Transferred Demand Forecast for Regional Passenger Rail Transport

S. W. Pessanha, C. V. C. Rocha, S. L. Issomura, V. B. G. Campos, R. A. M. Bandeira

***Abstract*— The purpose of this article is to present a methodology to develop a model to estimate transferred demand to passenger rail transport systems in regional or semi-urban links, with pendulous feature trips, i.e. home x work and home x school trips. A literature review was carried out to understand demand modeling on rail systems in order to identify models, variables and techniques used to estimate transferred demand. From the knowledge of the process to be developed, Stated Preference, Structured Pair-wise Comparison (SPC) process and Multimodal Logit Model methods were used, using Biogeme software for results analysis.**

Transferred demand forecast methodology was able to measure demand behavior when passenger rail transport was proposed to link regions, thereby expressing more reliable demand behavior.

***Index Term*-- Demand forecast, passenger train, transferred demand**

I. Introduction

TRANSPORT demand is important to adjust transport needs to region development. Improvement in transportation can be achieved through new systems implementation or improving existing ones. According to [1], transportation planning aims to define actions or strategies to suit transport supply with existing and future demand.

Historically, according to [2] Urban Transportation Planning Process originated from Detroit (1953-55) and Chicago (1955-61) urban transportation studies, in a research conducted by Mitchell and Rapkin in 1954. Transportation and Traffic Planning becomes increasingly necessary in nowadays society. According to [3], traffic, sustainable mobility, air and noise pollution and energy consumption issues are taken into consideration when Urban Planning and Public Management concepts are defined.

Transport planning and transport demand management includes several strategies that influence traveler's behavior in transportation choice for his or her trip. According to [4], it is important to understand the factors that affect such behavior.

[5] mentions that the estimative amount of trips, in present and at future date, is an important part of transportation planning process. Still, according to Campos [1], this estimative number will be used as a parameter for decision making over the most appropriate actions to meet each region needs.

Also according to [1], transferred demand is consequence of travel requirement, in order to perform some activity, and much of this demand is concentrated at peak hours. This demand is formed by routine travelers who performs the home-work / school (pendular movements), constituting the majority of demand and more impactful on transportation.

A. Pendular Movements Importance

According to [6] pendular or pendular migration process is linked to one of the traditional research lines of Urban Geography. Information about home-work / school trips is an important reference for urbanization processes and urban expansion analysis. The authors report that the movements today are occurring at increasing distances between traveler's origin and destination.

[6] and [7] analyzed migratory movements and reported amount and distance increase, regarding to pendular movements, which are observed in many cities of the world. The main cause would be transportation system improvement, which enables further distances traveled daily, besides lack of coordinated policies that do not limit or do not consider, for planning purposes, distance between home-work.

[8], who studied pendular and migration movements in Rio de Janeiro, state that intense migration movements in recent decades in this city were "responsible for population and urbanization spatial redistribution processes, contributing to intra-state migration significance in different regional areas."

[9], in 2010's census, provides Brazilian population displacement data about school and work destinations. In school destination cases, an amount of "59.6 million people attending school or day care, 7.3% (about 4 million) did not study in the same town where they lived", i.e. travel intercity to reach their destination. The largest student population recorded, that made this type of trip is in Brazil southeast region, mostly in São Paulo.

In work destination cases, from the amount of 86 million people "employed" in 2010, 11.8% (10,100,000) of workers were intercity travelers. Other 2010's census information was about travel time between home and work - for all travelers (intercity or not). A total of "32.2 million people (52.2% of total workers employed outside their homes) took six to 30

S. M. Pessanha is a master degree student at Military Institute of Engineering, Rio de Janeiro, RJ, Brazil (e-mail: swellenmendonca@gmail.com)
C. V. C Rocha is a master degree student at Military Institute of Engineering, Rio de Janeiro, RJ, Brazil (e-mail: cvrengenharia.com.br)
S. L. Issomura is a master degree student at Military Institute of Engineering, Rio de Janeiro, RJ, Brazil (e-mail: simonelie00@yahoo.com.br)
V. B. G. Campos, is a professor at Military Institute of Engineering, Rio de Janeiro, RJ, Brazil (e-mail: vaniabgcampos@gmail.com)
R. A. M. Bandeira, is a professor at Military Institute of Engineering, Rio de Janeiro, RJ, Brazil (e-mail: re.albergaria@gmail.com).

minutes to get to work in 2010 and 7.0 million (11.4%) took over an hour. "

According to [10] pendular movements are also at economic and social life production and reproduction basis, since it is through them that workers and students attend daily to their place of work or study, production and training spaces.

In 2015, IBGE conducted a study called "Brazilian Population Arrangements and Urban concentrations" [11], which urbanization in the country and integration between municipalities were studied. In this study, it is stated that population pendular movements happen when residential urban spaces far from work and study sites. Thus, population movements contribute to strong interactions between small and medium-sized centers.

As a result, 294 populational arrangements formed by 938 municipalities were identified in Brazil, and 7.4 million people are in pendular movement between neighbors municipalities, most of them performed in Southeast Brazil, where there are 112 municipalities which establish an integration relationship with each other.

It was concluded that the pendular movements between cities, more than meeting travelers needs on their travel purposes (study or work), are responsible for urban spatial redistribution processes, influence positively city interaction in a regional context and are important subjects to study.

B. Brazilian Current Scenario

Since 1997, a concern about Passenger rail transport Systems under Technical-Economic Evaluation from Regional Interest was pointed, when a governmental project to recover rail cargo sector mentioned the high level of idleness in most of the Brazilian rail network. So, this availability should be conducive to investment in passenger rail transport over regional distances, knowing that this was already a reality found in many developed countries [12]. In 2003, The Railways Revitalization Plan was launched, where "Passenger Rail Transport Redemption Program" and which initially indicated 14 priority tracks that could promote regional, social and tourism services [13].

These studies aim railways repair for regional connections, with integration, expansion, modernization and re-use of rail transport modal matrix projects, in order to improve population's quality of life in urban centers. Also, these studies would generate employment and income, tourism development and railway heritage preservation for tourist purposes; promoting regional integration, projects and services development along the railway and railway idle reduction; promoting connection by high-speed trains between Rio de Janeiro, São Paulo and Campinas cities and between Brasilia and Goiania city. [13]

According to [14] in 2011/2012, availability studies were developed, including the following rail track sections: Pelotas - Rio Grande, in Rio Grande do Sul state, Conceição da Feira - Salvador - Alagoinhas - Feira de Santana, Bahia state, Teresina / PI - Codó / MA and San Luis - Itapecuru Mirim, in Maranhão state. The studies about Caxias do Sul to Bento Gonçalves, in Rio Grande do Sul state and Londrina to Maringa, in Parana state were finished.

Therefore, focusing on regional rail transport from Brazilian current scenario, the methodology to estimate transferred demand was developed for passenger rail transport systems, in regional or semi-urban links, considering pendular trips.

For this purpose, influence factors that influence the choice of a transportation mode were analyzed and methods to estimate this type of demand based on a literature review was summarized in section 2. The methodology is presented in section 3 and its application is shown in section 4.

II. DEMAND FORECAST MODELS

The focus of this article includes pendular movements, i.e. home - work and home - school but considering other transportation modes, when there is a new transportation mode implementation in a particular region, that is in fact, transferred demand from existing modes to this new proposal - in this case, the regional passenger rail transport.

In general, there are two methods to estimate demand: conventional models or behavioral models. According to [1] conventional models take into account data whose observations were aggregated (population, employment, income, etc.). Behavioral models, in a disaggregated way, shape demand according to individual behavior, subjective factors that are relate to individual attitudes and perceptions, thus making it more difficult modeling to measure, if compared to traditional approach [15].

Procedures used for this type of analysis, articles, technical notes, papers and of government documents from 1997 to 2014 in several countries in the world were reviewed to develop transferred demand forecast methodology [16]. As a result of this research, variables, information gathering processes, as well as evaluation methods and software used for analysis were identified. Analyzing work developed in Europe, it is observed that there are many companies and researchers relevant publications in passenger demand area. Each work takes into account not only variables and characteristics in common with other studies, but also each application characteristics and each feature importance.

23 works were reviewed: [17] [18] [19] [20] [21] [22] [23] [24] [25] [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38] and [39] .

In the analysis it was found that data gathering for demand forecast is usually performed in three ways: obtaining historical data for transportation modes available in the region, revealed preference survey and Stated Preference Survey.

For transferred demand forecast, which measures the potential appeal to users who use other competing transportation modes, behavioral models should be used, whose data can be obtained from Revealed Preference researches, travelers revealed the choices made to perform a routine trip or the trip they were doing. Trip data such as purpose, transportation mode, etc. and traveler data such age, income, etc could be included in the research. Stated Preference Survey aimed to measure the traveler choice from a created scenario option, usually by comparing existing modes with a new modal proposal. Information about a transportation

mode not yet been implemented was provided, such as travel time, speed etc where travelers should decide which modal they prefer to make the trip [36], [22], [30].

Generally authors use two models on demand forecast procedures: regression model and logit models. For logit models, which are based on behavioral analysis, authors use various processes to determine the utility function, Tree-logit model.

It is also observed that most authors use statistical procedures to test data reliability. Student's t-tests, Maximum Likelihood, error correction model (ECM) are used.

Some authors use a proper model for demand modeling and some software. Among those used are the Alogit and Stata, which are used in Brazilian studies [37], [38], [39].

Among variables used by the authors, who took into account travel characteristics, those most presented in researches are: services attendance, travel time and cost, always analyzing according to Origin and Destination displacement and travel purpose. [36], [30].

For "services attendance" variable it was considered, for each transportation mode, the frequency of services, either by time or headway, or even indicating the number of cars available to carry out the trips. Delays in trip attendance are directly related to travel time - in this case outside the composition - which implies in longer waiting time.

For "travel time" variable, it is not only considered the time spent by the traveler inside the transportation mode but some authors also refer to total travel time, accounting for the access time and egress of the stations, connections times cases carried out by buses, trains and planes, in addition to the waiting time. Travel and transportation mode characteristics such as the distance between Origin and Destination, speed and amount of required transfers directly influence travel time.

For "travel costs" variable, as travel time, it is considered not only the ticket or fuel costs, in private cars case, but also the station access and egress costs and fees paid such as insurance, check-in, etc. Some variables related to travel cost were not taken into account by most of the works analyzed: type of rate, the chosen class and who is responsible for paying the fare or fuel.

Regarding to the variables that take into account the travelers characteristics, most of works presented: gross domestic product (GDP) data/ income, per capita GDP / per capita income, travelers age and individual car ownership. [30] analyzed demand changes and observed that improving socioeconomic conditions of a particular area, increases transportation demand [36], [22].

[26] assure that passenger's individual characteristics, such as age, income, education, car ownership / availability may influence the transportation mode choice, in addition to the most common features in transportation choice, such as activity location o, travel duration and purpose, activities attendance, Origin-Destination features.

Regarding to "car ownership" variable, it is clear that the majority of public transport users have a car, but many choose public transport in Europe. Some authors consider that many passengers are left at the public transport station by another person in a private car. In surveys, other information about trips attendance and public transport use frequency can be also found.

Some demographic factors were taken into consideration in the analyzed works, such as land use data, master plan and population density [36], [22].

The determining factors for demand forecast may vary from city to city and country to country, as well as short and long term demand forecast process have different elasticities [31].

According to [28], the discrete choice models for transportation mode choice are the key to inform demand forecast model.

Improvements in existing transport systems tend to influence in Stated Preference Survey. An example would be the highways post privatization trend, which can bring benefits to road transport.

III. RESEARCH MAIN GOAL DEVELOPMENT

One of the conclusions from previous section was that discrete choice models for transportation mode choice are the most used to a not yet implemented transportation mode demand forecast.

Thus, the proposed methodology for demand forecast was based on Stated Preference techniques and divided into 5 stages, given below:

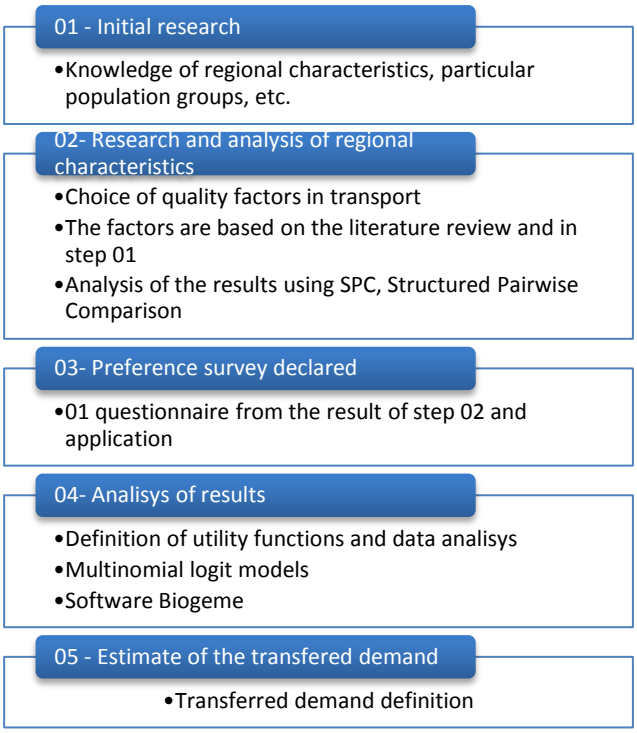

Fig. 1. Section III steps represented in blocks diagram

STEP 01: Initial research aiming to identify regional characteristics, existing transport and infrastructure modes in the region as well as particular population groups where the methodology can be applied.

STEP 02: Quality factors choice in the most representative transportation mode, through questionnaires where

respondents order and analyze pairwise the presented characteristics. The factors listed should be based on literature reviews and features observed in step 01. It is used the simplified AHP process, called SPC (Structured Pairwise Comparison) for result analysis.

STEP 03: After identifying local demand preference regarding to quality factors in transportation, Stated Preference Survey is developed, according to the following detailed steps, using the most significant parameters indicated in the previous survey.

STEP 04: According to Stated Preference Survey data, Utility functions are defined and collected data are analyzed, by using and developing modeling as Multinomial Logit models, using Biogeme software to analyze the results.

STEP 05: transferred demand is defined by applying previous results analysis regional demand.

A. Step 01: Initial Search

It consists in collecting general information and aims to know the region context, in which the proposed methodology will be applied. In addition to regional characteristics should be known transportation modes, infrastructure conditions available and particularities of each mode. The more information obtained at this early stage, the greater the knowledge of this region and consequently demand behavior tends to be measured in a realistic way.

B. Step 02: Regional Features Research And Analysis

It aims to offer research applicability in any region and in any group of people. Each region has behavior, when only demand forecast models with variables based on literature reviews are proposed, it is believed that the resulting model cannot translate reliably this demand choices.

Another motivation to enter this initial step was the difference between demand forecast models used throughout the world in comparison to Brazilian models. In international models, many studies considered special tickets, first class, indicating consideration of comfort in modal values.

According to [40], it is of fundamental to identify the transportation mode choice criteria for a given trip. The opinion of those who use a transportation mode between two points is not only important to know population preferences, as well as to guide a better operational and improvement management, and implementation of new services in micro planning and macro planning context.

Regarding to Passenger Transportation System, the performance of this service is directly related to user expectations when he or she chooses this or that option. According to [41] the parameters chosen by users can be characterized as a transport service quality indicator.

According to various authors' studies analysis, performed by [16], the quality indicators most used in the literature, which can affect demand behavior and should be considered in transport planning modeling. "Security", "Reliability", "Comfort", "Travel time" and "Cost of the trip" factors are indicated by most authors as quality factors that have the greatest influence on transport user's behavior.

According to [42] "security" factor may be related to the number of accidents in a transportation mode, and also involves road and maintenance conditions, traffic systems, operating conditions. However, according to [41], [43] and [44] this item is related to both driver conduction and to robberies and crimes risk in the arrivals and disembarkation facilities.

The "reliability" standard may be related to services regular performance, in a reliable and correct way, according to [43], and the fulfillment of services regularity, itineraries and information to users, according to [41].

According to [41] the "comfort" standard may be related to many qualitative aspects of subjective evaluation, linked to occupancy conditions, ventilation conditions, noise, car features like doors width, etc.

These quality factors regarding to transport are the ones that influence transportation mode choice. Peer to peer analysis and SPC method was developed from Analytical Hierarchy Process (AHP), and is an example of advanced model, developed by Thomas Saaty [45], [46] and [47]. It is a tool for decision analysis and multiple criteria planning, simplifying the decision-making process. This technique is based on choices comparison, pairwise, identifying thus the criteria in order of importance and stipulating weights for each.

SPC method has been developed to reduce weight process complexity, [48], [49] and [50] proposed a new AHP formulation, with structured peer to peer comparison process, wherein a judgment scale with 1-9 values, is compared to "strong" or "weak" importance of relations.

Thus, applying the research in the region to be studied, most important transport quality factors are identified, and Stated Preference Survey can be started.

Each criteria Standardized values represent their importance in relation to the user choice, so the higher the weight, the greater the quality factor importance in relation to other listed and vice versa. Thus, it can conclude that in a given group of respondents, which quality factors influence over decision-making in relation to transportation mode.

C. Step 03: Stated Preference Survey

After identifying local demand preference of in relation to transport characteristics, Stated Preference Survey is developed using the most significant parameters indicated in previous survey and rail system passenger characteristics, keeping in mind the objective of this research, which is the knowledge of transferred demand when a passenger rail system is implemented on regional or semi-urban links, with pendular trips, i.e. home x work and home x school trips.

1) Population And Sample Choice

Knowing that the sample to carry out the Stated Preference Survey can be taken directly from a pre-selected group and that it is recommended a minimum of 75 people for each interest group, the selected sample for this survey realization is routine travelers directly affected by a railway which will possibly be implemented, as bus trips groups, car and in some regions, air transport. The sample groups should be selected after transportation options existing in the region are already

identified.

In addition to existing transportation modes identification, it is important to know all transportation options characteristics, such as service characteristics, time and travel costs, standards and comfort options offered, safety standard and service reliability, if there are particular characteristics of each region, such as providing charter bus from one location to another.

2) Preparing the Quiz

The questionnaire draft begins determining which factors are important for the region and what is the research purpose, for example, interest in a new demand caused by a future transportation mode implementation.

3) Attributes Definition And Choices Levels

According to author's guidelines, it is recommended a maximum of four attributes and their levels, creating a number of combinations between 9 to 16 scenarios.

An important aspect for transferred demand forecast research case, is that when considering which transportation mode and which attributes will vary, include possible investments, changes and improvements in existing transport, short or medium / long term implementation [54]. Thus, if the transportation modes in the region are already established and the railroad project implementation is planned in the short term, existing modes do not suffer variation in values, thereby reducing the required number of scenarios, i.e., resulting in preferably mere transfer to new modal implanted, in this case, the railway.

If the new railroad characteristics are unknown, the attributes levels can be set based on the existing modes. For quantitative attributes, continuous levels are generally employed, uniformly spaced between two extremes. For qualitative attributes, levels are intended to represent relevant settings for each attribute.

Then, two quantitative attributes are defined, each of these with three levels, resulting in nine scenarios, which provides sufficient amount of search scenarios for a good experiment. Regarding qualitative factors in transport, it is suggested that only one is used, this being defined according to the initial research. If the qualitative attribute between the scenarios having three levels of variation search result in more combinations, resulting in 27 scenarios requires alternative to reduce the number of scenarios. It is therefore suggested that this attribute compose more than one choice for survey option, avoiding the increased number of scenarios.

Defining two quantitative attributes and one qualitative attribute, entering as another option to be chosen, it excludes the need for fractional factorial designs, or research division into blocks or any other method to decrease scenarios. Also it is proposed the non-application of technical removal of all dominant and dominated alternatives, offering greater reliability to collected data in the interviews.

4) Presentation of Scenarios for Respondents

The scenarios presented to respondents should have a discrete choice form, when the respondent only choose an alternative that suits him or herself, in the midst of a set of alternatives presented. It is the most comfortable and simple way for the respondent.

5) Research Method Definition

The Stated Preference Survey should be made face to face, as recommended by the authors. Thus, the respondent can better understand scenarios, choice procedure and also offer great accuracy and little loss of information.

6) Design and Survey Test

It is recommended to carry out a small test within a small group of respondents belonging to the interview interest group. In transferred demand research case, routine users of a transportation mode that will be directly affected by new railways implementation . It is recommended then to apply the test in 6 to 12 people.

7) Main Search And Data Collection

It is useful when the data to be collected in Stated Preference Survey include, in addition to the choices of respondents, data that characterize the sample and / or which may be important a possible transfer identification, as data services or forms of differentiated payment where respondents only mark with an X, the alternatives that best suit them.

Among other data such as trip origin and destination, travel reason, travel frequency, transportation mode in which the traveler makes the trip usually, if the traveler has or not an automobile, income, education level, which paid the passage of the traveler, educational institution attended, student groups, gender and age of the traveler is also collected.

From the collection of data, may analyze the new transport option and make statistical tests, according to each study purpose.

D. Step 04: Results Analysis

For result analysis, the use of Multinomial Logit Model was defined using the Biogeme, software designed to analyze data with discrete choice models in general and random utility models in particular. Bierlaire Optimization Toolbox for GEV Model Estimation (BIOGEME) is a free software based on logit models, including Logit Multinomial using the maximum likelihood estimation method to forecast various parameters models in a discrete choice [51], [52], [53].

Utility functions must be tested with the variables in two stages. The first shall contain transportation mode parameters, while the second should test traveler related variables impact in utility function.

1) First Analysis: Modal Parameters

After applying Stated Preference Survey, with scenarios showing variations of transportation mode attributes, this should be tested at first. They usually represent the variables that best explain the transportation mode change.

2) Second Analysis: Traveler Parameters

According to the region, characteristics traveler may influence in transportation mode choice. Factors such as traveler income, gender, age, and who pays the ticket and other search features, depending on each region should be tested in order to know if any of them can interfere with demand.

3) Utility Function Definition

After all variables tests, the one that contains acceptable statistical values is the best utility function.

According to [55] the main parameters to be analyzed to validate the utility function are the rho-square values (pseudo determination coefficient - ρ) and the t test.

For rho value, according to [55] and [56] acceptable models are those with values above 0.2 and above 0.4 can be considered very good for analysis by multinomial logit model (on a scale between zero and one, where zero indicates no adjustment and it means a perfect fit). The rho-square value evaluates the quality of model fit.

T test value, used for variable coefficients analysis, determines whether the estimated coefficients for the variables are significant to the model or not. For more than 30 observations, values greater than 1.96 (in absolute value) indicate that the variable has a 95% confidence and a significant effect on the model, this variable should be retained in the model.

P-value or p standard deviation indicates data variation degree in relation to an average value. P accepted values, on a confidence level of 95%, should be less than 0.05.

In these generated tests, the variables coefficients signs (positive or negative) must be analyzed, indicating the utility value direction as variable value variation and must be consistent to the variation theoretically expected [57].

Thus, the best utility function, with parameters that best obtained Rho-square values (greater than 0.2), t test (greater than 1.96, in module) and p-value (less than 0.05 for 95% confidence) is selected and applied in order to represent demand transfer according to each study purpose.

E. STEP 05: TRANSFERREDDEMAND FORECAST

After variable test and model estimation, each alternative utility function should be performed in order to calculate the probability to select each transportation mode.

The resulting utility function should be applied to each group, prone to change transportation mode. For example, an intercity transportation that could be impacted by a regional railway is road transportation - carried out by buses, chartered buses, cars, etc. - air transportation and others that may exist in the region.

1) Existing Demand

It is necessary to know how many people will be transported by each transportation mode between regions, in other words, it is necessary to know the demand for each mode, and then what percentage of these are likely to go by for rail transportation, if implemented.

2) Tendency Rate Application

To use the model to estimate change tendency or transportation use probability, it is necessary to determine the characteristics to be taken into account in the existing demand group. For transportation mode characteristics, for example, new travel time, new price and also population age or income in which utility function is being applied (for example, if this variable is important for forecast).

Therefore, if the researcher knows the railways features that will be implemented, simply modify the variables related to transportation mode and find the change tendency. If the features are unknown, the same characteristics defined in the scenarios stated in Stated Preference Survey will be considered.

A percentage of use of each mode is found by the application of change tendency rate to the new transportation mode. If this percentage is applied to the existing demand, it is possible to determine how many people tend to remain in current transportation mode or to transfer to new transportation mode.

After variables and estimated model test, it is necessary to perform the utility function application for each alternative, in order to calculate the choice probability n to a given alternative i. According to [39] this probability results indicate the percentage of users who will take each mode and consequently the tendency to transfer from a transportation modal to another.

Once region and volume of trips and passengers are determined, the last stage to forecast transferred demand is the application of transportation mode transfer rate, found in the researches, in current demand in the region.

According to the example given by [39], the transfer tendency rate from road transport to the railways (P1) and consequently the permanence rate in road transport (P2), is given by the following formula:

$$P_1 = \frac{exp^{U_1}}{exp^{U_1}+exp^{U_2}} \; ; \; P_2 = \frac{exp^{U_2}}{exp^{U_1}+exp^{U_2}} \quad (1)$$

In the author given example, regular bus users resulted in a tendency rate of 64.36% for railway and a 35.64% to remain in the current transportation mode option. Thus, once annual passenger volumes in a given region in known (50,423 passengers per year), transferred demand forecasted for railways resulted in 32,452 passengers per year [39].

IV. METHOD APPLICATION

In order to evaluate the procedure effectiveness, a region was chosen, where there is a real possibility to develop a regional rail passenger transport.

The *Programa de Resgate do Transporte Ferroviário de Passageiros* (Passenger Rail Transport Redemption Program), which selected 14 priority sections in Brazilian railroads to promote regional, social and tourist service, where the reference parameters set by the BNDES 2002 study are are met: track sections with a length of up to 200 km; at least one city with more than 100,000 inhabitants; high idle capacity of cargo transportation; permanent way continuity [13].

Assuming that the areas of interest in this program were defined and characterized by studies carried out by BNDES and Transportation Ministry, the rail section between Campos dos Goytacazes – RJ and Macaé – RJ was chosen. It is 94 km long, belongs to Ferrovia Centro-Atlântica (FCA) railway, owned by VLI company group, with high idle capacity of cargo transportation.

A. Step 01: Initial research

In addition to regional characteristics, infrastructure conditions and available features of each transportation modes in this region were identified.

Between 2015 July 31 and August 9, available information about these types of trips between aforementioned cities, including costs - considering only one direction travel taking into account groups of workers and students.

For workers, the most common transportation mode is regular buses, chartered buses and cars. For students is offered free chartered bus service starting from Macaé to Campos, departing from Macaé city.

The charter bus service for workers departing from Macaé to Campos exists in two ways: when an employer provides transportation to employee and when the employee seeks for an existing bus company and carries out a "contract". This second option is the most interesting to study because it works like regular bus service. It is a regional specific case where each employee chooses a line that is considered better and books his or her seat on the bus.

Cost and travel time by car were calculated based on 2015 August price, in this region, and compared with travelers information that make this car trip. Knowing that the section between the two cities has 109 km and the fuel liter costs R$ 3.59, the toll between cities costs 3.80 and the average consumption of a small car is 14 Km / l, so the cost per trip is R$ 31.75. Maintenance costs and vehicle depreciation of the vehicle were not considered. The average travel time, informed by other travelers is 1 hour and 40 minutes. The highway that connects Campos to Macaé is BR-101, section currently managed by Autopista Fluminense S.A., and has most of its roadway in well maintained double lanes.

There are also other types of transport between these cities, as transport services using vans, hitchhikers, air transport between Campos and Macaé coast. However, as these services are not offered regularly and trips are conducted mainly by buses or cars, it was chosen to not include this information in other transportation modes.

The data were obtained through Autoviação 1001 company (provides intercity service between Campos dos Goytacazes - Macaé) website, and in contact with workers and students. Information regarding to services, including tariff rates, schedule, travel time and comfort standard are in Table I.

TABLE 1
TRANSPORT SERVICES INFORMATION

		Price R$)	Attendance (bus per hour)	Attendance (bus per day)	Seats (per bus)	Travel time (hours)
Workers	Regular bus	28,76	2,13	51	46	2:00
	Chartered bus	26,65	Specific schedule	29	48	2:00
	Car	31,75	-	-	-	01:40
Students	Chartered bus	-	Specific Schedule	7	46	2:00

Bus types: conventional and conventional with air conditioning
Conventional: reclining chair e air conditioning
Conventional with air conditioning: arm chair, air conditioning

B. STEP 02: RESEARCH AND REGIONAL FEATURES ANALYSIS

Applying the research described in step 02, it was possible to identify which quality factors in transport are considered most important to Campos - Macaé passengers, allowing starting Stated Preference Survey.

The questionnaire was submitted to travelers and was comprised of an initial expectation, providing important information to respondents about the objectives and research operation and a second part, in which questions about traveler characterization and a decision making factors analysis were held.

The survey was held with 20 routine travelers - 10 travelers on business trip and 10 travelers on study purpose, from 2015 November 19th to 23th. Interviews were conducted face to face in the study sites and bus stops. The group was defined by students and workers who performed trips on chartered buses. Quality factors used in transportation mode choice analysis were: reliability, comfort, time, cost, frequency and safety, defined in Chapter 5. The importance and weight of factors analysis was performed using SPC method, obtaining the following results (Table II):

TABLE II
QUALITY FACTORS

Workers and students		
Attribute	Weight	Standard deviation
Safety	0,316	0,142
Cost	0,210	0,191
Reliability	0,198	0,132
Time	0,126	0,085
Comfort	0,107	0,079
Frequency	0,077	0,049

Thus, it is observed that the most important factors in quantitative study were time and cost. Regarding to quality factors, there is an importance given to safety, coming next to reliability and comfort. It presents that the safety and reliability factors must maintain or improve existing standard and be served in the new system to be deployed. Due to the fact that these two qualitative factors are difficult to measure, comfort factor was selected to be included in Stated Preference Survey for comparative analysis.

C. STEP 03: STATE PREFERENCE SURVEY

1) Initial Research

The objective of this research is to support an estimated demand to be transferred when rail transport system for passengers is developed, with pendular movement trips, i.e. trips made between home x work and home x study, between Campos dos Goytacazes and Macaé cities.

Information about the region was presented in previous step, as a way to enable the first stage of this proposed methodology.

Data were initially defined taking into account all

transportation modes; however, due to impracticability to conduct research with car travelers, it was used only in chartered buses.

2) Population Choice And Sample

The selected sample for Stated Preference Survey was routine travelers, such as workers and students, directly affected by railway to be implemented between Campos and Macaé cities. In this region, routine travelers usually travel by chartered bus. Thus, interviews were conducted on the chartered bus students (41 respondents) and employees (40 respondents), totaling 81 respondents.

3) Preparing the Quiz

As described above, questionnaire design starts by determining which factors are important to the region and by identificating research objective.

4) Definition of Attributes And Levels Of Choices

After Stage 2, cost, time and comfort factors have been identified as the most significant parameters in the region, which will be attributes for the scenarios. As existing services (buses) already have good levels of safety and reliability it is expected that the proposed railways have at least equal standard. Furthermore, comfort attribute is regarded as a new railway mode option, in order to reduce attribute variation and hence the number of cards to be analyzed.

Once attributes are known, the levels of each one should be defined. Since the region already have well established road and the highway is in good maintenance and operation conditions, it was considered that the region will not receive major investments, changes or improvements that may impact the estimated demand, if the railway project implementation occurs in short term. Thus, it was considered that transportation modes in this region are consolidated and for existing modes, attributes levels will not vary, as shown in Tables III and IV, thereby reducing the number of scenarios required for Stated Preferred Survey implementation.

TABLE III:
ATTRIBUTE LEVEL DEFINITION FOR CAR TRAVELERS

Attribute	Variable nature	Scenarios	Associated value levels	
Travel time	Quantitative	Real scenario	1	01h40min
Travel cost	Quantitative	Real scenario	1	R$ 31,75
Comfort standard	Qualitative	Real scenario	1	According to car comfort standards

TABLE IV
ATTRIBUTE LEVEL DEFINITION FOR BUS TRAVELERS

Attribute	Variable nature	Scenarios	Associated value levels	
Travel time	Quantitative	Real scenario	1	02h00min
Travel cost	Quantitative	Real scenario	1	R$28,76
Comfort standard	Qualitative	Real scenario	1	 Reclined arm chair, air conditioning and toilet

Different levels of existing modes, railways must be analyzed on different levels according to each search attribute if there are no forecast improvements in level. Service levels and features were determined in accordance to existing services. Thus, the traveler can analyze what-if scenarios, but with services features that they already know, and can thus analyze the train offered service standard in a realistic way.

There were different levels, travel time from 20 minutes to more and less than the average time, comparing car and bus; considering travel costs, the rates were varied by 15% to more and less than car and bus average travel cost. For comfort levels, it is defined that the average standard is the existing standard, offered by existing buses that perform the route. The best standard is "executive" bus service, as shown in Table V:

TABLE V
ATTRIBUTE LEVELS DEFINITION

Attribute	Variable nature	Scenarios	Associated level values	
Travel time	Quantitative	Best scenario	2	01h30min (-20 min)
		Average	1	01h50min (average time between car and bus)
		Worst scenario	0	02h10min (+20 min)
Travel cost	Quantitative	Best scenario	2	R$ 25,72 (-15%)
		Average	1	R$ 30,26 (average value between car and bus)
		Worst scenario	0	R$ 34,79 (+15%)
Travel standard	Qualitative	Best scenario	2	 Reclined armchair, legs rest, air conditioning e toilet
		Average	1	 Reclined armchair, air conditioning e toilet

Regarding to standard comfort in railway, it was considered in the scenarios as an option for the traveler, as an additional cost, not requiring to expand the number of scenarios.

It was researched about different "class" charge, in Brazil and Europe, in order to define the percentage of additional cost for train standard comfort as Table VI.

TABLE VI
TRAIN TICKET COST

	Local	Brazil	France	Spain
	Section	Curitiba - Morretes – Paranaguá	Paris - Chartres	Alicante - Albacete
	Extension	110 km	101 km	140 km
	Company	Serra Verde Express Ltda.	SNCF	RENFE
Service	Budget	R$ 79	$16	$24
	1ª class	R$ 99	$17,9	$23,25
	Difference	25%	50%	30%

Sources: Available at each company´s website

From the research carried out about rates charged by companies providing rail services, it was decided to put an

extra charge of 30% over fare value to a higher standard of comfort. It must be said that this value only represents an estimative cost, in order to evaluate traveler change tendency, since a real implementation was not analyzed.

Being with all levels and attributes values set, scenarios were assumed, as shown in Table VII. It was decided to not apply the technique of removing all dominant and dominated alternatives, offering greater reliability to data collected in the interviews, resulting in nine scenarios.

TABLE VII
ATTRIBUTE COMBINATION

		Roadway				Railway			
		Car		Bus		Train		Train + Comfort	
	Attributes	Cost	Time	Cost	Time	Cost	Time	Cost	Time
Scenarios	1	1	1	1	1	1	1	1	1
	2	1	1	1	1	1	2	1	2
	3	1	1	1	1	1	0	1	0
	4	1	1	1	1	2	1	2	1
	5	1	1	1	1	2	2	2	2
	6	1	1	1	1	2	0	2	0
	7	1	1	1	1	0	1	0	1
	8	1	1	1	1	0	2	0	2
	9	1	1	1	1	0	0	0	0
		Levels							

5) Scenarios presentation for respondents

The scenarios presented to respondents was according to discrete choice form, with attributes variations given according to Table VIII:

TABLE VIII
SCENARIOS WITH ATTRIBUTES VALUES AND DEFINED LEVELS

		Roadway				Railway			
		Car		bus		Train		Train + Comfort	
	Attributes	Cost (R$)	Time (h)	Cost (R$)	Time (h)	Cost (R$)	Time (h)	Cost (R$)	Time (h)
Scenarios	1	31,75	01:40	28,76	02:00	25,71	01:30	33,42	01:30
	2	31,75	01:40	28,76	02:00	25,71	01:50	33,42	01:50
	3	31,75	01:40	28,76	02:00	25,71	02:10	33,42	02:10
	4	31,75	01:40	28,76	02:00	30,26	01:30	39,34	01:30
	5	31,75	01:40	28,76	02:00	30,26	01:50	39,34	01:50
	6	31,75	01:40	28,76	02:00	30,26	02:10	39,34	02:10
	7	31,75	01:40	28,76	02:00	34,79	01:30	45,23	01:30
	8	31,75	01:40	28,76	02:00	34,79	01:50	45,23	01:50
	9	31,75	01:40	28,76	02:00	34,79	02:10	45,23	02:10
		Levels							

Thus, a set of nine cards was presented to respondents, leaving them the choice of a transport option on each card to the daily trips.

6) Research Process Definition

The surveys were conducted face to face, as recommended by authors. Thus, the respondent can better understand the scenarios and how the choice procedure works, offering better accuracy and little information loss in collected data.

7) Design and Survey Test

For procedure testing purposes, at this stage a small group of respondents (4 people) belonging to research interest was interviewed. For larger, official surveys, research application should be extended to 6 to 12 people.

8) Main Research and Data Collection

The main survey was held between 2015 November 25th to December 05th, with 41 students who performed Macaé to Campos trip, on chartered buses, departing from Macaé city. The interviews took place in universities where students disembarked. Between 2015 December 01st to 05th, surveys were conducted with 40 work travelers who performed Campos to Macaé trip in chartered buses. The interviews took place in waiting embarkation points and within the charter bus.

Collected data by Stated Preference Survey included all the variables described in the methodology, and site special features.

Data were collected by the author, with face to face interviews in printed forms, marked with an X the chosen alternative transport users, after cards with scenarios were presented, generating a spreadsheet for information analysis by Biogeme Software, as defined previously.

D. STEP 04: RESULTS ANALYSIS

When utility functions in Software Biogeme were tested, transportation mode characteristics such as time and cost, were initially analyzed. Then travelers characteristics were tested: income, gender, age and who pays the passage, in order to know if any of these variables would be significant or not for the model, as Table IX:

TABLE IX
VARIABLES FOR EACH UTILITY FUNCTION

Variables description		Alternatives			
		Car	Bus	Train	Train+Confort
ASC	Constant	Car	Bus	Train	Train
Time	Travel time	β-Time	β-Time	β-Time	β-Time
Cost	Cost travel	β-Cost	β-Cost	β-Cost	β-Cost
Income	Income in classes	β-Income	β-Income	β-Income	β-Income
Gender	Traveler gender	β-Gender	β-Gender	β-Gender	β-Gender
Age	Age in classes	β-Age	β-Age	β-Age	β-Age
Who	Who pays	β-Who	β-Who	β-Who	β-Who

1) First Analysis: Modal Parameters

Initially transportation mode variables were tested, in this case, time and cost based on the responses of 81 respondents, each responding to 9 scenarios.

The results obtained are shown in Table X:

TABLE X
VARIABLE VALUES, AFTER BIOGEME SOFTWARE ANALYSIS

Rho-square:	0,175
Adjusted rho-square:	0,169

Name	Value	T test	p Value
ASC_CAR	0,00		
ASC_BUS	1,85	8,35	0,00
ASC_TRAIN	1,73	8,52	0,00
ASC_TRAINC	2,89	10,50	0,00
BETA_COST	-0,211	-9,68	0,00
BETA_TIME	-0,0441	-8,12	0,00

Analyzing the results after the parameters estimation in Biogeme software, it is observed that the rho-square value (ρ) is 0.175, which is not shown, as explained in Chapter 05. Acceptable values for Rho-square must be greater than 0.2. Therefore, the model does not have good fit.

Regarding to t test, all variable coefficients values were higher than 1.96 in magnitudes. So it means that all variables have a significant effect for the model, with 95% confidence.

P values for all parameters are found equal to zero.

2) Invalid Research Exclusion

Since the results were not satisfactory in relation to Rho-square, they were excluded from some interviews that may be considered invalid, according to [57], which considers this option when respondents answered only one transportation option, without changing the answer, i.e. when the respondents did not consider maximizing modal utility.

Thus, 6 interviews were excluded, reducing the sample to 75 people.

The values obtained from this analysis are shown in Table XI below:

TABLE XI
VARIABLES RESULTS AFTER INVALID RESEARCH EXCLUSION

Rho-square:	0,267
Adjusted rho-square:	0,261

Name	Value	T teste	p Value
ASC_CAR	0,00		
ASC_BUS	1,61	6,85	0,00
ASC_TRAIN	1,53	7,18	0,00
ASC_TRAINC	2,95	8,90	0,00
BETA_COST	-0,311	-10,63	0,00
BETA_TIME	-0,0616	-8,95	0,00

Analyzing the results after parameter estimation using the software, it is observed that the rho-square value (ρ), which is 0.267, it is an acceptable value. Therefore this model has a good fit.

Regarding to t test in the variable coefficients, all values were higher than 1.96 in magnitudes. So, all variables have a significant effect for the model, with 95% confidence. P value for all parameters were found equal to zero, reaffirming the confidence of variables for the model.

These results will be used in the next step in analysis with the parameters related to the traveler.

3) Second Analysis: Traveler Parameters

Following the methodological procedure, after utility functions analysis with transportation mode parameters, tests should be performed in order to identify which traveler characteristics influence the transportation mode choice. Thus, the income characteristics: gender, age and who pays the passage for travelers were also analyzed.

Analyzing the results after adding "income", "Gender", "age" and "who pays" variables to utility function, the results are presented in Table XII:

TABLE XII
VARIABLE RESULTS AFTER ADDING TRAVELER PARAMETERS

Rho-square:	0,267
Adjusted rho-square:	0,259

Name	Value	T test	P value
ASC_CAR	0		
ASC_BUS	1,61	6,85	0
ASC_TRAIN	1,53	7,18	0
ASC_TRAINC	2,95	8,9	0
BETA_COST	-0,311	-10,63	0
BETA_TIME	-0,0616	-8,95	0
BETA_INCOME	-1,72E-14	0	1
BETA_GENDER	-5,9E-15	0	1
BETA_AGE	-5,15E-15	0	1
BETA_WHO	-9.56e-015	-0.00	1.00

Analyzing the results after parameter estimation using the software, it is observed that rho-square value (ρ), which is 0.267, indicating a good fit of the model.

Compared to t-test, the variables coefficients values obtained were not acceptable, presenting 0 and 1 value for p. Therefore, these variables do not have significant effects on the model used.

Therefore, the best values for the parameters, with the best Rho-square, t-test and p-value results were represented in Table 11 above, resulting in the following utility functions in the next session.

4) Utility Function Definition

After all variable tests, in order to know what makes difference in the model and in utility function, it is concluded that the best utility function, it the one that contains acceptable statistical values, as stated earlier.

Thus, the best parameters values, with the best Rho-square, t-test and p-value results are presented in the following functions:

For car option:

$$U_{car} = -0{,}0616 * \mathrm{t} - 0{,}311 * \mathrm{c} \quad (2)$$

Where:
Ucar= Car utility
t = Time
c = Cost

For chartered bus option:

$$U_o = 1{,}61 - 0{,}0616 * \mathrm{t} - 0{,}311 * \mathrm{c} \quad (3)$$

Where:
Uo= Bus utility

t = Time
c = Cost

For conventional train option:

$$U_t = 1{,}53 - 0{,}0616 * \mathrm{t} - 0{,}311 * \mathrm{c} \quad (4)$$

Where:
Ut = Conventional train utiliy
t = Time
c = Cost

For comfort train option:

$$U_{tc} = 2{,}95 - 0{,}0616 * \mathrm{t} - 0{,}311 * \mathrm{c} \quad (5)$$

Where:
Utc = Comfort train option
t = Time
c = Cost

E. STEP 05: TRANSFERRED DEMAND FORECAST

After variable and estimated model test, utility function application in performed for each regional transportation alternative.

It was researched transportation by chartered bus and the tendency to change the transportation mode change. 3 scenarios were analyzed, with variations in railway time and cost, as Table XIII shows below:

TABLE XII
ANALYZED SCENARIOS TO TRANSFERRED DEMAND FORECAST

		Roadway				Railway			
		Car		Bus		Train		Train + Comfort	
	Attributes	Cost (R$)	Time (h)	Cost (R$)	Time (h)	Cost (R$)	Time (h)	Cost (R$)	Time (h)
Scenarios	1	31,75	01:40	28,76	02:00	25,71	01:30	33,42	01:30
	2	31,75	01:40	28,76	02:00	25,71	01:50	33,42	01:50
	4	31,75	01:40	28,76	02:00	30,26	01:30	39,34	01:30
		Levels							

In study it was considered only one transportation mode option as an example of the methodology application. However, in a real problem, it should be taken into account Stated Preference Survey in all existing transport options that can be affected by regional rail transport.

1) Existing Demand

Since already searched in stage1, the existing demand for road transport are performed by chartered bus, with 1714 daily travelers population sample, as shown in Table XIV:

TABLE XIV
CHARTERED BUS PASSENGERS

	Workers	Students	Unit
Bus quantity	29	7	Bus (one way)
Avaiable seats	48	46	Seats per bus
Passengers	1392	322	
Passengers (total)	1714		Passengers/ day

2) Tendency Rate Application

For utility functions application, it was considered time and cost characteristics, as scenarios presented previously in Tab. 13.

Considering scenario 01, tendency rate is applied in defined scenarios according to Equation 6, in order to estimate the transferred demand for standard train.

$$P_{trem} = \frac{exp^{U_t}}{exp^{U_t} + exp^{U_{car}} + exp^{U_o} + exp^{U_{tc}}} \quad (6)$$

With the application of tendency rate, the results obtained are shown in Table XV.

TABLE XV
TENDENCY RATES TO CHANGE TO STANDARD TRAIN

	Scenario 01	Scenario 02	Scenario 04
Ut	-12,01	-13,24	-13,42
Ucar	-15,1	-15,1	-15,1
Uo	-14,73	-14,73	-14,73
Utc	-12,99	-14,22	-14,83
Results	0,672636	0,569361	0,588119

Thus, considering transportation mode conditions in the above scenarios, 67.26% of chartered bus demand are likely to be transferred to the train, i.e. among 1714 people traveling from one city to another by chartered bus, 1152 people would prefer the railway option. If the travel time increases 20 minutes, 975 people would transfer to train option, i.e. 56.94% of total demand. If the ticket cost increase by 15% then 1008 people would transfer to the train option, i.e. 58.81% of the travelers.

Tendency rate is then applied, according to EQ. 6, in defined scenarios in order to estimate the transferred demand to train with additional comfort.

$$P_{tc} = \frac{exp^{U_{tc}}}{exp^{U_{tc}} + exp^{U_{car}} + exp^{U_o} + exp^{U_t}} \quad (7)$$

Tendency rate application results are shown in Table XVI:

TABLE XVI
TRAIN WITH ADDITIONAL COMFORT TENDENCY RATE

	Scenario 01	Scenario 02	Scenario 04
Ut	-12,01	-13,24	-13,42
Ucar	-15,1	-15,1	-15,1
Uo	-14,73	-14,73	-14,73
Utc	-12,99	-14,22	-14,83
Results	0,252448	0,213687	0,143585

Thus, considering transportation mode conditions presented in the scenarios above, 25.24% of chartered bus demand are likely to be transferred to train option with additional comfort, i.e. among 1714 people traveling from one city to the another by chartered bus, 432 people would prefer the railway option with greater comfort. If travel time increases in 20 minutes,

366 people would transfer to the train option, i.e. 21.37% of total demand. If the rate increases by 15%, only 246 people would transfer to the train with additional comfort, i.e. 14:36% of travelers.

V. RESULTS AND DISCUSSION

Analyzing transferred demand forecast methodology application, it was observed that the second stage was able to offer the research objectified regional feature when travelers chose the item "comfort" as important for transportation mode decision-making.

Regarding to Stated Preference Survey, in the questionnaires, users who have tickets paid by companies or third parties may have difficulty understanding the presented hypothetical scenarios and tended not to evaluate the scenarios one by one, marking only the option that best suits him or her , making unrepresentative results for the utility function.

Regarding to scenarios and attributes, all were well understood by respondents. It was noticed that the train alternative with added comfort was valid, avoiding the need to have a greater number of scenarios and enabling more clear analysis to the user. Thus, data collection for use in indicated program using logit Multinomial model in Biogeme software was carried out without difficulty and the program was easy to use and understand.

On regional application and considering Brazilian economic scenario, there was a considerable variation in economy since the beginning of the study in 2014 to the end of data collection in 2015 and 2016 with process completion, when high unemployment level are observed. Thus, the dependence between the cities weakened job generation, directly impacting on demand between cities.

Future work could be extended to researches involving all groups of travelers between regions - workers, visitors, students - even if not routine, also including other ways to identify more accurately the percentage of travelers who would transfer to rail transportation. It is suggested also to conduce similar studies considering induced demands, different questionnaires for each group of passengers analysis, considering just the way it is already used by passenger and transport to be deployed; they could be tested in more logit models in order to know whether this model is ideal to estimate transferred demand;

It is proposed that the methodology applications could be carried out in different regions, identifying variables consistency and also demand check after railway implementation, in order to validate and reassess the proposed process.

Also, the inclusion of economic variables could be testes, based on GDP, employment and unemployment rates, among others, to include in this methodology an economic stability evaluation and how it can affect transferred demand.

REFERENCES

[1] V. B. G. Campos, *Planejamento de transportes: Conceitos e modelos* Rio de Janeiro: Editora Interciência, 2013. 188 p.

[2] H. T. Dimitrou."The Urban Transport Planning Process and its derivates: A critical review of their evolution and appropriateness to third world cities." 1987.

[3] F. Ciaffi; E. Cipriania; M. Petrellia; R. Ušpalytė-vitkūnienėb, "A new methodology for the public transport network design." In: International conference "environmental engineering", 9., 2014, Lithuania. Artigo, 2014. p. 1 - 6.

[4] L. M. A. Teixeira; S. C. C. Machado; G. M. I. Tedesco, "Identificação de eixos estruturantes para o planejamento de redes de transporte rodoviário de passageiros. " in *ANPET*, 18. Belém, PA, 2013.

[5] N. M. Gonçalves, "Economias de Escala em uma Linha de Ônibus Urbano: O Enfoque Micro-Análitico". Dissertação de Mestrado, Curso de Pós-Graduação em Engenharia de Produção, Universidade Federal de Santa Catarina. Florianópolis, SC. 1995.

[6] R. Moura; C. Branco; M. L. Gomes; O. L. C. Firkowski, "Movimento pendular e perspectivas de pesquisas em aglomerados urbanos. " São Paulo em perspectiva, v. 19, n. 4, p. 121-133, 2005.

[7] J. Beaujeu-garnier, "Geografia de população. " São Paulo: Companhia Editora Nacional, 1980.

[8] R. Randolph, e P. H. O. Gomes, "Urbanização, movimento pendular e migração: surgem novas territorialidades em áreas perimetropolitanas? O caso do Rio de Janeiro". Anais do *V Encontro Nacional sobre Migrações*. ABEP. Campinas, SP. October, 2007.

[9] IBGE (2010) Censo Demográfico 2010. Instituto Brasileiro de Geografia e Estatística. Brazil. [Online] Available: http://cod.ibge.gov.br/20UGX.

[10] M. I. S. Corrêa; S. C. B. Mello; A. C. R. Souza; K. R. S. Guerra; S. H. F. Silva, "A análise dos trajetos dos usuários dos sistemas de bilhetagem eletrônica." In *Congresso Brasileiro de Transporte e Transito*, 19., ANTP, 2013. p. 1 - 6. Brasília, GO. 2013.

[11] IBGE (2015) Arranjos populacionais e concentrações urbanas do Brasil. Instituto Brasileirod e Geografia e Estatística. Brazil. [Online] Available: www.ibge.gov.br/apps/arranjos_populacionais/2015/pdf/publicaca.pdf.

[12] BNDES. "Avaliação técnico-econômica de sistemas ferroviários de interesse regional." Volume I. Rio de Janeiro. ANTP. 1997.

[13] Ministério Dos Transportes (2012) Termo de referência: diagnóstico do potencial da malha ferroviária existente para o transporte ferroviário regional de passageiros e estudos de viabilidade. Agência Nacional dos Transportes Terrestres. Brasília, GO, Brazil. [Online] Available: http://www.antt.gov.br/html/objects/_downloadblob.php?cod_blob=12488

[14] Ministério Dos Transportes (2013) Projeto Trens Regionais. 2013. Atualização em 12/04/2013. Agência Nacional dos Transportes Terrestres. Brasília, GO, Brazil [Online] Available: http://www.transportes.gov.br/conteudo/1463-projeto-trens-regionais.html.

[15] J. I. de O. Lopes Filho Pós-Avaliação da Previsão de Demanda por Transportes no Município de Fortaleza. Dissertação de Mestrado, Programa de Mestrado de Engenharia de Transportes, Universidade Federal do Ceará, 2003. Fortaleza, CE, 179 fl.

[16] S. M. Pessanha . Estimativa de demanda transferida em sistemas de trens de passageiros com característica regional. Dissertação de mestrado, Programa de Mestrado de Engenharia de Transportes, Instituto Militar de Engenharia, Rio de Janeiro, 175 fl. 2016.

[17] G. Bel (1997) Changes in travel time across modes and its impact on the demand for inter-urban rail travel. Transportation Research Part E: Logistics and Transportation Review, v. 33, n. 1, p. 43-52. [Online] Available: < http://www.sciencedirect.com/science/article/pii/S136655459600004X

[18] J-D. Rolle (1997) Estimation of Swiss railway demand with computation of elasticities. Transportation Research Part E: Logistics and Transportation Review, v. 33, n. 2, p. 117-127. [Online] Available: http://www.sciencedirect.com/science/article/pii/S1366554597000094

[19] U. Crisalli (1999) User's behaviour simulation of intercity rail service choices. Simulation Practice and Theory, v. 7, n. 3, p. 233-249. [Online] Available:

http://www.sciencedirect.com/science/article/pii/S092848699900004X

[20] V. Stefanis; V. Profillidis; B. Papadopoulos; G. Botzoris (2001) Analysis and Forecasting of Intercity Rail Passenger Demand by Econometric and Fuzzy Regression Models. 8th SIGEF Congress: New Logic for the New Economy, International Association for Fuzzy Set Management and Economy. Naples, Italy. [Online] Available: http://gandalf.fee.urv.cat/sigef/english/congressos/congres8/pdf_ab/221.pdf

[21] G. Jovicic;, C. O. Hansen (2003) A passenger travel demand model for Copenhagen. Transportation Research Part A: Policy and Practice, v. 37, n. 4, p. 333-349. [Online] Available: http://www.sciencedirect.com/science/article/pii/S0965856402000198

[22] M. Wardman (2004) Demand for rail travel and the effects of external factors. Transportation Research Part E: Logistics and Transportation Review, v. 42, n. 3, p. 129-148. [Online] Available: http://www.sciencedirect.com/science/article/pii/S1366554504000596

[23] P. Burge, C. Kim; C. Rohr (2011) Modelling Demand for Long-Distance Travel in Great Britain. Rand Corporation. Santa Monica, CA. [Online] Available: http://www.rand.org/pubs/technical_reports/TR899.html

[24] A. A. Ahern; N. Tapley (2008) The use of stated preference techniques to model modal choices on interurban trips in Ireland. Transportation Research Part A: Policy and Practice, v. 42, n. 1, p. 15-27. [Online] Available: http://www.sciencedirect.com/science/article/pii/S0965856407000481

[25] Iarnród Éireann Intercity Network (2011) 2030 Rail Network Strategy Review. Dublin, Ireland. [Online] Available: http://www.irishrail.ie/about-us/rail-vision-2030

[26] T. Li; E. Van Heck; P. Vervest; J. Voskuilen; F.Hofker; F. Jansma (2006) Passenger travel behavior model in railway network simulation. In: Proceedings of the 38th conference on Winter simulation. Winter Simulation Conference. Monterrey, CA, United States. p. 1380-1387. [Online] Available: http://dl.acm.org/citation.cfm?id=1218364

[27] M. L. Trap, (2014) The Dutch Winter Timetable: Assessment of Alternative Line Systems for the Dutch Railway Network during Winter Weather. 108 f. Master Of Science In Transport, Infrastructure & Logistics, Delft University of Technology. Delft, Netherlands. [Online] Available: http://repository.tudelft.nl/2015.

[28] Network Rail (2009) Demand forecasting technical note. New Lines Programme. United Kingdom. [Online] Available: http://www.networkrail.co.uk/5879_Demandforecastingtechnicaln ote.pdf

[29] Network Rail (2009) Stated Preference Survey. New Lines Programme. United Kingdom. [Online] Available: http://www.networkrail.co.uk/5882_StatedPreferencesurveyreport .pdf

[30] E. Yao; T. Morikawa (2005) A study of on integrated intercity travel demand model. Transportation Research Part A: Policy and Practice, v. 39, n. 4, p. 367-381, 2005. . [Online] Available: http://www.sciencedirect.com/science/article/pii/S0965856404001168

[31] N. Sanko; T. Morikawa; Y. Nagamatsu (2013) Post-project evaluation of travel demand forecasts: Implications from the case of a Japanese railway. Transport Policy, v. 27, p. 209-218, 2013. [Online] Available: http://www.sciencedirect.com/science/article/pii/S0967070X13000279

[32] T. Kitagawa; O. Saratchai; S. Terabe (2005) Various Factors Affecting Modal Choice Behaviour of The Inter-City Passenger Between Keihanshin and Fukuoka. In: Proceedings of the Eastern Asia Society for Transportation Studies. 2005. p. 199-208. [Online] Available: http://www.easts.info/on-line/proceedings_05/199.pdf

[33] F. D. Dou; J. Xu; L. Wang; L. Jia (2013) A train dispatching model based on fuzzy passenger demand forecasting during holidays. Journal of Industrial Engineering and Management, v. 6, n. 1, p. 320-335, 2013. [Online] Available: http://www.jiem.org/index.php/jiem/article/view/699

[34] A. Wijeweera; H. Para; M.B. Charles,; K. Sloan (2014) A time series analysis of passenger rail demand in major Australian cities. Economic Analysis and Policy, v. 44, n. 3, p. 301-309, 2014. [Online] Available: http://www.sciencedirect.com/science/article/pii/S0313592614000447

[35] Virginia Department of Rail And Public Transportation (2009). Appendix G: Travel Forecasting Methodology.: Richmond Hampton Roads Passenger Rail Project. Virgínia, United States. [Online] Available: http://www.rich2hrrail.info/

[36] M.S. Anderson; J.M. Simkins (2012) Report D – Revised comprehensive report: development of long distance multimodal passenger travel modal choice model. Department of Transportation Federal highway administration. Washington, United States. [Online] Available: http://www.fhwa.dot.gov/policy/modalchoice/

[37] Ministério Dos Transportes (2012) Estudo de Viabilidade Técnica, Econômica, Financeira, Social e Ambiental. Universidade Federal de Santa Catarina – UFSC. Laboratório de Transportes e Logística – LabTrans. Brazil. [Online] Available: http://www.transportes.gov.br/images/consultas_publicas_viasNavegaveis/TRENS_REGIONAIS/Londrina_Maringa.pdf

[38] Ministério Dos Transportes (2011) Resumo executivo trecho Caxias do Sul – Bento Gonçalves. Universidade Federal de Santa Catarina – UFSC. Laboratório de Transportes e Logística – LabTrans. Brazil. [Online] Available: http://www.antt.gov.br/html/objects/_downloadblob.php?cod_blob=12427

[39] T. S. Ventura (2012) Procedimento metodológico para a estimativa de demanda transferida em sistemas de transporte ferroviário de passageiros com característica semiurbana: estudo de caso do trecho Florianópolis (SC) –Itajaí (SC). 238 p. Dissertação (mestrado) - Curso de Pós-graduação em Engenharia Civil, Universidade Federal de Santa Catarina – UFSC, Florianópolis, SC, Brazil. [Online] Available: https://repositorio.Ufsc.Br/handle/123456789/99225

[40] A. A. Souza; A. C. C. Pereira Critérios que influenciam na escolha dos modos de transporte nos deslocamentos ao aeroporto. XVI Congreso Chileno de Engenharia de Transporte, 2013. Santiago, Chile. 21- 25 Outubro 2013.

[41] G. Reck (2003) Apostila Transporte Público. Departamento de Transporte. UFPR, 2003. Paraná, Brazil. [Online] Available: http://www.dtt.ufpr.br/Transporte Publico/Arquivos/TT057_Apostila.pdf

[42] J. C. Mello, (1972) Planejamento dos Transportes Urbanos. Ed. Campus.

[43] O. F. Lima Jr., Qualidade em serviços de transportes: conceituação e procedimentos para diagnóstico. São Paulo, 1995. Tese (Doutorado) – Escola Politécnica, Universidade de São Paulo, 215 p.

[44] A. C. P. Ferraz; I. G. E. Torres Transporte público urbano. São Paulo, Rima Editora, 2004. 428 p.

[45] T. L. Saaty A scaling method for priorities in hierarchical structures. Journal of Mathematical Psycology, v.13, n.3, p.234-281, 1977.

[46] T. L. Saaty How to make a decision: the analytic hierarchy process. European journal of operational research, v. 48, n. 1, p. 9-26, 1990.

[47] T. L. Saaty What is the analytic hierarchy process?. Springer Berlin Heidelberg, 1988.

[48] M. A. Sharifi; L. Boerboom; K. B. Shamsudin,; L. Veeramuthu, Evaluating rail network options using multicriteria decision analysis. In: Case Study Klang Valley Malaysia. In Application of Planning and Decision Support Systems, Intrenational Islamic University Malaysia, p. 21–60, 2004.

[49] M. Taleai; M. S. Mesgari; , A. Sharifi; R. Sliuzas,; N. Barati A spatial decision support system for evaluating various land uses in a built up urban area. In: The 26th Asian Conference on Remote Sensing and 2nd Asian Space Conference. Hanoi, Vietnam, 2005.

[50] M. Taleai; A. Sharifi; R. Sliuzas,; M. Mesgari; Evaluating the compatibility of multi-functional intensive urban land uses. International Journal of Applied Earth Observation and Geoinformation, v. 9, n. 4, 375-391, 2007.

[51] M. Bierlair BIOGEME: A free package for the estimation of discrete choice models, 2003. Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland.
[52] M. Bierlaire BisonBiogeme 2.4: estimating a first model [Online] Available: hottm://biogeme.ep.ch
[53] M. Bierlaire (2008) Estimation of discrete choice models with BIOGEME 1.8. [Online] Available: hottm://biogeme.ep.ch
[54] J. D. Ortúzar; L. G. Willumsem Modelling Transport. 3. ed. West Sussex: John Wiley & Sons Ltd., 2001.
[55] M. Ben-Akiva, S. Lerman Discrete choice analysis: theory and application to travel demand. Cambridge University Press. Cambridge, 1985.
[56] L. R. Deus; S. P. Sanches. Influência da forma urbana sobre o comportamento de viagens urbanas. Caminhos de Geografia, v. 10, n. 29, 2009.
[57] A. N. Brito (2007) Aplicação de um procedimento de preferência declarada para a estimativa do valor do tempo de viagem de motoristas em uma escolha entre rotas rodoviárias pedagiadas e não pedagiadas. 185 f. Dissertação (Mestrado) - Curso de Engeharia de Transportes, Departamento de Engenharia de Transportes, Universidade de São Paulo. São Paulo, São Paulo, Brazil. [Online] Available: http://www.teses.usp.br/teses/disponiveis/3/3138/tde-27062007-183816/.

Swellen Mendonça Pessanha was born in Campos dos Goytacazes city, RJ, Brazil, in 1989. Graduated in Architecture and Urbanism from Federal Fluminense Institute (IFF) in 2012. Currently, she is pursuing the M.S. degree in Transportation Engineering at Military Institute of Engineering (IME), Rio de Janeiro, Rio de Janeiro, Brazil.
She has experience in Architecture, Urban Planning, Construction Technologies and Transportation Engineering, mainly in demand´s behavior, Transferred Demand, Passenger Trains systems and Stated and Revealed Preference Survey.

Cynthia Vargas Cuchava Rocha, was born in Itajaí city, Brazil in 1991. Graduated in Civil Engineering from the University of Vale do Itajaí - Santa Catarina state, Brazil (2013) and Master in Transportation Engineering from IME (2016). She has experience in civil construction through development and execution of projects (architectural, sanitary, electrical, structural) works monitoring of Compliance Projects Monitoring the disciplines: sociology and urban planning, architecture, design I and II, and transport engineering area has experience in urban mobility for freight transport.

Simone Lie Issomura was born in São Paulo city, Brazil, in 1981. She received the B.S. degree in civil engineering from State University of Campinas (UNICAMP), Campinas, São Paulo, Brazil, in 2004; quality and value engineering specialization degree from São Paulo University (USP), São Paulo, São Paulo, Brazil, in 2007; railway engineering specialization degree from Minas Gerais Pontifical Catholic University (PUC Minas), Belo Horizonte, Minas Gerais, Brazil, in 2008 and MBA degree from Getúlio Vargas Foundation (FGV), São Paulo, São Paulo, Brazil, in 2009. She is currently working pursuing the M.S. degree in transportation engineering at Military Institute of Engineering (IME), Rio de Janeiro, Rio de Janeiro, Brazil.
From 2005 to 2007 she has worked as Civil Engineer at São Paulo Subway Company and since 2008 she is working as Permanent Way Engineer at a Brazilian mining company in Vitoria, Espírito Santo, Brazil.

Vania Barcellos Gouvea Campos graduated in architecture at Rio de Janeiro Federal University (UFRJ), Rio de Janeiro, Brazil, in 1978. She received the master degree in transportation engineering from Military Institute of Engineering (IME), Rio de Janeiro, Rio de Janeiro, Brazil, in 1980; the Ph.D. degree in production engineering from UFRJ, Rio de Janeiro, Brazil, in 1997 and the PostDoc from Minho University, Minho, Portugal, in 2005.
From 1981 to 1982 she worked as Architect at Petropolis city hall, from 1982 to 1984 she worked as Planning Assessor at Sermapi S.A and from 1986 she has been working as a Professor at IME, Rio de Janeiro, Rio de Janeiro, Brazil. Her research interest includes: cargo and passenger urban transportation, traffic control, mobility, land use and transportation logistics.

Renata Albergaria de Mello Bandeira graduated in fortification and construction engineering at Military Institute of Engineering (IME), Rio de Janeiro, Brazil, in 2002. She received the master degree in production engineering from Rio Grande do Sul Federal University (UFRGS), Rio Grande do Sul, Brazil, in 2006 and the Ph.D. degree in administration from UFRGS, Rio Grande do Sul, Brazil, in 2009.
From 2009 to 2010 she worked as a Professor at UFRGS, from 2010 to 2011 she worked as Professor at TecBrasil and since 2011 she has been working as a Professor at IME, Rio de Janeiro, Rio de Janeiro, Brazil. Her research interest includes: logistics, supply chain management, logistics outsourcing, project management and statistics.