. The first five components have a cumulative variance percentile equal to 77.94%. Then, we considered these five components in the analysis.

Table 5. Eigenvalue and the proportion of variance of the principal component.

Component	Eigenvalue	Variance Percentile	Cumulative Variance Percentile
Component 1	4.38	39.83	39.83
Component 2	1.42	12.91	52.74
Component 3	1.10	10.00	62.74
Component 4	0.94	8.57	71.31
Component 5	0.72	6.61	77.92
Component 6	0.57	5.42	83.34
Component 7	0.54	5.04	88.38
Component 8	0.40	3.69	92.07
Component 9	0.36	3.36	95.43
Component 10	0.28	2.54	97.97
Component 11	0.22	2.03	100.00

Figure 5 shows the correlation circle between the attributes and the principal component, illustrating the eigenvalue ordered from the highest value for each component (called dimension in the plot). In this Figure, the attributes are also positively correlated, because they are grouped together. Further, the commonality (\cos^2) represents the quality of the attributes' representations. We observe that, in general, all attributes are representative (a warmer colour defines the most representative attribute), except for "distance in a route" and "area of delivery" (represented by the blue color).

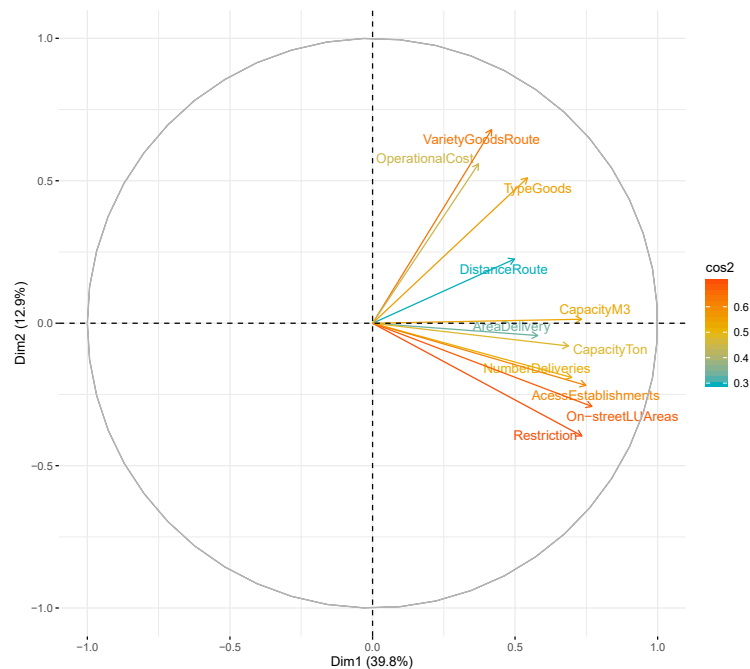


Figure 5. A correlation circle between the attributes and the principal component.

Table 6 presents the contribution of the attributes in the principal component (PC). The description of these components is:

- Principal component 1: restriction, on-street loading/unloading area, access of the establishments, and capacity of the vehicle (m^3). These attributes represent the route of the urban delivery;
- Principal component 2: type of product and variety of the goods in a route. These attributes represent the goods delivered in a route;
- Principal component 3: capacity of the vehicle in tons and m^3 . These attributes represent the area where the deliveries are performed, with the size of the vehicle reflecting its restrictions in urban areas. We excluded the attribute "area of delivery" due to its low significance in the Kruskal–Wallis test presented in Table 7, despite its contributing to this PC.
- Principal component 4: delivery route and distance of the route. These attributes represent the length of the route and are associated with the distribution cost;
- Principal component 5: operational cost. This attribute represents the expenses per kilometre of urban delivery.

The influence between these attributes in each component was analysed using a Kruskal–Wallis test. These results are presented in Table 7. In all cases, the null hypothesis was rejected due to the p -value being lower than 0.05. Thus, we conclude that the attributes in each component influence the urban freight vehicle choice.

Table 6. Contribution of the attributes in each principal component (PC).

Attribute	PC 1	PC 2	PC 3	PC 4	PC 5
(A1) Number of deliveries in a route	11.13	2.56	0.25	19.17	0.93
(A2) Total distance in a route	5.666	3.58	0.27	58.56	0.31
(A3) Area of delivery	7.67	0.13	24.26	0.02	12.84
(A4) Type of goods	6.74	18.31	1.17	9.08	3.64
(A5) Variety of goods in a route	3.99	32.54	0.74	0.01	16.99
(A6) Freight vehicle restriction	12.31	11.03	1.57	0.79	2.68
(A7) Conditions of on-street L/U areas	13.52	6.01	2.62	5.23	0.03
(A8) Condition of the access to establishments	12.76	3.35	7.78	3.34	0.01
(A10) Capacity of vehicle (tons)	10.78	0.45	29.95	0.37	0.55
(A11) Capacity of vehicle (m ³)	12.27	0.01	26.95	0.63	0.88
(A12) Operational costs by kilometre	3.15	22.04	4.43	2.49	61.13

Table 7. Kruskal–Wallis test of the attributes in each principal component.

Component	Kruskal–Wallis Chi-Squared	df	p-Value
PC 1	101.61	8	2.2×10^{-16}
PC 2	25.44	4	4.1×10^{-5}
PC 3	14.61	6	0.0235
PC 3 without “area of delivery”	104.06	4	2.2×10^{-16}
Component 4	39.34	4	5.9×10^{-8}

3.2. Influence of the Characteristics of the Companies in Choosing an Urban Freight Vehicle

Table 8 shows the influence of the characteristics of the companies in choosing an urban freight vehicle. We present only the models that are statistically significant, i.e., those with a *p*-value of <0.05.

Table 8. Proportional odds model (1: Totally Disagree; 2: Disagree; 3: Neutral; 4: Agree; 5: Totally Agree).

Model	Dependent Variable	Independent Variable	AIC	Odds Likert Intercepts			
				1–2	2–3	3–4	4–5
1	Delivery route		358.57	0.005	0.009	0.07	2.06
2	Distance route		358.27	0.004	0.02	0.11	4.47
3	Area delivery	Number of employees	401.94	0.01	0.04	0.16	4.26
4	Type of Goods		425.47	0.007	0.05	0.20	3.01
5	Capacity vehicle ton		335.48	0.005	0.015	0.05	2.74

4. Discussions

These results have been taken from a reliable sample, considering the Cronbach’s alpha results. The sample is composed of 202 logistics operators in Brazil who perform urban deliveries in different regions.

The attributes evaluated by these companies have low correlation, except in the following areas:

- Freight vehicle restrictions and the conditions of on-street loading/unloading areas could be explained by a phenomenon that happens in cities with truck time restrictions; many trucks occupy loading and unloading areas for a longer period of time to circumvent restricted hours;
- The correlation between the conditions of the on-street loading/unloading (L/U) area and the conditions of access of commercial establishments could be explained by the lack of guidelines to implement these L/U areas in Brazil;
- The capacity of the vehicle in m³ and tons is another obvious correlation.

The principal component analysis (PCA) indicated five components of the attributes. The first represents the route of the urban delivery, and is composed of restrictions, the on-street

loading/unloading area, access to the establishments, and capacity of the vehicle (m^3). The second component represents the type of goods being delivered in a route, and is composed of the type of product and the variety of the goods in the route. The third reflects the size of the vehicle, reflecting its restrictions in urban areas, and is composed of the capacity of the vehicle in tons and m^3 . The fourth component represents the length of the route and is associated with the distribution cost, associated with the delivery route and the distance of that route. Finally, the last component is associated with the operational cost and is composed of operational cost. We confirmed the influence of these attributes in each component using a Kruskal–Wallis test (for a component with three or more attributes) or a Mann–Whitney test (for components with two attributes).

The PCA results indicate that operating factors, product type, and operating cost influence freight vehicle choice. These results, although evident, change the selection criteria depending on local city policies. For example, the urban freight vehicle choice could be influenced by the types of goods being delivered or the distribution cost in a city without freight restrictions. In these cases, when there are no policy restrictions, Brazilian carriers worry about optimizing their load with the size of the vehicle in order to reduce the number of trips, and consequently reduce their costs within the distribution process. This result is important for an in-depth analysis of a city's fleet type and local policies, in order to improve urban mobility and accessibility.

Finally, the ordered logistic regression models indicate that the characteristic “number of employees” influences the choice of an urban freight vehicle based on the number of deliveries in a route, the total distance in a route, the area of delivery (central area, historical, area, or suburb), the type of goods, and the capacity of the vehicle (in tons). Since the number of employees is an indicator of the size of a company, we can conclude that large companies should take greater consideration of the operational attributes in freight vehicle choice than smaller companies. We can also highlight that small companies in Brazil are not very worried about the types of vehicle used to perform their delivery, as long as each delivery is in accordance with the final costs of the operation.

In general, the fleet of small companies is focused on their product and the total distance of a route. Small Brazilian companies, due to the impositions of the current legislation, do not concentrate on aspects that can involve operational impacts and possibly improve the level of their operational service, giving priority instead to common-sense solutions, which can help justify the results obtained.

5. Conclusions

In summary, this paper suggests, for Brazil, some of the most important attributes in the choice urban freight vehicles. These are attributes related to the route of the urban delivery, the features of the goods delivered on a route, the area where the deliveries are performed, and the distribution cost.

In addition, another important consideration for this paper is how the attributes of vehicle choice decision vary with the size a company. This means that large companies take some factors into account as related operational attributes, which are not the most important variables for small enterprises. This suggests that these companies are subject to different market conditions and are influential in the goods distribution process.

These results also allow us to conclude that the type and size of products influence the number of products inside the freight vehicle, and consequently, influence the number of deliveries by route. Therefore, the choice of an urban freight vehicle is strongly influenced by its operational cost and route, which are influenced by all the attributes mentioned above (i.e., a vicious cycle). These attributes agree with those found during the literature review.

The usage of principal component analysis is innovative, since this approach has been used with a higher number of attributes in the literature. Consequently, this method proved to be useful in reducing the number of attributes, even those with fewer elements. Similar analyses could be carried out based on the size of the companies and the types of products delivered, in order to identify if the attributes are the same as those obtained in this paper.

Finally, as a suggestion for future works, the correlation between city policies and attributes for urban freight vehicle choice, as well as the influence of the number of employees on this choice, could help us understand similar differences found between different cities and companies.

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