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Modelling travel mode choice and characterising freight transport in a Brazilian context

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Abstract

Freight transportation in Brazil is characterised by the predominance of the road travel mode. This imbalance in the sector suggests the need to develop efficient strategies that can increase competitiveness of alternative modes such as the railway network. However, in Brazil, there are few studies investigating firms' preferences concerning different attributes of travel modes. This study analyses the travel mode choice decision-making process of shippers in the state of Rio de Janeiro, Brazil. The main objectives of this article are related to model travel mode choice and characterise freight transport in a Brazilian context. Discrete choice models were estimated using Stated Preference data to identify shippers' preferences and discuss some possible sustainable policies that could increase the competitiveness of the railway network. Multinomial and mixed logit models were estimated. Elasticities and probability marginal effects were computed, and different scenarios were simulated to predict the possible effects of implementing alternative transport policies. The elasticity results imply that demand is more elastic regarding cost than other variables. A 1% decrease in the cost of rail induces a 2.71% increase in rail demand. Marginal effect values show that a door-to-door service has the highest potential to increase rail demand. However, providing a door-to-door service would likely have huge operational costs, which would increase the rail cost and therefore reduce the overall benefits. Simulation results show that shippers' preferences have low sensitivity to changing factors. Finally, covariates associated with the Brazilian context, how to measure them properly and apply them in freight models of similar regions are also discussed.

Keywords: Freight Transport; Mode Choice; Stated Preference; Discrete Choice Model; Road Transport; Rail Transport; Transport Policy.

1. Introduction

Economic growth has been accompanied by the increased use of freight transport. However, currently, further increases have been met with criticism, as the public has concerns regarding emissions and noise pollution (Feige, 2007). Concern about reducing road use has been growing in the world due to environmental problems, safety issues and reasons of efficiency (Bontekoning *et al*., 2004; Islam *et al*., 2014; Marcucci *et al*., 2021). According to Forkenbrock (2001), studies on the freight mode choice, mainly competition between road transport and rail transport, are becoming critical to improving freight efficiency. However, to analyse the freight mode choice, the different perceptions and criteria considered in the selection process need to be understood (Woxenius and Bärthel, 2008).

In Brazil, freight transport is marked by the frequent use of the road travel mode (Larranaga *et al*., 2017). Road transport accounted for 61% of total freight transport in the country (CNT, 2019a). The railway mode mainly transports commodities: iron ore accounted for 74% of the total cargo transported by rail; followed by agricultural bulk material (17%) and others (9%) (ANTT, 2018). This imbalance in the Brazilian transport matrix affects the relative prices charged per ton per kilometre in different travel modes (PELC, 2015a). Therefore, an important objective for the sustainable development of the freight transport sector is to encourage replacing the road mode with other alternatives (Behrends, 2017).

Travel demand models for cargo transportation have evolved more slowly and are considered methodologically more complex than passenger models. The difficulty of obtaining disaggregated data has been pointed out as a major challenge for freight transport models (Rashidi and Roorda, 2018), especially in developing countries (Tapia *et al*., 2019). Besides data, the decision-making process for freight transport is more complex than for passengers because it diverges from the latter in terms of players and product diversity (Arunotayanun and Polak, 2009; de Jong *et al*., 2013; Marcucci, 2013; Holguín-Veras *et al*., 2021). Advances in data acquisition and econometric techniques have led to using disaggregated models (Tavasszy and de Jong, 2014). Examples can be found in the choice of shipment size or mode choice models, which are often based on disaggregated data from Stated Preference (SP) or Revealed Preference (RP) data (De Jong *et al*., 2016). SP surveys ask respondents to make choices in a series of hypothetical scenarios, while RP data are records of real choices (Hess *et al*., 2012; Lavasani *et al*., 2017).

This study aims to model travel mode choice and to characterise freight transportation in Brazil, including important covariates for the Brazilian context. Furthermore, the decision-making process is analysed related to the travel mode choice for general cargo transportation firms in the state of Rio de Janeiro, Brazil. This study is based on responses to a SP questionnaire from companies operating in the state. Increasing the efficiency of transport systems can be achieved through appropriate transport policies. However, to formulate adequate transport policies, it is essential to know firms' preferences (Danielis and Marcucci, 2007; Marcucci *et al*., 2018). Therefore, this paper aims to meet three objectives: (i) to develop models using SP data to identify the most relevant attributes and predict travel mode choice; (ii) to characterise the Brazilian context of freight transportation; and (iii) to analyse different simulation scenarios to discuss which transport policies could encourage using rail transport. The analytical results suggest some strategies aimed at increasing the market share of railways. It is also worth noting that the types of products (general cargo) included in this study are mainly transported by road in Brazil.

This paper investigates the decision-making process in a different context from those generally reported in the literature. Few studies based on the competition of travel mode choice have been conducted in developing countries, and in particular, few studies have been found with a disaggregated approach in Brazil (e.g., Larranaga *et al*., 2017; Novaes *et al*., 2006). Freight transportation demand modelling in Brazil is still incipient due to the difficulty of obtaining data (Novaes *et al*., 2006). Therefore, analysing a Brazilian case study, considering its problems related to logistics and lack of infrastructure, is important to formulate public policies. In order to represent the characteristics of the Brazilian cargo transportation system, representative variables for the national context were used. Cargo theft is a critical issue, and Brazil and Mexico are the main examples of countries with high risks of cargo theft considering a global analysis (JCC Annual Cargo Forum, 2017). In Brazil, there is a concentration of cases in the Southeast region (84.8%). The states of Rio de Janeiro (41.4%) and São Paulo (39.4%) correspond to more than 80% of cargo theft cases (ISP/RJ, 2019). Service availability of rail transport is also an important issue for freight transport in Brazil, which has a lower rail density compared to developed countries or even other developing countries. The length of the Brazilian rail network amounts to around 29,320 kilometres. This length is equivalent to an average density of 3.5 Km/1000 km² of territorial area and still does not serve a significant number of states (ANTF, 2021). Other countries have the following density values (Km/1000 km²): USA (29.8); India (20.8); Argentina (13.3); China (13.2); Russia (5.1); Australia (4.8) (ANTF, 2018). Thus, the results obtained in this article can be used for developing regions with similar characteristics to the study area analysed in this paper.

In addition to this introductory section, the remainder of the paper is structured as follows. Section 2 provides a literature review. Section 3 provides an overview of freight transport in the region. Section 4 describes the proposed method. Section 5 presents the results. Finally, Section 6 presents the conclusions and suggestions for future research.

2. Literature Review

To promote alternative modes for freight transport, several studies have been carried out in different regions. There are a variety of factors that influence the travel mode choice process (Holguín-Veras *et al*., 2021). Table 1 shows the variables considered, in which freight rates, transit times and reliability are some of the most widely used in selected studies from different areas. Furthermore, Table 1 includes the main studies carried out in Brazil.

Even though many policies establishing the use of intermodal transportation around the world have been proposed, they have had little impact on inducing firms to change mode choice from road transport to alternative ones. One main reason might be that the companies´ requirements towards transportation modes are still not well understood (Tavasszy *et al*., 2020). In fact, the lack of knowledge about the behavioral response of the firms could lead to negative unintended effects or ineffective policymaking (Holguín-Veras *et al*., 2021).

In the Brazilian context, there are only a few studies regarding the freight mode choice. Novaes *et al*. (2006) examined the demand for high value cargo, analysing road, rail and cabotage. The study identified the relative importance of the tariff and reliability variables in the mode choice process. Larranaga *et al*. (2017) analysed shippers´ preferences in the state of Rio Grande do Sul (South region of Brazil) for road, rail and waterways. The study concluded that increasing the reliability of intermodal alternatives is more effective in encouraging these modes than reducing freight rates.

Table 1: Factors analysed in freight mode choice literature

Article	Area	Factors
Abate *et al.* (2019)	Europe	Freight, time, shipment size, commodity type, shipment value
Arencibia *et al.* (2015)	Europe	Freight, time, frequency, punctuality
Brooks *et al.* (2012)	Australia	Time, frequency, reliability
Comi and Polimeni (2020)	Europe	Freight, time, frequency, shipment size
Feo-Valero *et al.* (2016)	Europa (Spain)	Time, cost, frequency, reliability
Jensen *et al.* (2019)	Europe	Freight, time, shipment size, commodity type
Keya *et al.* (2019)	North America	Freight, time, shipment size, commodity type, shipment value, industry sector, shipment density, inventory costs
Kim *et al.* (2017)	Oceania (New Zealand)	Freight, transit time, reliability, cost of damage
Larranaga *et al.* (2017)	Brazil	Freight, time, delay, punctuality
Novaes *et al.* (2006)	Brazil	Freight, time, frequency, reliability, security
Nugroho et al. (2016)	Asia (Indonesia)	Freight, time, reliability and emissions
Tapia *et al.* (2019)	Argentina	Freight, time, frequency, reliability, loss and damage
Tapia *et al.* (2020)	Argentina	Freight, time, frequency and reliability

In the European context, Jackson *et al.* (2014) interviewed shippers and identified the following companies' requirements to assess the market potential of rail transport:

1. Reliability: Transit time and reliability of the rail mode must be competitive with road alternatives.
2. Costs: Rail transport generally, but not always, has higher costs than road transport, particularly for shorter distances.
3. Door-to-door service: Service availability in the origin and destination zones is important. However, rail mode has limitations compared to road mode with respect to flexibility.
4. Ecological alternative: rail has an advantage over other transport alternatives to provide sustainable service.
5. Safety: rail transport reduces the possibility of losses and theft.

Thus, the presence of a railway infrastructure (third requirement) in origin and destination is a fundamental factor for analysing policies to encourage the railway mode. In Brazil, which has a low rail density in the territory, encouraging railway use is even more challenging. Shippers in most situations only have the road alternative in Brazil. The situation of a single available travel mode is rare for the passenger context, but it is much more common in freight transport since underlying competing networks are limited (Rich *et al*., 2011).

In this context, the variation of elasticities reported in freight demand modelling studies in Europe (Beuthe *et al*., 2001; Bjørner and Jensen, 1997; Forss and Ramstead, 2007; Yin *et al*., 2005; Feo-Valero *et al*., 2011, de Jong *et al*., 2013) and the United States (Abdelwahab, 1998; Chow *et al*., 2010; Samimi *et al*., 2010; Winebrake *et al*., 2015) tends to have a wide range. This variation is due to methodological and geographical differences (Rich *et al*., 2009, 2011), distance and types of products (Vassallo and Fagan, 2007; Wang *et al*., 2013). In addition, there may be major differences in travel mode freight competition between developed and developing countries due to natural or inherited causes (Tapia *et al*., 2019).

The impact of local conditions is supported in the literature. Forss and Ramstead (2007) showed that the impact of road charging is not relevant in the mode choice in Sweden. Rich *et al*. (2011) pointed out that, in the case of road charges imposed in regions with poorly developed travel mode alternatives (e.g., rail networks), the modal shift may be modest due to the "*structural inelasticity*", which is a result of the lack of alternative modes to compete with road transport.

3. Overview of Freight Transport in the State of Rio de Janeiro (Brazil)

The state of Rio de Janeiro is located in the southeast region of Brazil. It is bordered by the states of Minas Gerais (north and northwest), Espírito Santo (northeast) and São Paulo (southwest), in addition to the Atlantic Ocean (east and south).

It has an estimated population of 16,635,996 inhabitants and is the second largest economy in the country in terms of Gross Domestic Product (GDP). The state has an area of 43,782 km² and 92 municipalities (IBGE, 2016a).

3.1 Road Transport: infrastructure and types of products

The main road corridors in the state of Rio de Janeiro are formed by federal highways. It is worth noting that six products correspond to 85% of the road flow in the state, especially in General Cargo[1]. The following products are considered relevant in the road flow: General cargo (44%); Iron ore (15%); Cement (8%); Non-ferrous metal ores (Bauxite) (5%); Semi-finished, flat-rolled, long and steel tubes (5%); and Ethanol (5%) (PELC, 2015a).

3.2 Rail Transport: infrastructure and types of products

In Rio de Janeiro, there are two freight rail companies: *MRS Logística* (MRS) and *Ferrovia Centro-Atlântica* (FCA). The MRS network starts in Belo Horizonte (MG), connecting the capital of Rio de Janeiro and the Port of Itaguaí (RJ) (Figure 1a). The FCA network is broad and includes the states of Espírito Santo, Minas Gerais and São Paulo (Figure 1b).

In the MRS network, the cargo is transported from the state of Minas Gerais to the state of São Paulo. The main product transported in this network is iron ore (61%). Transporting steel products to the capital of São Paulo is also significant. The origin of

[1] General Cargo corresponds to seven types of products: (i) Machines and equipment; (ii) Food and beverage; (iii) Construction material for equipment parts in the air, naval and railway sectors.; (iv) Drugs, hygiene and hospital; (v) Plastics and rubber; (vi) Graphic industry; and (vii) Others (PELC, 2015b).

FCA cargo is Minas Gerais and its destination is the state of Espírito Santo (ES). The main products transported are agricultural products, such as soybeans, corn and soybean meal (Table 2).

There are two relevant rail corridors connecting Rio de Janeiro with other states in the Southeast region: i) the state of Minas Gerais (MG) – the state of Rio de Janeiro (RJ) and ii) the state of São Paulo (SP) – the state of Rio de Janeiro (RJ). The first corridor is strategically important, connecting the state of Minas Gerais (MG) to the two main ports in the state of Rio de Janeiro (RJ): Itaguaí and Rio de Janeiro. The rail network of this corridor is formed by the MRS network and is 1,013 km long. The main products transported are (i) Iron ore, (ii) Cement, (iii) Steel products, (iv) Industrial products and (v) Minerals (Figure 1a). The second corridor is important due to the integration of the region with the largest industrial concentration in Brazil to the main ports of the state of Rio de Janeiro. The main products transported in this corridor are (i) Iron ore, (ii) Coal and (iii) Industrialised products (Figure 1b).

Table 2: Products transported through the state of Rio de Janeiro

PRODUCT	ORIGIN	DESTINATION	VOLUME BY NETWORK %	RAILWAY
Iron ore	MG	SP	61%	MRS
Steel products	MG	SP	18%	MRS
Cement	MG	SP	12%	MRS
Limestone	MG	SP	4%	MRS
Manganese	MG	SP	3%	MRS
Pig iron	MG	SP	1%	MRS
Steel products	SP	MG	1%	MRS
Soy	MG	ES	41%	FCA
Corn grains	MG	ES	34%	FCA
Soybean bran	MG/GO	ES	12%	FCA
Full 20 feet container[2]	MG	ES	4%	FCA
General cargo	MG	ES	3%	FCA
Copper	GO	ES	3%	FCA
Limestone	MG	ES	1%	FCA

Legend: ES: State of Espírito Santo; GO: State of Goiás; MG: State of Minas Gerais; SP: State of São Paulo.

Source: PELC, 2015b.

[2] Cargo type is not bulk. Products are included in a container.

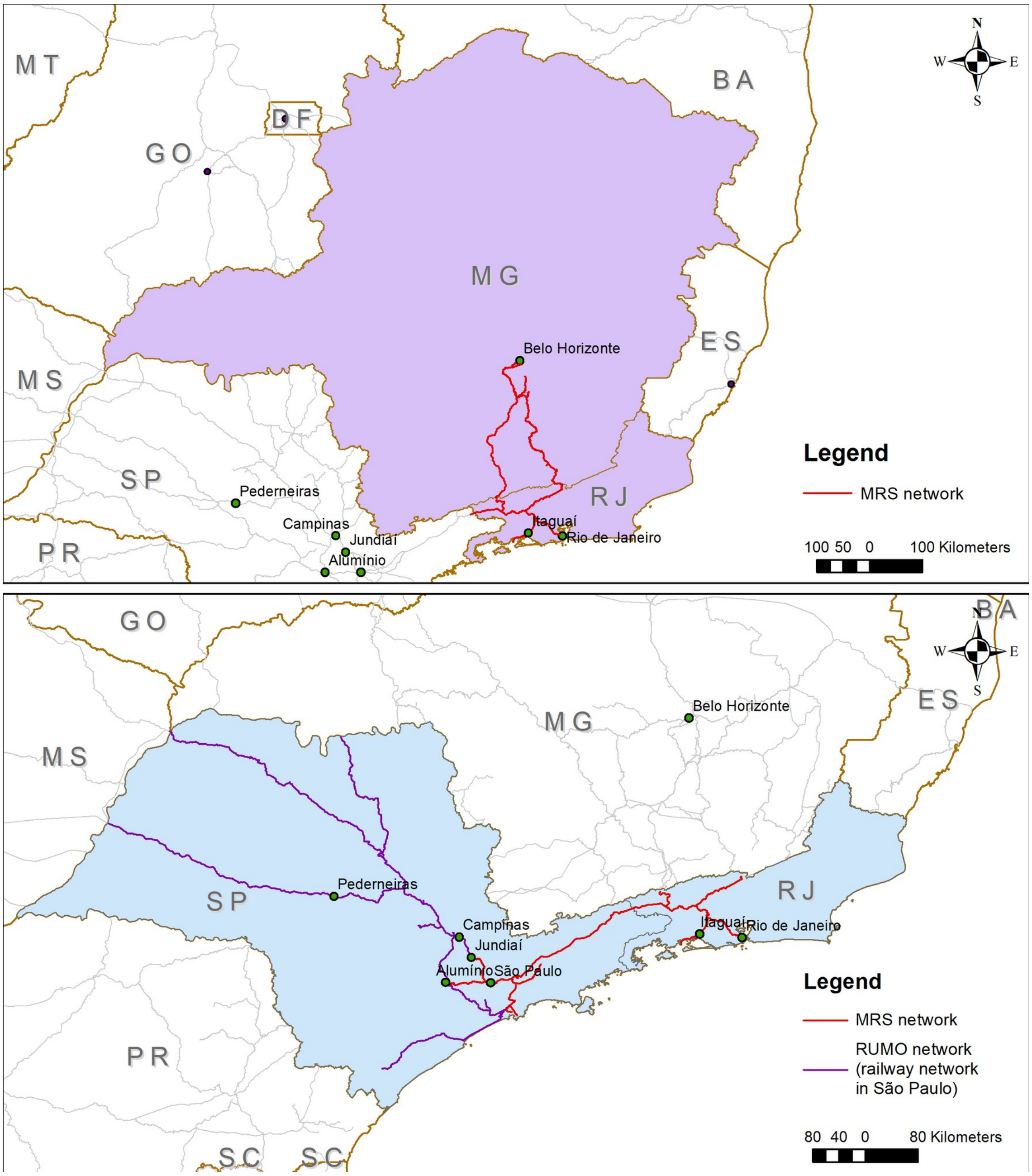

Figure 1: Maps of Rail corridors connecting: a) Rio de Janeiro (RJ) and Minas Gerais (MG) (upper); b) Rio de Janeiro (RJ) and São Paulo (SP) (lower).

Source: PELC, 2015b

4. Materials and Method

This section presents the research development regarding the modelling approach, data collection and questionnaire design. For the development of the SP study, an adaptation of the sequence proposed by Louviere *et al*. (2000) was used (Figure 2).

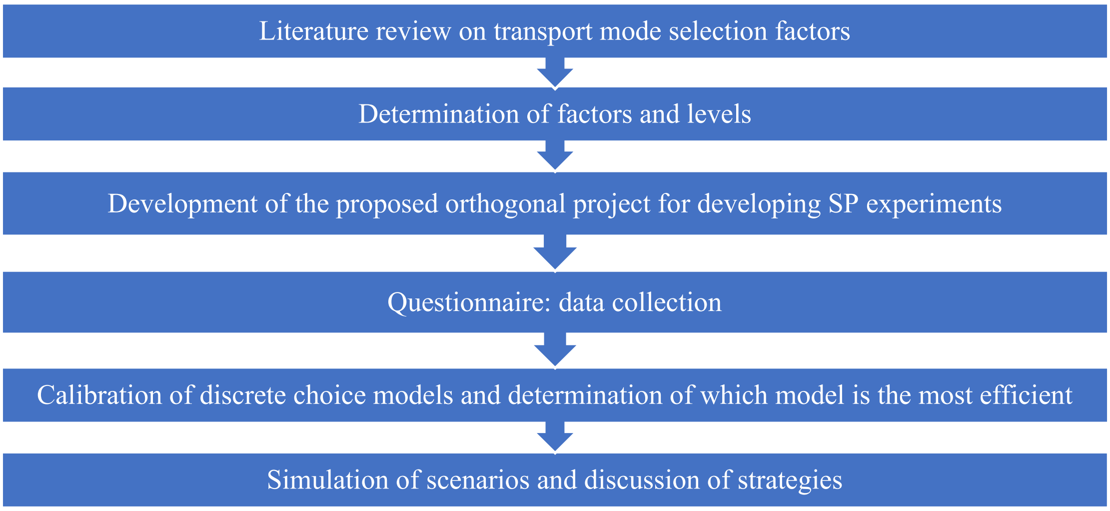

Figure 2: Stages of the study (adapted from Louviere *et al*., 2000)

4.1 Modelling approach

Discrete choice analysis was used to model shippers' preferences, based on the random utility theory (McFadden, 1974). This theory assumes that every individual is a rational decision-maker, maximising utility relative to his/her choices. The models adopted in this study comprise Multinomial Logit (MNL) and Mixed Logit (ML) with linear and non-linear attribute effects. Simpler structures were tested first, such as MNL models (McFadden, 1974), assuming that stochastic errors have an IID Gumbel distribution. This assumption for the distribution of residuals is rather simplistic, as they depend on the hypothesis of independence and homoscedasticity of residues (Ben-Akiva *et al*., 2003). Thus, ML models with random coefficient specification (McFadden and Train, 2000) were estimated to account for preference heterogeneity and correlation among the choices of the same shippers, considering normal distributions of the parameters. In this article, for ML models, linear and non-linear parameters were tested. Non-linearity was tested for ML models by using different mathematical transformations related to logarithmic and power series transformations for time and cost. Several studies highlight the importance of non-linearities in the freight context (Gatta and Marcucci, 2016; Marcucci *et al*., 2015). Model estimation was performed using R (R Core Team, 2020) and the Apollo package (Hess and Palma, 2019).

Elasticities and marginal effects of the probability of choosing a travel mode regarding the independent variables were computed to analyse the change in demand due to changes in the independent variables. In the case of a continuous variable (x_{ink}), the direct and cross elasticity were computed using Equation 1 and 2, respectively (Ben-Akiva and Lerman, 1985).

$$E_{x_{ink}}^{P_n(i)} = \left(1 - P_n(i)\right) x_{ink} \beta_k \quad Eq.1$$

$$E_{x_{jnk}}^{P_n(i)} = -P_n(j) x_{jnk} \beta_k \quad Eq.2$$

where n enumerates individuals, i is the chosen alternative and k enumerates attributes. $P_n(i)$ is the probability of individual n choosing alternative i, $P_n(j)$ the probability of individual n choosing alternative j, x_{ink} is the value of attribute k for alternative i for individual n, β_k is the coefficient of attribute k, and $E_{x_{ink}}^{P_n(i)}$ is the elasticity of the choice probability of alternative i with respect to changes in the value of attribute k of the same alternative. Finally, $E_{x_{jnk}}^{P_n(i)}$ is the cross-elasticity of the probability of choosing alternative i with respect to changes in attribute k of another alternative j. Elasticities indicate the percentage change in the probability of choosing an alternative due to a 1% increase in the independent variable. The direct-elasticities relate to attributes of the alternative under consideration and the cross-elasticities to attributes of competing alternatives. In the case of dummy variables, marginal effects were calculated using Equation 3 for the direct marginal probability effect and Equation 4 for the cross marginal probability effect.

$$\Delta P_{nk}(i) = P_n(i | x_{ink}=1) - P_n(i | x_{ink}=0) \quad Eq.3$$

$$\Delta P_{nk}(i \vee x_{jn}) = P_n(i | x_{jnk}=1) - P_n(i | x_{jnk}=0) \quad Eq.4$$

Elasticities and marginal effects were computed for individuals' choices and aggregated by sample enumeration techniques for the overall value (Wooldridge, 2010). Aggregated choice probabilities were calculated for different scenarios to predict market shares based on applying different policies. Aggregated values of elasticities and marginal effects were computed by sample enumeration techniques.

Estimated parameters from the discrete choice models were used to simulate the market shares of the alternatives and predict the possible effects of implementing different possible policies. The baseline scenario was defined based on useful information from the Secretary of State for Transport of Rio de Janeiro, aiming to obtain an initial scenario close to the current conditions in the region. Different scenarios were simulated, varying the attributes identified as significant to assess possible policies to promote railroads.

4.2. Data collection and questionnaire design

4.2.1 The sample: survey, sample size and type of products

An online SP survey was conducted to analyse shippers' decision-making for freight transport service in the state of Rio de Janeiro during August and September of 2016. Logistics managers were previously contacted by the authors to explain the entire survey and check their availability to participate. In the case of a positive response, the online survey was sent. During the data collection stage, 35 companies were contacted, and 26 companies answered. It is worth mentioning that from the questionnaires, it was found that small companies hardly use the railway mode due to the low volume of cargo. This fact restricted the sample to large companies.

Even though the sample size is smaller than conventionally used for passenger travel demand modelling, it is in line with the minimum sample size required for SP studies (Bliemer and Rose, 2005, 2009, 2010; and Rose and Bliemer, 2005, 2012). The sample size used in freight transport demand modelling is lower than that usually used for passenger transport because the population of interest is smaller (Larranaga *et al.*, 2017). Furthermore, restrictions on obtaining data from freight companies and the lack of public available disaggregated data related to freight transport make it less common to estimate disaggregated models (Tavasszy and de Jong, 2014).

Respondents in our sample were large companies in the following categories: 1) producers and distributors and 2) companies in the wholesale sector that operate over long distances. They were selected based on recommendations from Feo-Valero *et al*. (2016), Fridstrom and Madslien (1995) and Masiero and Hensher (2010, 2012).

Regarding the type of companies' products, the study sought to analyse the main products included in general cargo flow between the states of Rio de Janeiro and São Paulo. It is worth mentioning that the state of São Paulo has the highest GDP in Brazil (32.2% of the total GDP of the country), followed by the state of Rio de Janeiro (IBGE, 2016b). The main types of products between these states in the general cargo category flow are: 1) Machinery and Equipment, 2) Food and Beverages, 3) Drugs, Hygiene and Hospital and 4) Others. These types of products correspond to about 85% of the general flow of General Cargo between these two states (PELC, 2015a). Thus, these products were selected for the final sample.

The 26 companies were distributed into four types of products in the general cargo: Food and Beverage (11), Drugs, Hygiene and Hospital (5), Machinery and Equipment (4) and Others (6). The questionnaire had two sections: 1) General information about the company operations and opinions (e.g., Use of rail mode, Main origin region of the company's cargo, Main destination region of the company's cargo, Main problems in the transportation infrastructure); (2) The SP experiment, in which eight choice situations were presented to the logistics managers. In each of them, they were asked to choose their preferred travel mode between two alternatives, (i) Road and (ii) Rail.

4.2.2 Attribute Selection

Six attributes were used to describe each alternative in the SP experiment.

i. <u>Cost</u>: Transportation tariff expressed as Brazilian Reais (BRL[3]) per ton.
ii. <u>Total travel time</u>: Measured from the time of collection to delivery to the customer.
iii. <u>Service availability that each transport operation can offer</u>: It may be "door-to-door", meaning the cargo is collected at the customer's address and delivered at the final destination; or "mode-to-mode", meaning that the cargo is only transported between two points where the transport operator has cargo terminals.
iv. <u>Reliability</u>: Frequency (%) at which the transport service is performed without delays.
v. <u>Availability</u>: Period of the year during which the travel mode can be used.
vi. <u>Cargo theft risk</u>: Likelihood of cargo loss due to theft during road transport.

The attribute selection was based on a literature review of relevant national and international papers in the freight transport field (Beuthe and Bouffioux, 2008; Cullinane and Toy, 2000; Danielis and Marcucci, 2007; Daniellis *et al*., 2005; De Jong *et al*., 2001, 2014; Feo *et al*., 2011; Feo-Valero *et al*., 2016; Kofteci *et al*., 2010; Masiero and Hensher, 2012; Moschovou and Giannopoulos, 2012; Norojomo and Young, 2003; Novaes *et al*., 2006; Nugroho *et al*., 2016; Puckett and Hensher, 2008; Shinghal and Fowkes, 2002; Tsamboulas and Kapros, 2000; Zamparini *et al*., 2011). The selected attributes and their respective levels were discussed with the Secretary of State for Transport of Rio de Janeiro.

The service availability represents the presence of infrastructure for the transportation of cargo between the origin and final destination, as suggested by Jackson *et al* (2014) as an important requirement. The term "door to door" was previously defined in the questionnaire and it was understood by the respondents as having a train station next to their production sites and their destination sites. The term "mode to

[3] 1 BRL = 0.20 US Dollars (date: December 16, 2020).

mode" was defined as a situation in which cargo is only transported between two regions where the transport operator has freight terminals. This is the current situation in the region.

Danielis *et al*. (2005) and Novaes *et al*. (2006) analysed the cargo theft risk. The inclusion of this attribute was based on the current situation in Brazil, especially in the state of Rio de Janeiro, which recorded 9,870 cases of cargo theft in 2016 and is the state with the highest number of cargo theft occurrences in Brazil (ISP/RJ, 2017). Table 3 displays the attributes adopted and their corresponding levels. Conveying risk levels is a difficult task due to multiple perception biases (Baron, 2004). In our study, risk was described qualitatively, only using two levels, "likely" and "unlikely". This enabled us to control the attribute, while not drawing excessive attention to it due to an overly detailed description. However, its simple description may have introduced additional variabilities considering different interpretations by respondents.

Respondents were asked to consider a context where they had to send a load of 20 product pallets over a distance larger than 350 km (representing the average distance between Rio de Janeiro and São Paulo). This context was defined following the strategy used by studies in New Zealand (Kim, 2014; Kim *et al*., 2017).

Table 3: Attributes and corresponding levels for each travel mode

Attribute	A) Road	B) Rail
Cost (logistic cost level)	**100 (BRL)[4]/ton**	**60%** or **90% of current values for Road**
Time (travel time levels between origin and destination)	**6 hours[5]**	**20%** or **60% of current values for Road**
Service Availability	**Door-to-Door**	**Door-to-Door** or **Mode-to-Mode**
Reliability (deliveries made within the stipulated time)	**100%**	**70%** or **90%**
Availability	**All Year Round**	**Between Harvests** or **All Year Round**
Cargo Theft Risk	**Likely or Unlikely**	**Unlikely**

4.2.3 Experimental design

The experimental design was structured using an orthogonal fractional factorial design. Prior information about the parameters was not available, leading to an orthogonal design instead of an efficient design (Rose and Bliemer, 2009).

The final design included 16 choice situations divided into two blocks to avoid fatigue and simplify the interviewees' choice process. Each respondent answered one block. Questionnaires 1 and 2 were then distributed to the interviewees, completing the design for every two respondents. Figure 3 shows an example scenario from the final questionnaire.

[4] 100 BRL = 19.60 US Dollars (date: December 16, 2020).

[5] Travel time between Rio de Janeiro and São Paulo, based on an average speed of 60 kilometres per hour

First Scenario		
The company is sending a shipment of 20 pallets of products over a distance of 350 kilometers. Evaluate the conditions of each travel mode and select which would be the company's choice.		
	A) Road	B) Rail
Cost	100 BRL/ton	60 BRL/ton
Time	6 hours	7 hours and 20 minutes
Service	Door to door	Mode to mode
Reliability	100%	70%
Availability	All Year Round	All Year Round
Cargo Theft Risk	Likely	Unlikely
Which option would the company choose?		

Figure 3: Example of the scenarios presented to companies

4.2.4 Information on companies

- **Use of rail mode**

Only three companies declared the use of rail mode, one in the "Machinery and Equipment" sector, one in the "Food and Beverage" sector and one in the "Other" sector. Two companies declared that they tried to use Rails but were unable, mainly due to the lack of rail networks (one in the "Food and Beverage sector" and one in the "Machinery and Equipment" sector). Twenty-one companies stated that they do not use rail transport. The low number of companies with industrialised products in the sample reveals the difficulty in obtaining data from companies with railway operations, especially for the category of products included in this study, as these products have greater adherence to the road mode.

- **Main origin and destination regions of the company's cargo**

The states of Rio de Janeiro, São Paulo and Minas Gerais were the most cited origins, while the states of Rio de Janeiro and São Paulo were the most common destinations, as Table 4 shows.

Table 4: Main origins and destinations of cargo among the surveyed companies (%)

State/Region	*Origin*	*Destination*
Minas Gerais	23	
Sao Paulo	23	13
North-East Region	4	3
Rio de Janeiro	27	36
South Region	4	3
South-East Region	4	3
Bahia (BA)	3	7
Uberlândia (MG)	3	3
Rio Grande do Norte (RN)	3	
Ceará	3	
Brazil	3	10
Macaé (RJ)		3
Cambará (PR)		3
Ibipora (PR)		3
Uberaba (MG)		3
Cuiabá (MT)		3
Rio Grande do Sul (RS)		7
Total	100	100

- **Main problems in the transportation infrastructure in the state of Rio de Janeiro**

Figure 4 summarises the main factors considered critical faced by companies with logistical operations in the state of Rio de Janeiro, according to the interviewees. In total, 10 critical factors were mentioned by companies. Traffic and cargo theft were the most cited factors. It should be noted that the problems reported by the companies were related to daily operations in road mode. Since most companies use road mode as the only alternative, the answers were directed to questions related to traffic, cargo theft and the road situation. Few companies have made considerations about the railways. In the questionnaire, each respondent company could include more than one factor considered critical.

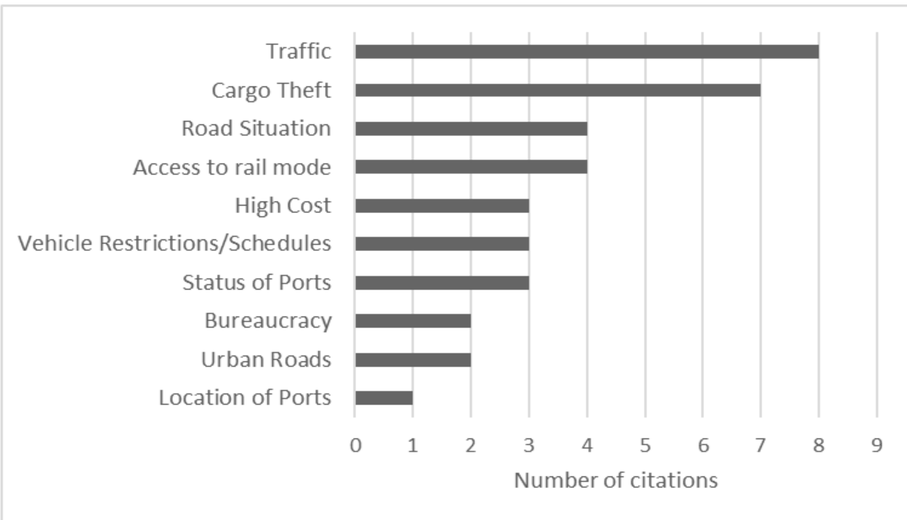

Figure 4: Main problems companies faced in logistics operations in the state of Rio de Janeiro

5. Results

The responses of 26 companies generated 208 choices, with a volume of observations considered sufficient to estimate the choice models. Table 5 presents the estimation results for the MNL and ML models. Contrary to expectations, the coefficient associated to *Cargo Theft Risk* was not significantly different from zero (95% confidence level) in any of the estimated models. Thus, this variable was excluded from the estimated models presented in this paper.

The estimated models showed a good overall fit (Pseudo-R^2 of 0.26 and 0.31) and the signs for the parameters are in line with the microeconomic theory and previous assumptions. Estimated parameters for *Cost and Time* were negative, indicating that the utility of a travel mode decreases when tariff and travel time are increased. Estimated parameters for *Service, Reliability and Availability* were positive, indicating that the utility of a travel mode increases when the levels of these attributes rose.

The alternative specific constant for the road alternative (*Road constant*) was not significantly different from zero (95% confidence level), making it impossible to compare the propensity to choose between road and rail modes. The alternative specific constant of rail was normalised to zero.

A likelihood ratio test was performed to test whether there is a significant improvement in the goodness-of-fit of the ML model in relation to the MNL. The likelihood ratio test was 14.76 (critical value for chi-squared distribution $\chi_{0.95;1}$ is 3.84), and therefore we can assume that the ML model brings accuracy improvements.

After estimating Model 2 – ML, non-linearity was tested for ML models by using different mathematical transformations related to logarithmic (Model 3 – ML) and power series transformations (Model 4 -ML). The improvement in goodness-of-fit due to the introduction of the logarithmic and power series transformation (for time and cost) in the model specification was not significant. The null hypothesis that the cost/time coefficient is linear cannot be rejected.

The tests performed suggest that Model 2-ML, error component logit-mixture model with panel data, fits the data better than the alternative models, selecting this specification among the others. The parameters estimated from Model 2-ML were used to compute elasticities and marginal effects. Table 6 presents elasticity values (for continuous independent variables) and Table 7 marginal effect values (for discrete independent variables).

The elasticity results imply that demand is more elastic to cost than to other continuous variables. A 1% increase in the cost of rail induces a 2.71% decrease in demand. A 1% increase in total travel time by rail induces a 2.26% decrease in demand. In absolute terms, the elasticity in relation to cost obtained values close to the elasticity regarding reliability. This may show concern from companies in the state of Rio de Janeiro with delays during the transportation of the products. The delay for perishable products included in this study (e.g., Food, Beverage and Drugs) can be a critical factor for transport planning. In addition, a (relative) 1% increase in Rail reliability induces a 2.41% increase in demand. Similarly, if a door-to-door service is provided by the rail mode, its choice probability will be 34 percentage points higher than if the service is mode-to-mode. Increasing the availability of rail in the off-season scenario for the whole year enhances its chances of being chosen by 14.6 percentage points.

Table 5: Model results

	Model 1 - MNL		Model 2 - ML		Model 3- ML logarithmic		Model 4- ML power series	
	Value	**T -Test**	**Value**	**T-test**	**Value**	**T-test**	**Value**	**T- test**
Road constant	-0.855	-1.47	-1.1416	-1.58	-1.3998	-1.88	-0.8893	-1.24
Cost	-0.044	-2.98	-0.053	-3.23	-3.9222	-3.23	-0.0004	3.23
Time	-0.3	-2.06	-0.3941	-2.32	-3.3232	-2.31	-0.0232	-2.32
Service	2.07	4.67	2.5638	4.93	2.5639	4.93	2.5671	4.93
Reliability	0.035	2.06	0.0459	2.32	0.0459	2.32	0.0459	2.32
Availability	0.992	2.23	1.1484	2.36	1.1481	2.36	1.1515	2.36
Sigma			-0.953	-3.56	-0.9528	-3.56	-0.9518	-3.56
No. Observations	208		208		208		208	
No. Shippers	26		26		26		26	
No. of parameters	6		7		7		7	
Draws			1500		1500		1500	
Final Log-Likelihood	-106.892		-99.51374		-99.51374		-99.5138	
Pseudo-R^2	0.26		0.31		0.31		0.31	

Table 6: Elasticity of mode choice probability with respect to changes in the attributes (for continuous independent variables)

Attribute	Alternative	Road	Rail
Cost	Road	-1.78	3.53
	Rail	1.26	-2.71
Time	Road	-0.79	1.57
	Rail	1.09	-2.26
Reliability	Road	1.54	-3.05
	Rail	-1.27	2.41

Table 7: Marginal effects on choice probability due to changes in the attributes (for discrete independent variables)

Attribute	Alternative	Road	Rail
Service	Road	0.343	-0.343
	Rail	-0.340	0.340
Availability	Road	0.159	-0.159
	Rail	-0.146	0.146

Larranaga *et al.* (2017) showed in the state of Rio Grande do Sul that the cost elasticity and time elasticity for the road mode were -4.83% and -0.72%, respectively. On the other hand, the cost elasticity and time elasticity for the rail mode were -1.79% and -0.58%, respectively. These values show that companies in the State of Rio de Janeiro are more sensitive to time variations in the road mode compared to companies in the state of Rio Grande do Sul. For the rail mode, companies in Rio de Janeiro have a greater sensitivity. One possibility for this difference is the type of product. The products included in this paper are essentially industrialised and highly adherent to the road mode in Brazil; while the products included in Larranaga *et al.* (2017) are more diversified, including basic products with lower added value, such as soybeans. These types of products have greater adherence to the rail mode in Brazil.

The selected model was applied to simulate the market shares of the alternatives and predict the possible effects of implementing different possible transport policies to promote rail transport. Table 8 presents the baseline scenario for each travel mode and their respective attributes with the corresponding values.

Table 8: Baseline Scenario for each Travel Mode

Attributes	Road	Rail
Cost	100 (BRL) /ton	60 (BRL) /ton
Time	6 hours	9 h and 40 min
Service	Door-to-Door	Mode-to-Mode
Reliability	100 %	70 %
Availability	All Year Round	Between Harvests

The market shares for the baseline scenario are 92.9% for the road mode, while rail reaches only 7.1% participation, showing evidence of the high use of road mode. Different scenarios were simulated to predict market shares based on implementing policies.

A policy of increasing the cost of the road mode (e.g., imposed tariffs) was simulated where the road cost increased by 25% compared to the baseline scenario. An increase in the level of costs in road operations was not able to transfer significant participation to the rail mode (Figure 5).

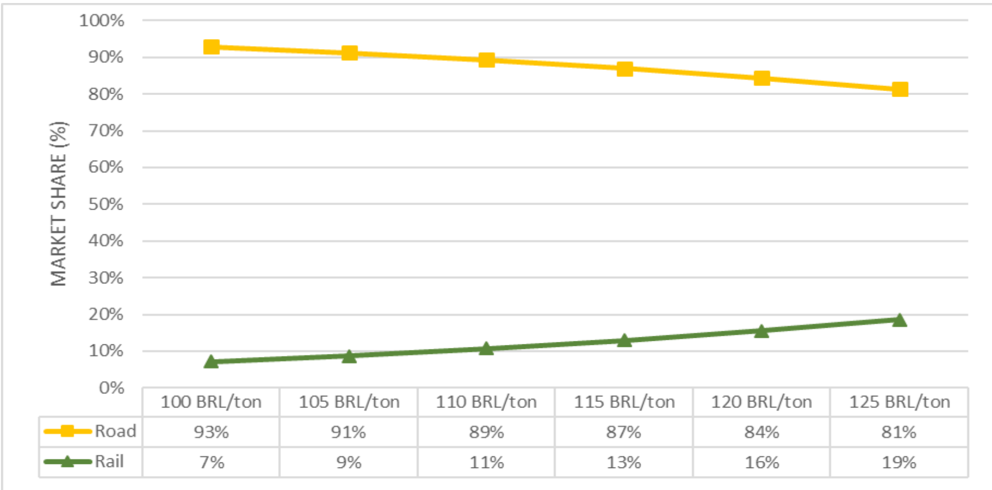

Figure 5: Variation of demand to the increase in road costs (BRL) up to 25%

The results are in line with those obtained by Forss and Ramstead (2007) and Rich *et al.* (2011). Forss and Ramstead (2007) showed that the impact of road charging is not relevant in the mode choice in Sweden. Rich *et al.* (2011) pointed out that in the case of charges imposed in a region with alternatives for poorly developed travel modes, the effects may be modest due to the "*structural inelasticity*", which is a result of the lack of the physical network in the system. This situation leads to elasticity of mode substitution close to zero and imposes a reduced sensitivity to factors such as cost and time. Kreutzberger (2008) pointed out that if the distance between origin and destination is short, the fraction of origin and destination pairs with only one mode (truck) is relatively large, while for longer distances there is greater competition between modes. Thus, this inelasticity may occur due to the last mile issue where trucks are always used.

Figure 6 shows the variation of demand in a scenario of increasing the reliability (%) of the railway mode. Figure 7 displays the variation of demand in a scenario of decreasing the travel time (hours) of the rail mode. These scenarios were not able to transfer significant participation to the rail mode.

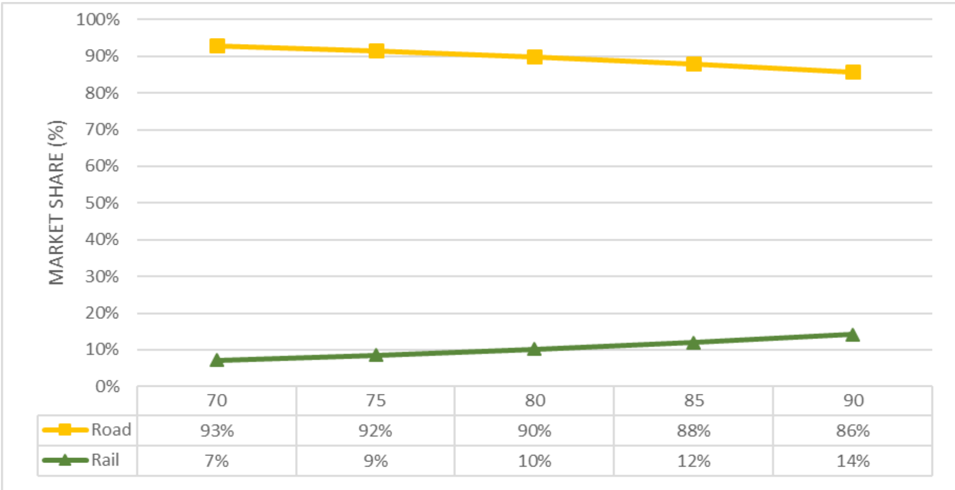

Figure 6: Variation of demand to the increase in railway reliability level (%)

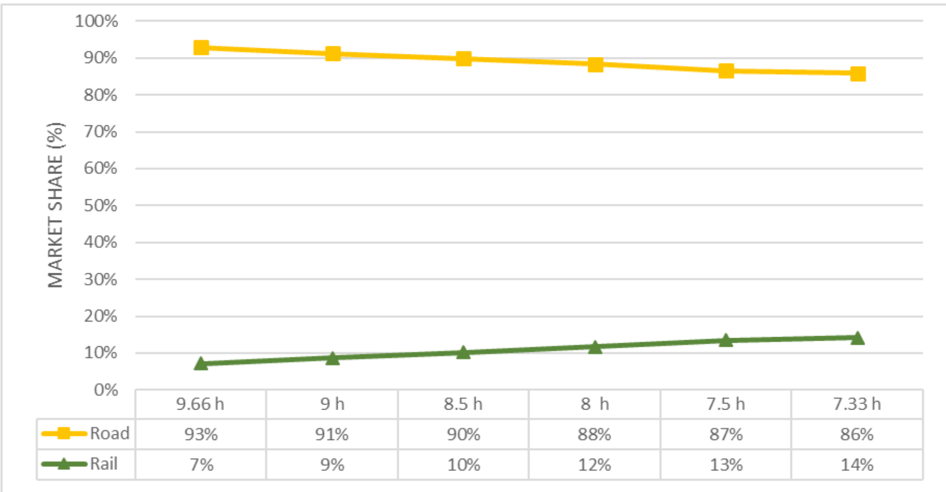

Figure 7: Variation of demand to the decrease in railway travel time operation (hours)

A policy of increasing the cost of the road mode has not been able to significantly increase the demand for the railway mode (Figure 5), as well as increasing the reliability of the railway mode (Figure 6). Thus, a new simulation combining these two factors was developed. In a scenario with a higher level of reliability in the railway mode (90%), the cost of the road mode was increased by 25%. The results are displayed in Figure 8. This combination of factors allows for a greater increase in the market share of the railway mode (from 14% to 32%). This result shows that a possible strategy may be the combination of strategies between the travel modes (improvements in the railway operation and imposed tariffs for the road mode).

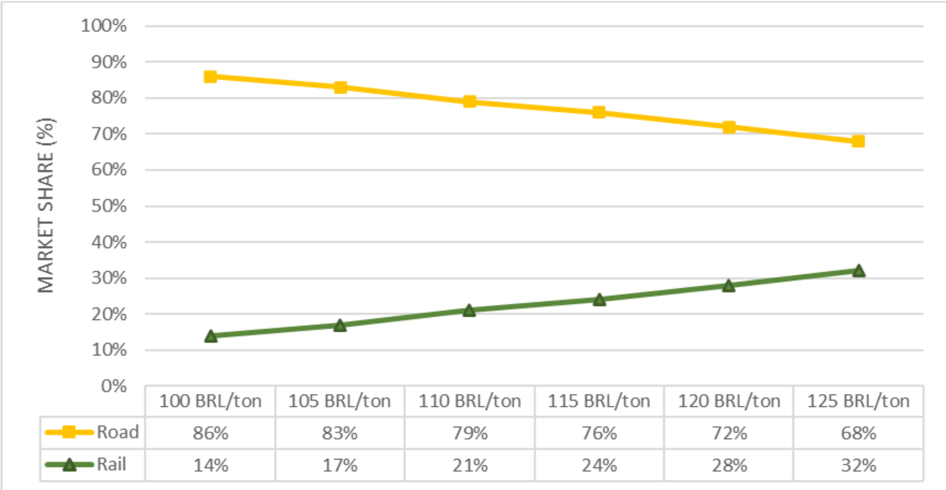

Figure 8: Variation in demand due to the increase in road mode cost (BRL) by up to 25% with railway reliability at 90%

Regarding the availability attribute, increasing the level of availability in the rail mode to All-Year-Round availability did not change the market share. The level of availability changing from Between Harvests to All-Year-Round increased the rail mode split from 7.1% to 16.54% in the simulated scenario.

An important scenario capable of significantly changing the market share was if the rail provided a door-to-door service. A change to door-to-door service was simulated from the base scenario of mode-to-mode service. The level of service increased the rail mode split from 7.1% to 37.16% in the simulated scenario. The increase in the level of service in the rail mode, reaching a door-to-door service, was the scenario with the greatest capacity for change in the competition between the two modes. Even though providing a door-to-door service has the highest potential of increasing demand for rail (*ceteris paribus),* this would likely have huge operational costs, which would increase the rail cost and therefore diminish the overall benefits. For example, starting from the baseline scenario, an increase of 48.5 BRL/ton is enough to nullify any benefit from a door-to-door service. In other words, providing a door-to-door service will not increase demand for rail unless it implies an additional cost to shippers less than 48.5 BRL[6]/ton.

Therefore, in the analysed region, the main obstacles for railways were the shipper's reduced response to variations such as cost and time, as well as the lack of infrastructure available in origin/destination pairs. The results are in line with those obtained by Rich *et al*. (2011) and Wang *et al*. (2013). These studies emphasise that the available infrastructure in the zones of origin and destination is considered fundamental. Thus, policies aimed at railway development will be the most effective for developing a transportation system less dependent on the road mode.

5.1 Analysis of the Cargo Theft Risk factor

The Cargo Theft attribute was the second most pointed out factor by companies among the transportation problems (Figure 4). However, the coefficient associated with this attribute was not significant in any estimated models. The standard deviation of this attribute obtained a high value in estimated models, suggesting heterogeneity of this factor within the analysed sample. This fact may indicate that the attribute was not well defined in qualitative terms, and different respondents interpreted it in different ways. Possibly, numerical values could be better interpreted by the respondents. Further

[6] 48.5 BRL = 9.51 US Dollars (date: December 16, 2020).

investigations may be conducted by simulating other models, testing different levels and new SP surveys. Novaes *et al.* (2006) indicated that although safety is critical in the road mode, the variation in mode choice is small in the case of changes in security level. This section described another study case (port choice model), also in Rio de Janeiro state, with different measures of security. Although in this article we do not have a significant coefficient to measure the influence of safety on mode choice in Brazil, the study, summarised below, shows the importance of adequately representing these measures that characterise the Brazilian context.-

In a recent study carried out in the same state (Rio de Janeiro), a SP survey regarding port choice was conducted. The study sought to analyse port selection in the region and included variables such as i) *ship calls*; ii) *port tariff*; iii) *freight price*; iv) *cargo release time* and v) *risk of cargo theft in transport to the port*. The variable risk of cargo theft was defined with three quantitative levels (0%, 15% and 30%). Thirty shippers responded to the SP survey and all firms stated that they use the road mode to transport cargo to ports in the region. The results of the estimated model (Model 5-MNL) are shown in Table 9.

Table 9: Port Choice model (MNL)

	Model 5 - MNL	
	Value	T -Test
Constant 1	-0.07178	-0.21
Constant 2	-0.05566	-0.15
Constant 3	0.69675	2.51
Ship Calls (calls/week)	0.21704	1.89
Port Tariff (R$)	-0.00124	-2.06
Freight price (R$)	-0.00228	-5.22
Cargo release time (days)	-0.22041	-2.72
Risk of cargo of theft (%)	-5.89731	-7.70
No. Observations	300	
No. Shippers	30	
No. of parameters	8	
Final Log-Likelihood	-321.27149	
Pseudo-R^2	0.26	

The estimated MNL model showed a good overall fit (Pseudo-R^2 of 0.26) and the signs for the parameters are in line with the microeconomic theory and previous assumptions. *Cargo Theft Risk* was significantly different from zero (99% confidence level). The fact that the study of port choice with companies in the state of Rio de Janeiro indicates that the coefficient associated with cargo theft is highly significant showing that the variable has an impact on routing to minimise risk. Shippers seek to minimise the risk of cargo theft during transport changing the port selection.

One of the consequences of cargo theft, in addition to direct losses, results in an increase in the cost of freight, especially due to the price of cargo insurance, which has been progressively increasing (Instituto Modal, 2019).

Although cargo theft is considered a high-impact issue for firms, this variable still has no effect on mode choice because the lack of railway infrastructure means that companies do not have alternatives for using the railway, therefore maintaining the use of trucks to transport cargo. In parallel, as shown by Hora *et al*. (2018), companies in Rio de Janeiro aim to adopt a series of investments and measures aimed at mitigating the occurrence of claims: i) Intensive vehicle monitoring in risk areas; ii) Escorts and changes in delivery procedures; iii) Training employees; iv) Delivery of few products (few customers being served at once); v) Shorter routes, with concentrated deliveries. In addition, in daily operations, the company prefers to stop vehicles in places considered safe (for example, near police stations) and prefers daytime delivery operations to minimise risks. Many of these measures are directly associated with using the road mode for cargo transportation.

Therefore, an increase in the rail service availability in Brazil could help companies to have a viable alternative that offers a lower possibility of cargo theft than the road mode.

6. Conclusions and suggestions for future research

This study analysed the decision-making process of freight shippers for mode choice decisions in the state of Rio de Janeiro. An SP survey was conducted, analysing the general cargo flow between the states of Rio de Janeiro and São Paulo (Brazil).

MNL and ML models with linear and non-linear attribute effects were estimated. The estimated models showed a good overall fit. The likelihood ratio test indicated there was a significant improvement in the goodness-of-fit of the ML model compared to the MNL. The error component logit-mixture model with panel data (Model 2-ML) presented a better fit than the alternative models. Contrary to expectations, the coefficient related to *Cargo Theft Risk* was not significant in any of the estimated models for mode choice.

The simulation results show that shippers' preferences have low sensitivity to changing factors such as cost and time. An alternative policy would be the combination of strategy between modes leading to improvements in the railway operation (increasing rail reliability) and tariffs imposed for the road mode to encourage the use of railways, as simulated in Figure 8. However, increasing the service availability in the rail mode, reaching a door-to-door service, was the scenario with the greatest capacity for change in the competition between the two modes. Considering the structural changes in terms of improved rail infrastructure, the impacts may deliver more efficient results by expanding rail use. The increased availability of rail networks at origin and destination leads to increased use of rail mode. Therefore, the results indicate that infrastructure development (terminal availability, availability of routes, improved access to terminals, etc.) is a key factor for using rail transport more frequently in the state. A similar result was indicated by Wang *et al.* (2013) who carried out a mode choice study (road and rail) in the United States and defined a variable "transportation mileage ratio" (Highway mileage/Railway mileage) in the origin zone and destination zone. The coefficient was positive and significant, indicating that higher transportation mileage ratio contributes to a lower propensity to rail use for shipment trips. Thus, policies focusing on improving railway network infrastructure will be more effective.

From the point of view of the factors that influence the choice of the freight travel mode, the results can help freight modellers to establish the freight demand models in similar regions and in making transport policies to promote the rail mode. Policies to increase the cost of road mode to reduce the share of road transport may have a low impact on the trade-off between road and rail in the region. This political strategy could increase the cost of transportation since the likelihood of companies changing their mode choice is low due to the structural inelasticity of demand in the region. Many measures affect the business of different firms at the same time. The changes may require different players to cooperate in new ways or require a change in the business models of firms and the Brazilian government.

Transport infrastructure is an important driver of economic growth and social development. However, in Brazil, this sector contributed to reducing competitiveness. In 2019, transport investments corresponded to 0.14% of GDP (CNT, 2019b)[7], a very low value compared to the emerging countries (India, China, Korea, Chile and Colombia), which invest, on average, 3.4% of their GDP in transport. Brazil needs to multiply the current level of investments in transport by at least four times to eliminate accumulated bottlenecks (IPEA, 2014). In the current context, the best way to improve transport infrastructure is to unite the public sector and private sector resources to leverage investments. Issues of bureaucracy, legislation, and the effectiveness of industry policies should be reviewed with a direct consequence on attracting investments.

It is worth mentioning that this article sought to analyse road and rail. However, for future studies, the inclusion of cabotage transport is suggested. The state has low development in this mode. This study suggests a detailed analysis of cabotage as an important issue related to the sustainable development of freight transport in the state of Rio de Janeiro.

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[7] This is the lowest percentage recorded, considering the last 12 years. As a result, the indicator remains on a practically continuous downward trajectory since 2011, after registering a peak of 0.40% in 2010 (CNT, 2019b).

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