# *Gender differences in the user satisfaction and service quality improvement priority of public transit bus system in Porto Alegre and Fortaleza, Brazil*

**Gender Differences in the User Satisfaction and Service Quality Improvement Priority of Public Transit Bus System in Porto Alegre and Fortaleza, Brazil**

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**Abstract**
Previous studies have shown that the rider satisfaction on bus services vary between males and females. As women make a significant number of transit trips in developing countries nowadays, it is crucial to understand their perceptions and satisfactions towards different service aspects of public transit, thus to provide transit agencies with the gender-differentiated policy suggestions. In this study, we use the QualiÔnibus rider satisfaction survey data in two Brazilian cities: Porto Alegre and Fortaleza, to examine the differences between male and female in their ratings of various transit service attributes, and their perceptions of the relative importance of different service attributes on riders' overall satisfaction, and based on which detect the high priority service attributes to act on for each gender. The random forest method is applied to determine the attribute importance, which captures both the non-linear and asymmetry influences of the service attributes on riders' overall satisfaction. Our findings show that the gender difference exists in terms of both the importance type and the improvement priority of the attributes. Specifically, women are associated with higher improvement priorities regarding "speed", "customer service", "security", "exposure to noise and pollution" and "customer information" in Porto Alegre, and regarding "access to transport", "customer information", "easiness to transfer", "comfort at integration terminals" and "speed" in Fortaleza. Our findings illustrate the effectiveness of using our methods to distinguish different importance types of service attributes between different genders, which could help the transit agency develop gender-oriented actions regarding service improvements.

**Keywords:** User Satisfaction, Service Attribute Importance, Improvement Priority, Random Forest, Gender, QualiÔnibus Survey

## 1. Introduction

User satisfaction is an essential criterion to evaluate the performance of public transit (Aniley and Negi, 2010; Ojo, 2019). It is essential to examine the rider-facing performance of current transit services, and the relative importance of each service attribute, thus to help policymakers and planners decide which improvement to prioritize regarding transit service attributes. To understand rider's satisfaction towards public transit, satisfaction surveys are often conducted to collect riders' satisfaction towards each specific service attribute and the overall transit system. A sizable amount of literature has examined the influence of service qualities on user satisfaction, as well as the determination of service improvement priorities (e.g. Wan et al., 2016; Cao et al., 2016; Zhang et al., 2019; Wu et al., 2020). In terms of methodology, linear regression, correlation analysis and structural equation models are typically deployed to analyze the importance of attributes, but these methods assume that the service attributes have linear and symmetric impact on people's satisfaction, discounting the fact that a negative rating and a positive rating of a service attribute have systematically different effects on people's overall satisfaction. Also, the improvement strategies for service attributes that perform poorly and for those that perform well should be different. Therefore, this study adopts a three-factor theory (TFT) approach to capture this non-linear effect and develop the attribute improvement strategy. The random forest method is applied to study the impact of service attributes on riders' satisfaction, which is a non-parametric technique that does not depend on pre-defined underlying relationship between dependent and independent variables (de Oña and de Oña, 2013).

The gender differences could be significant when men and women are evaluating their satisfactions with products/services (Hoyer and MacInnis, 2010), and thus may result in differences on satisfaction level and

the assessment of perceived service quality. Therefore, it is essential to include the gender differences into evaluating the rating of perceived service quality and analyzing the association between service quality and overall satisfaction, which can provide the transit agencies with gender-differentiated policy suggestions regarding the priorities of service improvements.

On the other hand, gender is an important factor to be considered in transport equity. It has been revealed by previous research that gender affects the perceptions of service quality due to the differences between male and female in the importance they place on the core and peripheral services, consumption motivations and behaviors, and emotional functioning (Iacobucci and Ostrom, 1993; Dittmar et al., 2004; Brody & Hall, 2008). As a consequence, a better understanding of gender differences in their perceptions towards transit service qualities is necessary to enact better policies for male and female transit users and to promoting public transit services (Di Ciommo and Shiftan, 2017; Sheller, 2020).

Therefore, this paper analyzes the QualiÔnibus rider satisfaction survey data in two Brazilian cities: Porto Alegre and Fortaleza, and answers the following three research questions: (1) Are there significant differences in the rating of service qualities between male and female riders? (2) How do the service attributes influence riders' overall satisfaction as perceived by each gender? (3) How should we prioritize the improvement of service attributes for each gender? This study is an initial attempt to examine the performance of the service attributes as well as the relationship between each service attribute and user satisfaction for different gender groups in the context of public transportation user satisfaction analysis.

The rest of the paper is organized as follows. In Section 2, we review the methods to assess the attribute performance and the importance of each attribute to transit riders' overall satisfaction, as well as previous research on the gender differences in perceived service quality and user satisfaction. Section 3 and 4 introduce the study area, data, and methods. Section 5 discusses the results from the analysis. And lastly, Section 6 summarizes the key findings and contributions of this study.

## 2. Literature Review

### 2.1 User Satisfaction and the Importance of Service Attributes

Determining the improvement priority for each public transit service attribute is critical to public transit management, since public transit agencies often need to prioritize the essential service attributes to improve riders' overall satisfaction under constraint budgets. Performance of each service attribute and its relative importance to overall rider satisfaction are two key concerns in the determination of the service improvement priority. A service attribute may not need further enhancement if it does not have significant impact on improving riders' overall satisfaction, or if it already performs well; on the other hand, a service attribute that has a poor performance and is important to the overall satisfaction should be given a higher priority of improvement.

Evaluating the performance of each service attribute is relatively straightforward. Mean score of each attribute is normally used as a measurement, where the mean of all riders' rating towards each attribute is calculated and compared. However, assessing the relative importance of each service attribute to riders' overall satisfaction is more complicated.

Many of the previous studies assumed a linear relationship between the service attributes and overall satisfaction, and thus adopted correlation analysis or regression to assess the relative importance of each service attribute. For example, Baltes (2003) applied STEPWISE regression to identify the important service attributes of the Bus Rapid Transit (BRT) systems in Miami and Orlando, Florida. Wan et al. (2016) examined the importance of various service attributes of the 'light' BRT system in New York City using OLS regression. Mouwen's research on Dutch public transit also assumed a linear relationship, but further considered the interactional effect between the attribute satisfaction of person and his/her characteristics (Mouwen, 2015). Shen et al. (2015) adopted a structural equation model (SEM) to examine the factors that

influence the overall satisfaction. Cao et al. (2016) used a multivariate ordered probit regression to examine the importance of different service attributes to the overall satisfaction of Guangzhou BRT riders. Some other studies calculated correlations between riders' perceived service qualities and the overall satisfaction as a measurement of the importance (Weinstein, 2000; Cain et al., 2009; Mahmoudi et al., 2010). However, assuming a linear relationship has limitations as previous studies have revealed that nonlinear relationship exists in the relationship between many of the public transit service attributes and the overall satisfaction (Cao and Cao, 2017; Wu et al., 2018; Wu et al., 2020).

Based on the Kano Model (Kano et al., 1984), three-factor theory (TFT) has been widely adopted in public transit satisfaction studies to capture the non-linear relationship between service attributes and overall satisfaction. Service attributes are classified into three factors: Basic factors, Performance factors, and Exciting factors (Matzler et al., 2004): Basic factors have significant impacts on the overall satisfaction only when they perform poorly, Exciting factors have significant impacts on the overall satisfaction only when they perform well, and Performance factors have significant impacts on the overall satisfaction when they perform both well and poorly. Factors that fall outside any of these three categories are Unimportant factors as they do not have significant impacts on overall satisfaction.

Importance grid and regression with dummy variables are two commonly-used approaches to implement TFT. Zhang et al. (2019) applied the TFT importance grid approach to compare and contrast the relative importance of service attributes in BRT, bus, and van services of Indore, India. Wu et al. (2018) applied the TFT regression with dummy variables to explore the influence of service attributes on rider satisfaction of public transit systems in Twin Cities, Minnesota. Cao and Cao (2017) adopted both approaches to analyze the survey data of BRT, bus, and metro in Guangzhou, China.

Although both the importance grid and regression with dummy variables capture the non-linear relationship between service attributes and riders' overall satisfaction, they are parametric methods that rely on pre-defined relationship between the dependent and explanatory variables. Besides, these methods only capture the significance level but not the effect size of the influence, while the effect size could be essential in determining the improvement priority. Very few previous studies applied the non-parametric models. Wu et al. (2020) applied the impact-asymmetry analysis framework and gradient boosting decision trees to capture both the non-linear relationship and the effect size of the influence of service attributes.

In this study, we apply the TFT framework to examine the importance of service attributes on the overall satisfaction. The random forest (RF) method is adopted to implement TFT. Previous studies have shown that the use of RF improves prediction accuracy by accounting for variability in the data (Cheng et al., 2019; Ermagun et al., 2015; Hou et al., 2015). Also, unlike traditional regression that assumes people base their general satisfaction on all service attributes, RF assumes that different riders may rate their overall satisfaction depending on different (subsets of) conditions and can capture this attitudinal randomness by using an ensemble of simple decision trees, each dependent on a set of conditions (Rasouli and Timmermans, 2014). To the best of our knowledge, this study is the first approach to examine the gender difference in the impact of service attributes on riders' satisfactions using RF with TFT method.

### 2.2 Gender Differences in Rider Satisfaction and Perceived Service Qualities

Several previous studies have examined the differences between men and women about their attitudes towards one or more public transit service attributes. It has been revealed that female tends to have more negative attitudes toward public transit (Beirão and Cabral, 2008; De Oña and De Oña, 2013; Namgund and Akar, 2014). Arabikhan et al. (2016) examined the differences between young men and young women regarding their expectations and perceptions of public transit service quality in the city of Reggio, Italy. Hsu et al. (2019) conducted a pre- and post-opening travel surveys near a new light rail transit service in Los Angeles, and found that female had higher security concerns related to transit use than male, which even offsets their intention to increase transit use out of environmental concerns or the improving accessibility to public transit systems. Rosenbollm and Burns (1993)'s study indicated that women were less concerned with the bus service improvements of accessibility and frequency. Namgung and Akar (2014)

analyzed the 2012 campus transportation survey at Ohio State University, and concluded that women are more likely to consider comfort as an important factor that influences their transit use, while the improvement of service frequency may increase the transit use of both women and men. However, these studies didn't systematically examine the gender differences in the improvement priority of transit service attributes, which becomes one of the motivations of this study.

Some literature has investigated how priority of service quality improvement differs among riders with different socio-demographics, such as income and age (Wong et al., 2017; Ye et al., 2019), but the difference between male and female is not fully studied. To the best of our knowledge, Rojo et al. (2011) and De Oña and De Oña (2013) are the only two existing studies that examined how women and men differ in the relative importance of service qualities to the overall satisfaction. Roje et al. (2011) studied the interurban bus services, and found that the seat comfort on the bus, road safety, and frequency of service are more important factors to the overall satisfaction of female riders, while male riders cared more about journey time, cleanliness and noise in the bus. De Oña and De Oña (2013) applied Decision Trees to analyze the data from three consecutive customer satisfaction surveys in the metropolitan transit service of Granada (Spain), and found that from 2009-2011, the most influential attribute varies among safety, punctuality, and timetable for men, while the key factor varies among speed, frequency, and timetable for women. However, none of the relevant literature applied the random forest method, which has proven to be efficient by using randomization that produces diversity and build classifiers different from each other (Tin Kam Ho, 1998). This study is the first research into utilizing the random forest method to study the gender difference in the impact of attributes on people's overall satisfaction.

## 3. Data and Study Area

### 3.1 Study Area

We carry out our studies in two Brazilian cities, Porto Alegre and Fortaleza, to compare the gender differences. Porto Alegre is the capital of the southernmost state of Brazil, Rio Grande do Sul. It is the 10th most populous city in the country (1,409,351inhabitants), and has the 7th highest GDP and is the main city of the 5th most populous metropolitan area (more than 4 M inhabitants) (IBGE, 2020). The metropolitan area of Porto Alegre is shown in **Figure 1** (Porto Alegre, 2015).

Public transport holds 43% of the mode share of the city according to the last origin destination survey (EPTC, 2004). The system is composed of one metropolitan suburban train line, one metropolitan ferry and a robust metropolitan and municipal bus network. Within the city, the public transport system is regulated and supervised by the Empresa Pública de Transporte e Circulação de Porto Alegre (EPTC) and the Municipal Secretary of Urban Mobility (SMMU). The bus system was bided in 2015 and five different companies operate the network (one public and four private consortia) that is comprised by a fleet of 1,601 buses running 422 routes and carrying on average 845,000 passengers per day (WRI Brasil, 2020).

Porto Alegre was one of the first Brazilian cities that deployed dedicated busways in early 80's (BRT Data, 2020), however, as elsewhere in the country in the last few years, it has presented a substantial reduction in the demand of public transport due to lack of major investments, new infrastructure and new competitors (e.g. ride hailing apps, which are not regulated in the city).

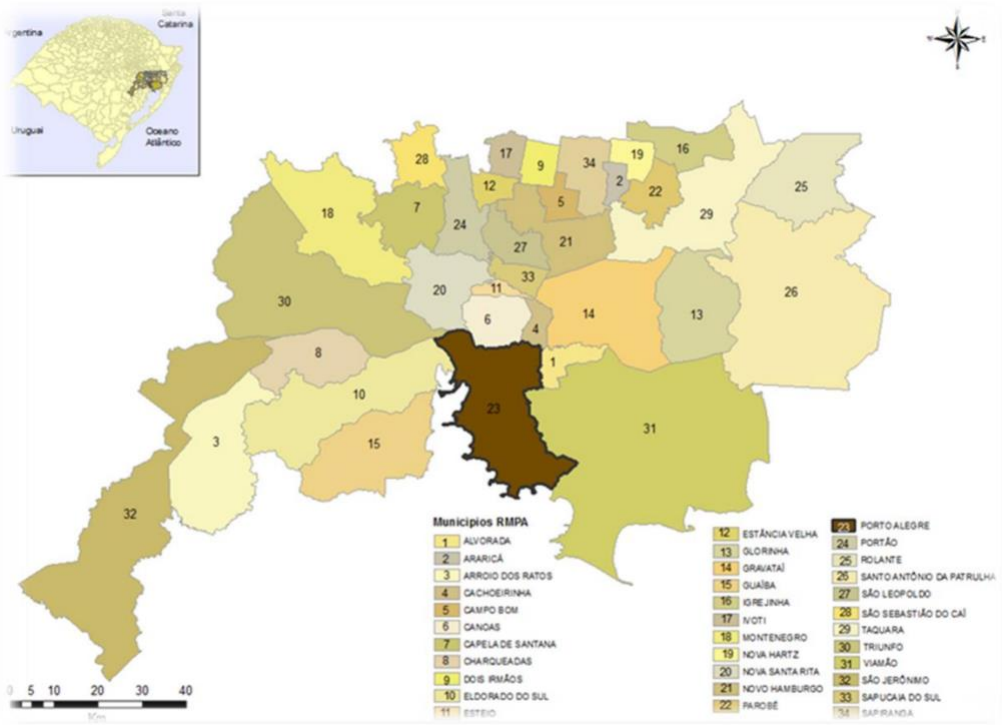



**Figure 1 The metropolitan area of Porto Alegre (in dark brown)**

Fortaleza is a city in the northeast of Brazil, in the state of Ceará. Fortaleza is the 5th most populous city in the country (2,452,185 inhabitants) (IBGE, 2020), has the 9th highest GDP (IBGE, 2018) and is the main city of the 6th most populous metropolitan area (more than 4 M inhabitants) (IBGE, 2019). The metropolitan area of Fortaleza is shown in orange in **Figure 2** (IPECE, 2007).

According to the last origin destination survey, sustainable transport represents 65% of daily commuting. Of these, commuting on foot holds the majority of 32% and public transport holds 28% (Diário do Nordeste, 2020). The system, shown in **Figure 3,** is composed by one metropolitan metro line (South-red) and another in construction (East-yellow), one metropolitan suburban train line (West-green), one light rail transit line (blue) (METROFOR, 2018), in addition two Bus Rapid Transit corridors (Global BRT Data, 2018) and a robust metropolitan and municipal bus network. Within the city, the public transport system is regulated and supervised by the Fortaleza's Urban Transport Company (ETUFOR, in Portuguese *Empresa de Transporte Urbano de Fortaleza*).


**Figure 2 The metropolitan area of Fortaleza (red star)**

The bus system was bided in 2012 and fourteen different companies won the right to operate the network. Of those, three companies went bankrupt between 2014 and 2018. (UNIBUS RN, 2019). The municipal bus network is comprised by a fleet of 2,270 vehicles, running 288 routes and carrying more than 1.2 million passengers per day – data before pandemic (Prefeitura de Fortaleza, 2018).


**Figure 3 Fortaleza metro system network (SEINFRA, 2016)**

### 3.2 Data and Variables

This study analyzes the data from the QualiÔnibus Satisfaction Survey. It was conceived by WRI Brasil Ross Center for Sustainable Cities based on an extensive literature review of existing practices (e.g. reports from TCRP, European Standard 13816, among others) and on surveys applied in different cities and systems worldwide (Barcelos and Albuquerque, 2018).

QualiÔnibus Satisfaction Survey measures the perceptions of bus transit system users. The survey, in its basic module, consists of four sections: (i) customer profile; (ii) usage profile; (iii) satisfaction; (iv) general perception. The satisfaction section uses a 5-point Likert Scale to measures riders' satisfaction: "very dissatisfied", "dissatisfied", "neither satisfied nor dissatisfied", "satisfied", "very satisfied". Riders' satisfaction towards 16 specific quality factors and their general satisfaction towards the transit system is collected, as described in **Table 1** (Barcelos and Albuquerque, 2018).

**Table 1 Variables in QualiÔnibus Satisfaction Survey to measure the perceptions of users**

| Variable Name | Definition |
|---|---|
| access to transport | ease of getting to points of access and circulating in stations and terminals |
| availability | time interval between buses at the required period and location |
| speed | speed |
| reliability | if the bus arrives on time |
| easiness to transfer | between bus lines and other means of transport to get to destination |
| comfort at bus stops | lighting, protection, cleanliness, loading |
| comfort at stations | lighting, protection, cleanliness, loading |
| comfort at integration terminals | lighting, protection, cleanliness, loading |
| comfort inside buses | lighting, cleanliness, loading, availability of seats, temperature |

| | |
|---|---|
| customer service | respectfulness, friendliness, qualification of drivers, ticket collectors, staff and call center |
| customer information | including timetables, routes, lines and general information |
| security | against theft, robberies and assault on the way to bus stops, stations and terminals as well as inside the bus |
| road safety | road safety |
| exposure to noise and pollution | exposure to noise and pollution produced by the buses |
| easiness to pay fares | easiness of fares payment and travel card reload |
| expenses | expenses with bus transit (i.e. fares). |
| **overall satisfaction** | **general satisfaction with the public transit bus system** |

To assure the representativeness of the samples, the methodology considers a minimum confidence level of 95% and maximum sampling error of 5% (Barcelos and Albuquerque, 2018). As it is a standardized survey, the benchmarking analysis and solutions were allowed to be exchanged among cities (Lindau et al., 2017). The QualiÔnibus Satisfaction Survey has been used to verify the impact of interventions in the public transport system and to support decision making at the local level in more than 15 cities thus far (WRI Brasil, 2020). For the work reported in this study, we use data obtained from the application of QualiÔnibus Satisfaction Survey in Porto Alegre in the year 2019, with in total 1765 respondents (1087 female respondents and 678 male respondents), and the data obtained in Fortaleza in 2019, with in total 1538 respondents (891 female respondents and 647 male respondents).

## 4. Methods

This study adopts the random forest (RF) method to determine the importance of each service attribute taking the following steps.

### 4.1 Step 1: recode independent variables

First, with reference to the approach offered by Wu et al. (Wu et al., 2018), the independent variables – riders' satisfaction score given to each service attribute - was recoded into two mutually exclusive dummy variables — "high-performance" and "low-performance" indicators. Using "neither satisfied nor dissatisfied" as the reference category, "very dissatisfied" and "dissatisfied" are recoded as 1 for the low-performance indicators and 0 for the high-performance indicators, whereas "very satisfied" and "satisfied" are recoded as 1 for the high-performance indicators and 0 for the low-performance indicators; "neither satisfied nor dissatisfied", the reference category, is recoded as 0 for both high-performance indicators and low-performance indicators. The recoding strategy is summarized in **Table 2**.

**Table 2 The coding strategy for the service attributes**

| Performance in survey | High-performance dummy variable | Low-performance dummy variable |
|---|---|---|
| Very dissatisfied (1) | 0 | 1 |
| Dissatisfied (2) | 0 | 1 |
| Neither satisfied nor dissatisfied (3) | 0 | 0 |
| Satisfied (4) | 1 | 0 |
| Very satisfied (5) | 1 | 0 |

### 4.2 Step 2: random forest analysis

Given the uncertainty in forecasting owing to the inherent variability in people's perceptions (Rasouli and Timmermans, 2014), we apply random forest to determine the effects of the different transit service attributes on riders' general satisfaction. Random forest assembles K decision trees which are built on random samples from the dataset (Breiman, 2001). Each tree recursively partitions the training data using a subset of randomly selected condition variables for each split. To illustrate, the predicted outcome is specified as:

$$P(X) = \text{argmax}_j \left[ \frac{\sum_{k=1}^{K} I(h(X,\theta_k)=j)}{K} \right],$$

where $P(X)$ represents the output of the random forest, namely the rating of the overall satisfaction; $X$ denotes the vector of the independent variables; $h(X, \theta_k)$ denotes the tree-structured classifier for tree k; $\theta_k$ represents the parameters in tree k, which characterizes the split variables, cutpoints at each node and terminal node values (Ogutu et al., 2011). In this equation, if the prediction given by the classifier $h(X, \theta_k)$ is equal to j, then $I(h(X, \theta_k) = j)$ is equal to 1, otherwise $I(h(X, \theta_k) = j)$ is equal to 0 (Ghasri et al., 2017). The random forest modeling is carried out using the "caret" package in R.

After fitting the data with the model, the "varImp" function in R is used to calculate the importance score for each attribute. To calculate the importance of a variable, the method measures the increase in the prediction error of the model after the values of that variable are permuted (Ghasri et al., 2017). The importance score is first calculated for each attribute regarding the influence of the attribute on each of the 5 levels of the dependent variable, and is scaled to a range of 0–100. The average importance score across all 5 levels for each attribute is then computed and used as the final importance score to categorize the importance type of that attribute. Therefore, the final importance score of each attribute reflects the relative importance of that attribute compared with other attributes.

### 4.3 Step 3: Categorize the importance types of attributes

A performance-related dummy variable ("high-performance" indicator or "low-performance" indicator) is identified as having a significant impact on riders' overall satisfaction if the importance score of the variable derived from the RF modeling is higher than the average importance score across all the predictors in the RF modeling. **Table 3** summarizes how an attribute is categorized into one of four types of factors--Basic, Exciting, Performance and Unimportant factors--based on the importance of its low-performance and high-performance dummies for the prediction of riders' overall satisfaction, and an illustration of these different types of attributes is shown in **Figure 4** (Matzler et al., 2004; Wu et al., 2018). Specifically, Basic factors are the attributes that significantly affect overall satisfaction only when they perform poorly, but do not significantly affect overall satisfaction when they perform well. On the contrary, Exciting factors are the attributes that significantly affect overall satisfaction only when they perform well, but do not significantly affect overall satisfaction when they perform poorly. Performance factors can be seen as a combination of the two. These are the attributes that significantly affect overall satisfaction both when performing poorly and when performing well. Unimportant factors are attributes that do not have significant relevance to overall satisfaction no matter they perform poorly or well.

**Table 3 Determining the Importance Type of the Variables**

| Type of Factor | Definition | Low-performance dummy has higher-than-average | High-performance dummy has higher-than-average |
|---|---|---|---|

| | | **importance score in RF analysis** | **importance score in RF analysis** |
|---|---|---|---|
| Basic | the attribute significantly affects overall satisfaction only when it performs poorly | Yes | No |
| Exciting | the attribute significantly affects overall satisfaction only when it performs well | No | Yes |
| Performance | the attribute significantly affects satisfaction when it performs both poorly and well | Yes | Yes |
| Unimportant | the attribute does not significantly affect overall satisfaction | No | No |

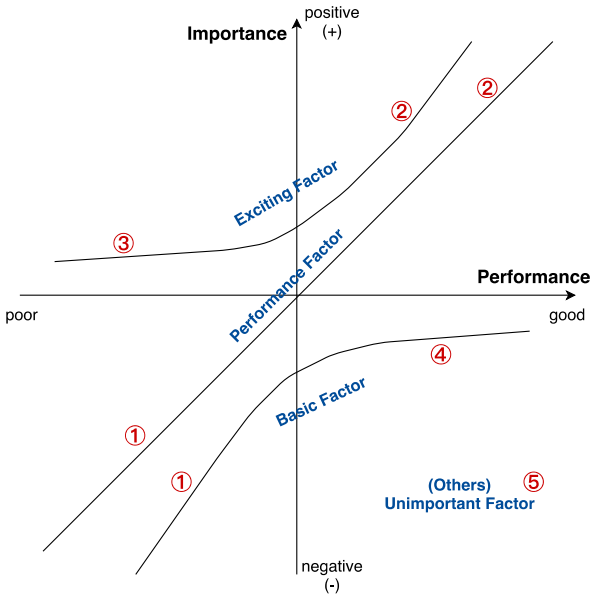



**Figure 4 The illustration of the three-factor theory**

### 4.4 Step 4: Determine the improvement priorities of attributes

Based on the performance of each service attribute, and its importance type categorized in Step 4, the improvement priority for each attribute is determined. The mean performance score of each service attribute is calculated by averaging all surveyed riders' rating of their satisfactions towards each attribute with the following 5 levels: 1 (very dissatisfied), 2 (dissatisfied), 3 (neither satisfied nor dissatisfied), 4 (satisfied) and 5 (very satisfied). The mean performance score of each attribute is then compared with the reference performance score (the score which is averaged across all observations and all attributes). If the mean performance score of an attribute is lower than the reference score, the performance of this attribute is

"poor"; otherwise, if its mean performance score is higher than the reference score, the performance of the attribute is "good".

**Table 4** summarizes the rules for determining the improvement priority for each attribute based on its performance and importance type: Basic and Performance factors that perform poorly are given the first priority, as they significantly reduce riders' overall satisfaction. Exciting and Performance factors with good performance significantly increase riders' satisfaction, but they are given the second priority since it may not be cost-effective to improve the well-performed factors. The third priority is given to Exciting factors that perform poorly, since they will generate significant impacts if their performances become better than the reference. Basic factors with good performance are given the fourth priority. Lastly, Unimportant factors are least prioritized as they don't significantly influence riders' overall satisfaction.

**Table 4 The rule for determining the improvement priority**

| Priority Ranking | Performance Type | Importance Type |
|---|---|---|
| 1 | Poor | Basic |
| | Poor | Performance |
| 2 | Good | Exciting |
| | Good | Performance |
| 3 | Poor | Exciting |
| 4 | Good | Basic |
| 5 | Poor | Unimportant |
| | Good | Unimportant |

## 5. Random forest training results

### 5.1 Model specifications

When training the random forest model in step 2, we use a 10-fold cross-validation method to measure the overall model performance and tune the parameter values. We use 500 trees and tune the number of splitting variables m when making analysis for both female and male. The variations of average performance across 10 folds by m for both genders are shown in **Figure 5** (for Porto Alegre) and **Figure 6** (for Fortaleza). **Figure 5** indicates that for Porto Alegre, m=8 gives the best model performance for male, whereas m=1 gives the best model performance for female. **Figure 6** indicates m=5 for male and m=3 for female give the best results when analyzing the data for **Fortaleza**. Therefore, we settle on these values of m for our implementation.

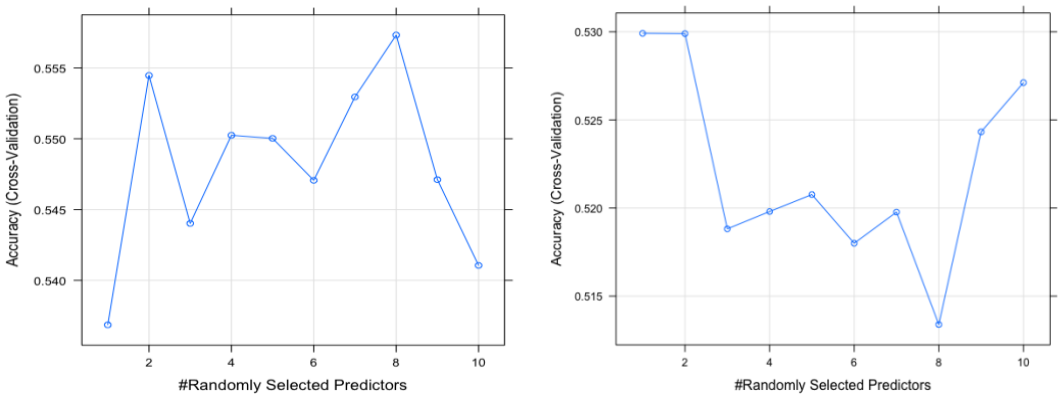



**Figure 5 RF performance with the number of splitting variables (left: male; right: female); city: Porto Alegre**

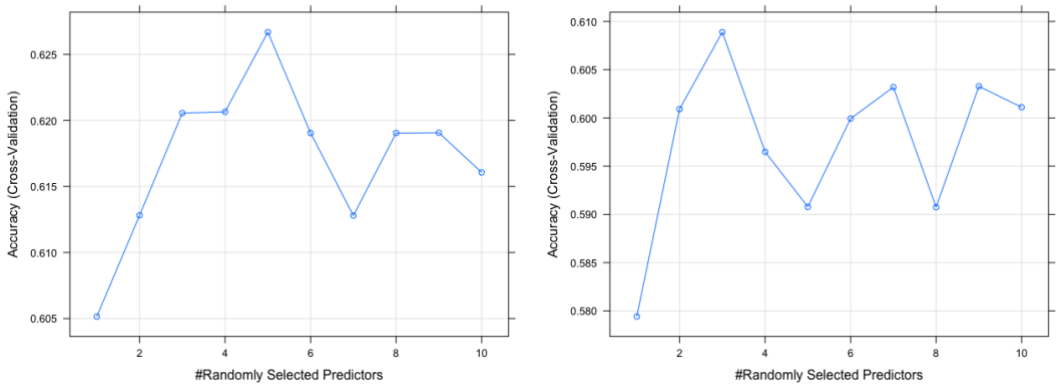



**Figure 6 RF performance with the number of splitting variables (left: male; right: female); city: Fortaleza**

### 5.2 Model comparison

To show the prediction capability of our method, we compare our method with the commonly used multinomial logit (MNL). MNL has been widely used in previous literature to determine the influence of different service attributes on people's overall satisfaction (Abenoza et al., 2019; Wu et al., 2018). Therefore, we want to compare the predictive performances between these two models. We use the same set of predictors that have been utilized in RF to construct the predictions in MNL. 10-fold cross-validations have been applied to both methods for fair comparisons.

**Table 5** gives the comparison of prediction accuracies between RF and MNL. It can be observed that RF outperforms MNL for all the data examined. RF generally results in an accuracy that is 2%-4% higher than MNL. This result indicates that RF would be a better model for prediction compared with MNL.

**Table 5 Prediction accuracies for RF and MNL**

| Model | Porto Alegre | | Fortaleza | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| RF | 0.557 | 0.530 | 0.627 | 0.609 |

| | | | | |
|---|---|---|---|---|
| MNL | 0.524 | 0.501 | 0.600 | 0.573 |

## 6. Results and Discussions

### 6.1 Gender differences in the satisfaction towards each service attribute

Firstly, we compare the difference between male and female riders in their ranking of different transit service attributes. **Table 6** and **Table 7** report the means and the standard errors of the means regarding the performance scores of various service attributes in two cities. As we can see, women generally have lower satisfaction level than men in terms of all bus service aspects as well as the overall satisfaction in both cities. This is consistent with findings from previous research that female tends to have more negative attitudes toward public transit (Beirão and Cabral, 2008; De Oña and De Oña, 2013; Namgund and Akar, 2014).

To examine if the differences in attribute ratings between male and female riders are statistically significant, we then deploy statistical analysis to test the equality of means for different genders. Specifically, Mann–Whitney U test is deployed for all the ordinal variables, namely all the service attribute satisfaction indicators as well as the variables "education level" and "income level", and t-test for all the numerical variables, including "age" and "car ownership". First, we compare the gender difference for Porto Alegre. The results in **Table *6*** show that women have significantly lower level of satisfaction than men regarding "security", "road safety" and "comfort inside buses" at 0.1 significance level, while the difference in satisfaction levels between genders for other service attributes is not significant. The higher concern towards security and safety for female than for male is in line with the findings of many previous studies (Ceccato and Paz, 2017; Hsu et al., 2019).

**Table *6*** also compares the socio-demographic characteristics of different genders in the Porto Alegre sample. Compared with men, women in the Porto Alegre sample are more likely to be older, more educated and less wealthy. The mean percentage of respondents who own a car is lower for women than for men, but this difference is not statistically significant.

Examining the gender difference in Fortaleza which is shown in **Table 7**, we find that women's satisfaction levels for "availability", "speed", "reliability" and "security" are significantly lower than men. What's more, women's overall satisfaction score is significantly lower. In terms of the socio-demographic characteristics, we find that women surveyed are generally more educated but have lower income compared with men in the sample.

**Table 6 The summary statistics of bus services' performance scores and riders' socio-demographics in Porto Alegre**

| Variable | Male | | Female | | p-value |
|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | |
| Satisfaction scores of bus service attributes: | | | | | |
| Access to transport | 3.70 | 0.04 | 3.54 | 0.03 | 0.60 |
| Availability | 2.94 | 0.05 | 2.71 | 0.04 | 0.33 |
| Speed | 3.24 | 0.05 | 3.04 | 0.04 | 0.12 |
| Reliability | 3.24 | 0.05 | 2.97 | 0.04 | 0.50 |
| Easiness to transfer | 3.36 | 0.04 | 3.24 | 0.03 | 0.44 |
| Comfort at bus stops | 2.49 | 0.05 | 2.33 | 0.04 | 0.12 |
| Comfort at stations | 2.65 | 0.05 | 2.48 | 0.04 | 0.29 |
| Comfort at integration terminals | 2.63 | 0.05 | 2.45 | 0.04 | 0.20 |

| | | | | | |
|---|---|---|---|---|---|
| Comfort inside buses | 2.86 | 0.05 | 2.71 | 0.04 | **0.05** |
| Customer service | 3.72 | 0.04 | 3.70 | 0.03 | 0.36 |
| Customer information | 3.61 | 0.04 | 3.58 | 0.03 | 0.26 |
| Security | 2.56 | 0.05 | 2.43 | 0.04 | **0.01** |
| Road safety | 3.30 | 0.04 | 3.15 | 0.03 | **0.02** |
| Exposure to noise and pollution | 2.52 | 0.05 | 2.43 | 0.04 | 0.63 |
| Easiness to pay fares | 3.80 | 0.04 | 3.74 | 0.03 | 0.77 |
| Expenses | 2.55 | 0.05 | 2.41 | 0.04 | 0.12 |
| Overall satisfaction | 3.16 | 0.04 | 2.94 | 0.04 | 0.58 |
| Socio-demographic variables: | | | | | |
| Age | 34.96 | 0.59 | 38.47 | 0.44 | **0.00** |
| Education Level (1-7) | 4.93 | 0.06 | 5.04 | 0.04 | **0.00** |
| % Car Ownership | 0.52 | 0.02 | 0.48 | 0.01 | 0.64 |
| Income Level (1-7) | 3.89 | 0.06 | 3.46 | 0.05 | **0.03** |

Note: an attribute with the p-value in bold font indicates that the satisfaction scores for that attribute between male and female are significantly different at 0.1 significance level.

**Table 7 The summary statistics of bus services' performance scores and riders' socio-demographics in Fortaleza**

| Variable | Male | | Female | | p-value |
|---|---|---|---|---|---|
| | Mean | SE | Mean | SE | |
| Attitudinal Variables: | | | | | |
| Access to transport | 3.51 | 0.03 | 3.43 | 0.03 | 0.15 |
| Availability | 2.97 | 0.04 | 2.87 | 0.03 | **0.04** |
| Speed | 3.17 | 0.03 | 3.07 | 0.03 | **0.03** |
| Reliability | 3.13 | 0.04 | 3.03 | 0.03 | **0.08** |
| Easiness to transfer | 3.51 | 0.04 | 3.47 | 0.03 | 0.62 |
| Comfort at bus stops | 2.76 | 0.04 | 2.67 | 0.04 | 0.14 |
| Comfort at stations | 3.29 | 0.04 | 3.21 | 0.03 | 0.26 |
| Comfort at integration terminals | 3.29 | 0.04 | 3.23 | 0.03 | 0.26 |
| Comfort inside buses | 3.19 | 0.04 | 3.16 | 0.03 | 0.57 |
| Customer Service | 3.38 | 0.04 | 3.39 | 0.03 | 0.80 |
| Customer Information | 3.38 | 0.04 | 3.35 | 0.03 | 0.40 |
| Security | 2.29 | 0.04 | 2.20 | 0.03 | **0.09** |
| Road safety | 2.94 | 0.04 | 2.86 | 0.03 | 0.16 |
| Exposure to noise and pollution | 2.80 | 0.04 | 2.73 | 0.03 | 0.13 |
| Easiness to pay fares | 3.14 | 0.04 | 3.14 | 0.03 | 0.82 |
| Expenses | 2.99 | 0.04 | 2.92 | 0.03 | 0.15 |
| Overall Satisfaction | 3.27 | 0.03 | 3.15 | 0.03 | **0.01** |

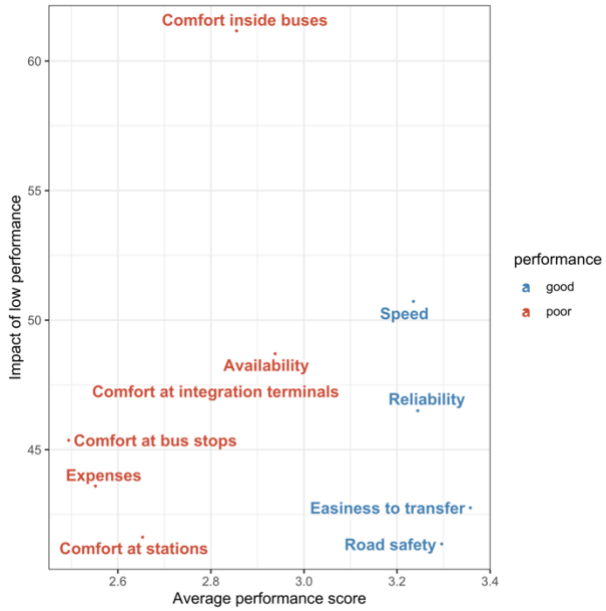
| Socio-demographic Variables: | | | | | |
|---|---|---|---|---|---|
| Age | 35.63 | 0.66 | 34.95 | 0.56 | 0.43 |
| Education | 4.95 | 0.05 | 5.13 | 0.04 | **0.01** |
| Car Ownership | 0.33 | 0.02 | 0.37 | 0.02 | 0.18 |
| Income | 3.14 | 0.06 | 2.97 | 0.05 | **0.02** |

Note: an attribute with the p-value in bold font indicates that the satisfaction scores for that attribute between male and female are significantly different at 0.1 significance level.

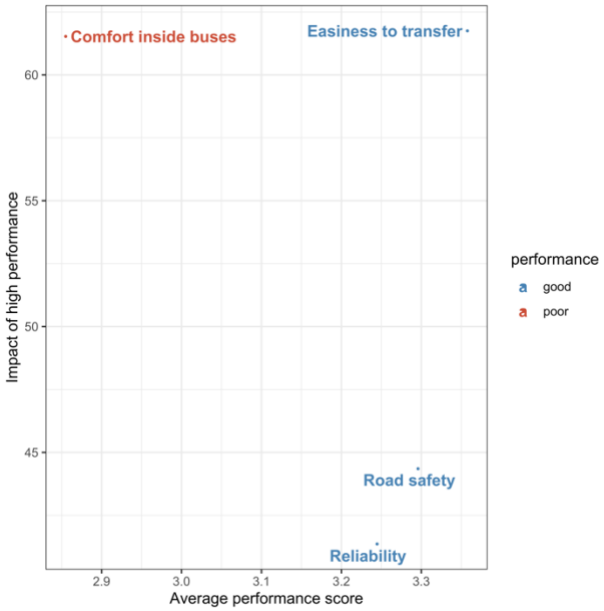
By assessing the results in these two cities, we find that the satisfaction scores regarding "security" are among the lowest for both genders. According to the Crime Index 2021 in NUMBEO, the crime scores of Porto Alegre and Fortaleza are respectively 73.72 and 78.24, indicating very high levels of crime for both cities (NUMBEO Crime in Porto Alegre, Brazil: https://www.numbeo.com/crime/in/Porto-Alegre; NUMBEO Crime in Fortaleza, Brazil: https://www.numbeo.com/crime/in/Fortaleza). Specifically, the levels of crime regarding "problem property crimes such as vandalism and theft" and "problem violent crimes such as assault and armed robbery" are both very high in two cities. The high level of crime in these two cities largely explains why the satisfaction scores regarding "safety" are so low. On top of that, our results show that female riders give significantly lower scores in terms of "security" than male riders in both cities. This finding is in line with previous studies on female riders' concerns about security in Brazilian cities. For instance, Ceccato and Paz (2017) reported that many women in the Sao Paulo metro felt unsafe as they were usually exposed to sexual harassment during the peak hours. Nourani et al. (2020) carried out a survey at Rio Claro, Brazil focusing on the perception of transit safety, and found that the fear of gender-based violence in public transport proportionally affected more women than any other social group, hindering their freedom of movement in city spaces. In the case of sexual harassment, women's concerns about transit problems were more than double that of men, both on the bus and at the bus stops.

### 6.2 Gender differences in the importance type of attributes

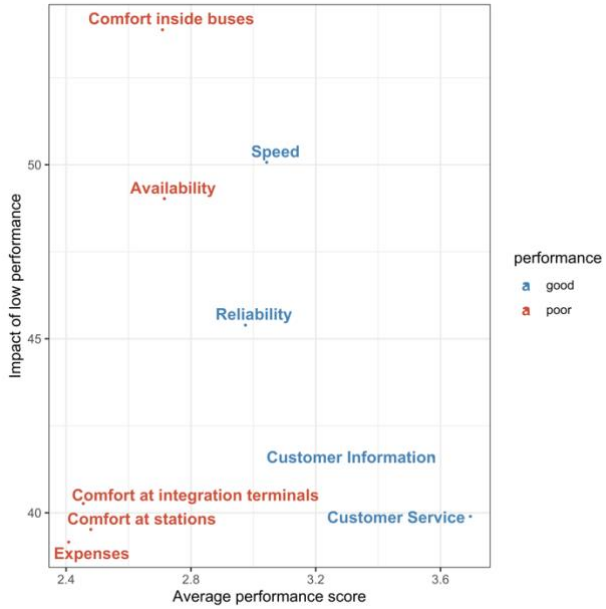
The RF method is employed to explore the influence of 16 bus service attributes on riders' overall satisfaction while controlling for socio-demographic variables including age, education level, car ownership and income level.



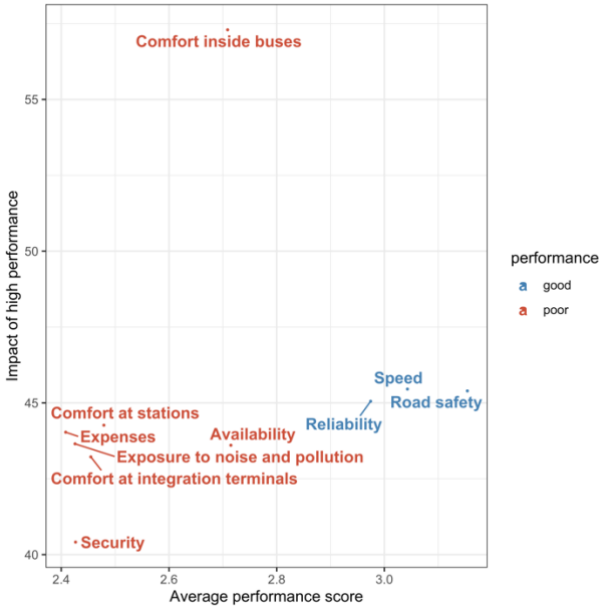

(1) Low-performance indicators (for male)




(2) High-performance indicators (for male)

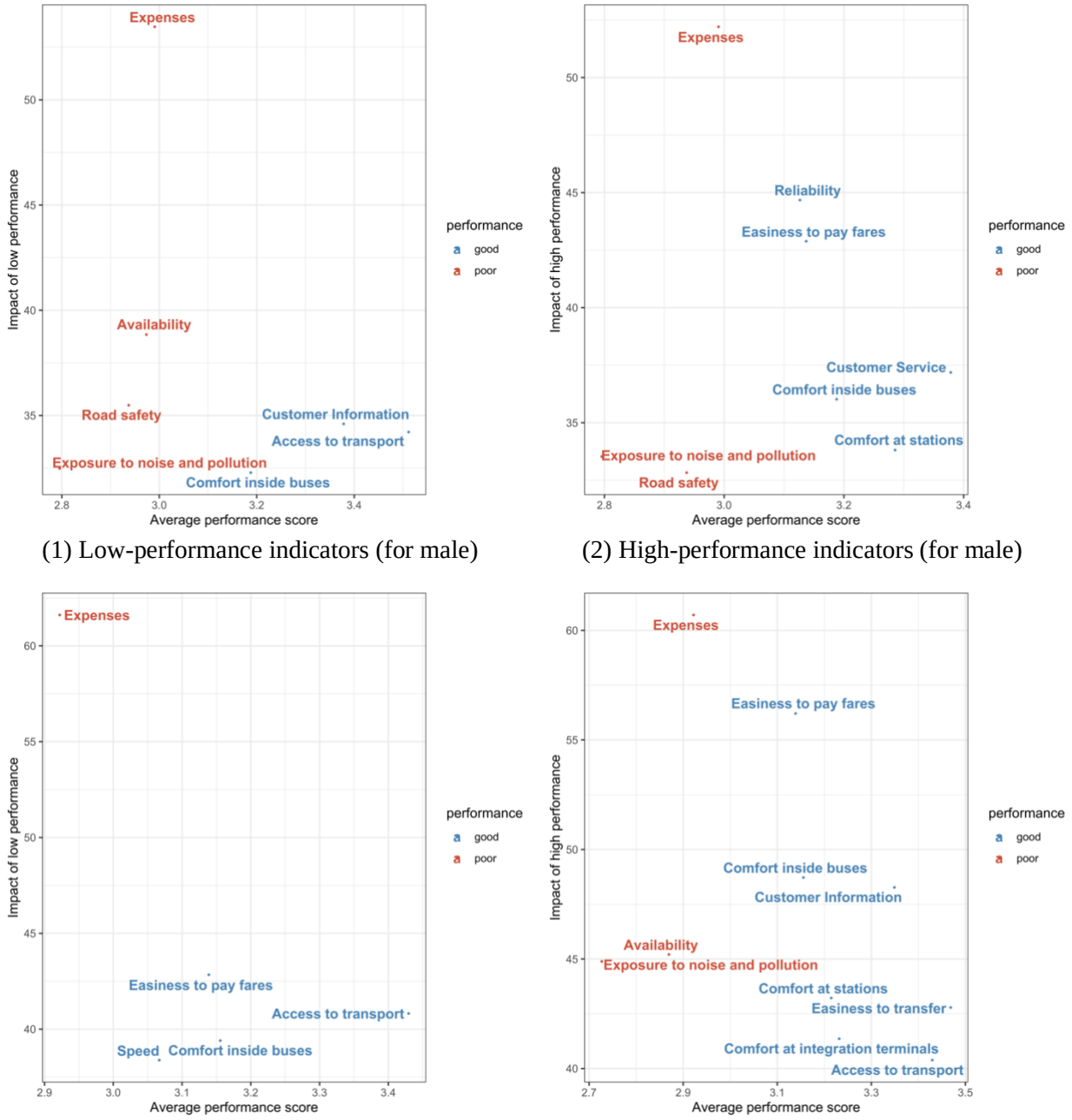



(3) Low-performance indicators (for female)




(4) High-performance indicators (for female)

**Figure 7 Random Forest Results for Porto Alegre**




(1) Low-performance indicators (for male) (2) High-performance indicators (for male)

(3) Low-performance indicators (for female) (4) High-performance indicators (for female)

**Figure 8 Random Forest Results for Fortaleza**

**Table 8 Factor Categorization for the 16 Service Attributes by Gender in Porto Alegre**

| Name (1) | Gender (2) | Average Performance (3) | Importance Score | | Importance Type (6) | Improvement Priority (7) |
|---|---|---|---|---|---|---|
| | | | Low-Performance Part (4) | High-Performance Part (5) | | |
| Expenses | Male | 2.55 (P) | **43.6** | 37.7 | basic | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Female | 2.41 (P) | **39.2** | **44** | performance | 1 |
| Availability | Male | 2.94 (P) | **48.7** | 31.8 | basic | 1 |
| | Female | 2.71 (P) | **49** | **43.6** | performance | 1 |
| Comfort at stations | Male | 2.65 (P) | **41.6** | 30.7 | basic | 1 |
| | Female | 2.48 (P) | **39.5** | **44.3** | performance | 1 |
| Comfort at integration terminals | Male | 2.63 (P) | **47.3** | 35.6 | basic | 1 |
| | Female | 2.45 (P) | **40.3** | **43.2** | performance | 1 |
| Comfort inside buses | Male | 2.86 (P) | **61.2** | **61.5** | performance | 1 |
| | Female | 2.71 (P) | **53.9** | **57.3** | performance | 1 |
| Road safety | Male | 3.3 (G) | **41.4** | **44.4** | performance | 2 |
| | Female | 3.15 (G) | 36.7 | **45.4** | exciting | 2 |
| Reliability | Male | 3.24 (G) | **46.5** | **41.4** | performance | 2 |
| | Female | 2.97 (G) | **45.4** | **45.1** | performance | 2 |
| Speed* | Male | 3.24 (G) | **50.7** | 39.5 | basic | 4 |
| | Female | 3.04 (G) | **50.1** | **45.5** | performance | 2 |
| Comfort at bus stops* | Male | 2.49 (P) | **45.4** | 33.1 | basic | 1 |
| | Female | 2.33 (P) | 32.5 | 36.4 | unimportant | 5 |
| Customer Service* | Male | 3.72 (G) | 39.6 | 38.6 | unimportant | 5 |
| | Female | 3.7 (G) | **39.9** | 35.8 | basic | 4 |
| Easiness to transfer* | Male | 3.36 (G) | **42.8** | **61.7** | performance | 2 |
| | Female | 3.24 (G) | 36.2 | 38.4 | unimportant | 5 |
| Security* | Male | 2.56 (P) | 35.9 | 37.1 | unimportant | 5 |
| | Female | 2.43 (P) | 34.4 | **40.4** | exciting | 3 |
| Exposure to noise and pollution* | Male | 2.52 (P) | 34.4 | 33.7 | unimportant | 5 |
| | Female | 2.43 (P) | 30.9 | **43.7** | exciting | 3 |
| Customer Information* | Male | 3.61 (G) | 37.4 | 36.4 | unimportant | 5 |
| | Female | 3.58 (G) | **41.6** | 35.7 | basic | 4 |
| Access to transport | Male | 3.7 (G) | 31.8 | 36.9 | unimportant | 5 |
| | Female | 3.54 (G) | 37.3 | 37.9 | unimportant | 5 |
| Easiness to pay fares | Male | 3.8 (G) | 27.9 | 28.8 | unimportant | 5 |
| | Female | 3.74 (G) | 27 | 25.8 | unimportant | 5 |
| Social-demographic variables (control variables) | | | | | | |
| Age | Male | 34.96 | 36.36 | | N/A | N/A |
| | Female | 38.47 | 30.73 | | | |
| Education Level | Male | 4.93 | 39.40 | | N/A | N/A |
| | Female | 5.04 | 30.41 | | | |
| Car Ownership | Male | 0.52 | 26.30 | | N/A | N/A |
| | Female | 0.48 | 22.92 | | | |
| Income Level | Male | 3.89 | 35.58 | | N/A | N/A |

| | | | | | |
|---|---|---|---|---|---|
| | Female | 3.46 | 24.72 | | |
| Reference level for service attributes | | | | | |
| Average Score (reference) | Male | 3.07 | 40.07 | N/A | N/A |
| | Female | 2.93 | 39.03 | | |

Note: In the "Name" column: (*) denotes attributes which have a gender difference regarding improvement priority. In the "Average Performance" column: G = "Good", P = "Poor". In the "Importance Score" column, the importance scores in bold font are scores higher than the reference level; In the "Average Score" rows, the average scores for "Average Performance" are the average performance scores across all the service attributes, while the average scores for "Importance Score" are the average values across all the variables—including the service attributes and the socio-economic attributes.

## Table 9 Factor Categorization for the 16 Service Attributes by Gender in Fortaleza

| Name (1) | Gender (2) | Average Performance (3) | Importance Score | | Importance Type (6) | Improvement Priority (7) |
|---|---|---|---|---|---|---|
| | | | Low-Performance Part (4) | High-Performance Part (5) | | |
| Expenses | Male | 2.99 (P) | **53.5** | **52.2** | performance | 1 |
| | Female | 2.92 (P) | **61.6** | **60.7** | performance | 1 |
| Exposure to noise and pollution | Male | 2.8 (P) | **32.5** | **33.5** | performance | 1 |
| | Female | 2.73 (P) | 25.9 | **44.9** | exciting | 3 |
| Easiness to pay fares | Male | 3.14 (G) | 23.3 | **42.9** | exciting | 2 |
| | Female | 3.14 (G) | **42.8** | **56.2** | performance | 2 |
| Availability | Male | 2.97 (P) | **38.8** | 29 | basic | 1 |
| | Female | 2.87 (P) | 32.7 | **45.2** | exciting | 3 |
| Comfort at stations | Male | 3.29 (G) | 31.1 | **33.8** | exciting | 2 |
| | Female | 3.21 (G) | 37.2 | **43.2** | exciting | 2 |
| Comfort inside buses | Male | 3.19 (G) | **32.3** | **36** | performance | 2 |
| | Female | 3.16 (G) | **39.4** | **48.7** | performance | 2 |
| Access to transport | Male | 3.51 (G) | **34.2** | 31.2 | basic | 4 |
| | Female | 3.43 (G) | **40.8** | **40.4** | performance | 2 |
| Customer Information | Male | 3.38 (G) | **34.6** | 30.8 | basic | 4 |
| | Female | 3.35 (G) | 36.8 | **48.3** | exciting | 2 |
| Road safety | Male | 2.94 (P) | **35.5** | **32.8** | performance | 1 |
| | Female | 2.86 (P) | 25.1 | 36.9 | unimportant | 5 |
| Customer Service | Male | 3.38 (G) | 24.5 | **37.2** | exciting | 2 |
| | Female | 3.39 (G) | 35.9 | 35.2 | unimportant | 5 |
| Reliability | Male | 3.13 (G) | 30.6 | **44.7** | exciting | 2 |
| | Female | 3.03 (P) | 36.9 | 35.4 | unimportant | 5 |
| Easiness to transfer | Male | 3.51 (G) | 29.3 | 31 | unimportant | 5 |
| | Female | 3.47 (G) | 34.4 | **42.8** | exciting | 2 |
| | Male | 3.29 (G) | 27 | 29.9 | unimportant | 5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Comfort at integration terminals | Female | 3.23 (G) | 32.7 | **41.4** | exciting | 2 |
| Speed | Male | 3.17 (G) | 31.6 | 28.6 | unimportant | 5 |
| | Female | 3.07 (G) | **38.4** | 30.4 | basic | 4 |
| Security | Male | 2.29 (P) | 28.9 | 25.7 | unimportant | 5 |
| | Female | 2.2 (P) | 29.6 | 28 | unimportant | 5 |
| Comfort at bus stops | Male | 2.76 (P) | 29.5 | 30.2 | unimportant | 5 |
| | Female | 2.67 (P) | 36.2 | 34.9 | unimportant | 5 |
| Social-demographic variables (control variables) | | | | | | |
| Age | Male | 35.63 | 22.63 | | N/A | N/A |
| | Female | 34.95 | 28.90 | | | |
| Education Level | Male | 4.95 | 21.78 | | N/A | N/A |
| | Female | 5.13 | 25.46 | | | |
| Car Ownership | Male | 0.33 | 26.08 | | N/A | N/A |
| | Female | 0.37 | 27.52 | | | |
| Income Level | Male | 3.14 | 24.38 | | N/A | N/A |
| | Female | 2.97 | 34.49 | | | |
| Reference level for service attributes | | | | | | |
| Average Score (reference) | Male | 3.11 | 32.26 | | N/A | N/A |
| | Female | 3.05 | 38.21 | | | |

The model results regarding the 16 bus service attributes are summarized in **Table 8** for Porto Alegre and **Table 9** for Fortaleza. We explore the importance of each service attribute by analyzing two indicators of that attribute: the low performance dummy variable (indicating negative satisfaction rating) and the high-performance dummy variable (indicating positive satisfaction rating). In both **Table 8** and **Table 9**, column (4) and (5) report the importance score given by RF of each variable, with the bold font indicating the importance score higher than the reference level (which is the average RF importance score across all the variables, including the service attributes and socio-demographic variables). The important attributes in both cities are plotted on **Figure 7** and **Figure 8** based on their performance scores and importance scores. For each of the figures, the subfigure (1) and (3) present the attributes that are important in the low-performance dimension for male and female, meaningly the attributes that are denoted as bold in column (4) of **Table 8** (corresponding to **Figure 7**) and **Table 9** (corresponding to **Figure 8**); similarly, the subfigure (2) and (4) present only the attributes that are denoted as bold in column (5) of **Table 8** and **Table 9**.

An attribute with a coefficient that has a higher-than average importance score in RF is counted as important in that dimension, based on which, the importance type of each service attribute is determined by each gender, using the rules explained in section 4.4. We then compare different service attributes' importance types between male and female for both cities.

In Porto Alegre, it is found that for both male and female riders, "comfort inside buses" and "reliability" are categorized as Performance factors, and "access to transport" and "easiness to pay fares" are categorized as Unimportant factors. Female riders consider more attributes as Performance factors than male, such as "expenses", "availability", "comfort at stations", "comfort at integration terminals", and "speed", while these attributes are categorized as Basic factors for male riders. This finding indicates that these attributes

would significantly influence the overall satisfaction of female riders whenever they perform well or poorly, whereas will only impact the overall satisfaction of male riders when they perform poorly. Several attributes are categorized as Unimportant factors for male riders but as Basic, Exciting, or Performance factors for female riders, including "customer service", "security", "exposure to noise and pollution", and "customer information", indicating that these factors have some impacts on female's overall satisfaction, but do not significantly influence the overall satisfaction of male riders. "Road safety" and "easiness to transfer" are important factors to male riders, whereas are categorized as Exciting factor and Unimportant factor for female riders, respectively.

In Fortaleza, "expenses" and "comfort inside buses" are categorized as Performance factors whereas "security" and "comfort at bus stops" are classified as Unimportant factors for both genders. Different from Porto Alegre, the numbers of attributes that are considered as Performance factors by female and male riders are the same. In addition to "expenses" and "comfort inside buses", female riders also consider "easiness to pay fares" and "access to transport" as Performance factors, whereas "exposure to noise and pollution" and "road safety" are Performance factors for male riders only.

### 6.3 Gender differences in the service improvement priorities

Based on the performance and the categorized importance type of the attributes, the improvement priorities of the service attributes for each gender in these two cities are determined using the rules explained in the section 4.4 (**Table 4**).

6.3.1 Attributes with the same improvement priorities

First, we examine the results for Porto Alegre. The result shown in **Table 8** indicates that for both male and female riders, "expenses", "availability", "comfort at stations", "comfort at integration terminals" and "comfort inside buses" are given the first improvement priority. These attributes have mean performance scores lower than 3 for both male and female, and have significant negative impact on the overall satisfaction when they perform poorly. Therefore, they should be prioritized first.

"Road safety" and "reliability" are given the second priority for both male and female, indicating that these two attributes both have good performance scores and positively impact riders' overall satisfaction when they perform well. Therefore, policymakers should maintain or enhance their performance in order to obtain improvement in the overall satisfaction with these two attributes.

Then, looking at the results for Fortaleza in **Table 9**, we find that fewer attributes are associated with the highest improvement priorities for both genders, and the improvement priorities for different attributes show more discrepancies between male and female riders. Among those attributes that are given the same improvement priorities, "expense" is the only attribute that is given the first priority for both genders. "Easiness to pay fares", "comfort at stations" and "comfort inside buses" are given the second priority for both male and female.

Comparing the results between Porto Alegre and Fortaleza, it is found that "expenses" is always associated with the highest improvement priorities for both genders, showing that it has a consistently important influence on passengers' satisfaction. Both "comfort at stations" and "comfort inside buses" are given the first priorities in Porto Alegre and the second priorities in Fortaleza for male and female. The reason of improvement priorities changing from 1$^{st}$ to 2$^{nd}$ is that while the performance levels of these two attributes are "poor" in Porto Alegre, their performance levels are "good" in Fortaleza. Therefore, they no longer need to be improved the first in Fortaleza. However, the fact that these two attributes have very high improvement priorities in both cities still shows that they both have important influence on riders' overall satisfaction.

6.3.2 Attributes with different improvement priorities

In this section, we compare the difference of improvement priorities between men and women. First, we compare the gender differences in Porto Alegre. **Table 8** shows that "speed", "customer service", "security", "exposure to noise and pollution" and "customer information" are ranked higher for women than for men in Porto Alegre. To be specific, "speed" has a good performance for both genders, but is identified as a Basic factor for men and a Performance factor for women. As a Basic factor, it only significantly impacts riders' overall satisfaction when it performs poorly, thus the improvement priority is lower ($4^{th}$) than when it is a Performance factor ($2^{nd}$).

While "security" and "exposure to noise and pollution" perform poorly for both genders in Porto Alegre, both of them are identified as Exciting factors for female whereas neither of them significantly impacts the overall satisfaction for male. This means that these two attributes can generate positive impacts on women's overall satisfaction if they perform well. However, our findings in **Table *6*** show that in Porto Alegre, the average satisfaction scores towards "security" are quite low for both genders, and female riders give a significantly lower average satisfaction score for "security" than male. Therefore, effective prevention measures should be taken to combat the assaults, thefts, robberies and sexual harassment. Porto Alegre already has a specialized police station focused on public transport for enhancing crime detections and also allows buses to on/off-board passengers at any point of the route at night, but further actions can be taken as defining a clear protocol for denouncing sexual harassment. Here, Fortaleza has a good experience, in 2019 they implemented Nina![1], a tool that allows victims and witnesses to denounce sexual harassment in the public transport through a standardize protocol. After two successful years, the functionality is under bidding process right now. In terms of the concern towards pollutions, Morton et al. (2016) found that women generally have relatively negative opinions with regards to the quality of the carbon environment, which is consistent with our findings. This suggests that the local transit company should work on reducing riders' exposure to noise and pollution in order to increase riders' satisfaction in this aspect, such as adopting clean fuels on buses. Though this is not a gender-oriented action, women and men can both benefit from the improved cleanliness and reduced noise of transit.

"Customer service" and "customer information" perform well for both genders. However, their associated improvement priorities are both higher for women than for men. The action priorities of these two attributes are both $4^{th}$ for women, whereas the improvement priorities of these two attributes are both $5^{th}$ for men. Although the performance scores of "customer service" and "customer information" are already quite high, the bus company can make further improvement on these two aspects to increase riders' overall satisfaction. For instance, the bus company can provide training to the conductors and drivers to make them capable of handling problems specific to women. The bus company can also take generic improvement measures such as providing passengers with real-time information regarding various service metrics such as bus locations, bus arrival time, nearby routes and crowding features. To better understand gender-specific preferences, dedicated surveys should be conducted.

In contrast, the improvement priorities of "comfort at bus stops" and "easiness to transfer" are ranked higher for men than for women. For "comfort at bus stops", the performance of this attribute is poor for both genders. However, the impact of the low-performance on men's overall satisfaction is much larger than on women's overall satisfaction. For "easiness to transfer", the performance of this attribute is good for both genders. However, the impact of the high-performance is only significant for men.

It should also be noted that more attributes are identified as important for women than for men. The reason is that the socio-demographic variables have higher importance scores for men than for women, meaning

[1] https://wribrasil.org.br/pt/blog/2019/09/dados-de-den%C3%BAncias-online-ajudam-fortaleza-investir-para-coibir-ass%C3%A9dios-nos-%C3%B4nibus

that a larger proportion of the overall satisfaction variation is explained by the socio-demographic factors for men than for women.

Focusing on Fortaleza, we see that "access to transport", "customer information", "easiness to transfer", "comfort at integration terminals" and "speed" are ranked higher in terms of improvement priority for women than for men (**Table 9**). The higher improvement priorities for "customer information" and "speed" are consistent with the attributes improvement results in Porto Alegre. Aside from that, women riders in Fortaleza seem to be emphasizing more on the easiness of getting to points of access and transferring between bus lines and other means of transport, based on the fact that "access to transport" and "easiness to transfer" are given higher priorities for female than for male, whereas these two attributes are considered as Unimportant factors in Porto Alegre. Fortaleza has an on-going project to qualify their bus stops that tackles several attributes mentioned above. It includes providing static and dynamic information about bus lines (customer information), facilities, as wi-fi, and deploying security cameras (security) as well as improving lightning (comfort).

In contrast, the improvement priorities of "exposure to noise and pollution", "availability", "road safety", "customer service" and "reliability" are ranked higher for men than for women. For "exposure to noise and pollution", the improvement priority is 1$^{st}$ for male and 3$^{rd}$ for female, since the attribute is a Performance factor for male and is an Exciting factor for female. However, this finding should be taken with caution as the importance scores associated with the low-performance and high-performance indicators of "exposure to noise and pollution" for male are 32.5 and 33.5, which are only slightly higher than the reference score which is 32.26. On the contrary, the importance score associated with the high-performance indicator of "exposure to noise and pollution" for female is 44.9, which is much larger than the reference score 38.21. Therefore, we conclude that although "exposure to noise and pollution" ranked higher in terms of improvement priority for male than female in Fortaleza, it does not invalidate our argument that the attribute is very relevant to female riders' overall satisfaction. In fact, the result indicates that reducing riders' exposure to noise and pollution is essential for both male and female riders.

"Availability" and "reliability" have higher improvement priorities for men than women in Fortaleza. Noted that these two attributes are somewhat correlated, as both of them are related to either reliability or the length of the time intervals between sequential vehicle arrivals. "Road safety" is also given higher improvement priority for male than for female, as it is a Performance factor for male and an Unimportant factor for female, showing that this attribute significantly affects overall satisfaction for male but does not significantly affect overall satisfaction for female, and this statement holds no matter the attribute performs well or poorly. This finding largely corresponds to the finding in Porto Alegre, where "road safety" is only a Performance factor for male but not for female. These results show that "road safety" has a higher relevance to the overall satisfaction for male riders than for female riders. Lastly, "customer service" is ranked higher in terms of the improvement priorities for male than female in Fortaleza. The reason is that this attribute, which performs well for both genders, is identified as an Exciting factor for male. However, though a little bit counterintuitive, it does not show significant influence on the overall satisfaction for female in Fortaleza.

Lastly, we summarize the service attributes in terms of their improvement priorities in **Table 10**, where we categorize each attribute into one of the four domains: reliability (functional), safety (security), customer services (hedonic), and comfort (hedonic). These four domains are developed by Allen et al. (2019), who used a structural equation (SEM) approach to validate the grouping strategy. In their study, the authors proposed a hierarchy of service attributes based on Maslow's hierarchy of needs. To be specific, they found that the attributes have the following order of preference: 1) functional attributes, 2) safety and protection attributes and 3) hedonic attributes. However, our research results show a different pattern. As shown in **Table 10**, the attributes falling into the first and second improvement priorities are dominated by "C1: reliability" and "C4: comfort" for both genders and both cities. This result indicates that comfort-related

attributes consistently have a high influence on riders' satisfaction in general. In terms of the attributes in "C2: safety", we find that most of this group's attributes are associated with the 3rd improvement priority for female, meaning that these attributes currently perform poorly for female, but will have a significant influence on female riders' overall satisfaction when they perform well. Noted that the satisfaction scores towards "security" and "exposure to noise and pollution" are among the lowest ones for female in both cities, this indicates that female riders are generally unsatisfied with these attributes, but they base their overall satisfaction more on other attributes. However, since "security" and "exposure to noise and pollution" have important influence on overall satisfaction when they perform well, the transit agencies should try to bring these attributes to a better performance level. As such, measures should be taken to build a safer transit system, such as the actions to combat harassment in the system. The transit agencies should also work on reducing noise and pollution on buses, as this aspect is important for both female and male riders. Lastly, the attributes in "C3: customer services" are associated with either the 2nd or the 4th priorities for both genders (if the attributes are not Unimportant factors), owing to the fact that this group of attributes always perform well for both genders.

**Table 10 Different groups of service attributes by improvement priorities**

| | Female | | Male | |
|---|---|---|---|---|
| Improvement priority | Porto Alegre | Fortaleza | Porto Alegre | Fortaleza |
| 1 | C1: Expenses | C1: Expenses | C1: Expenses | C1: Expenses |
| 1 | C1: Availability | | C1: Availability | C1: Availability |
| 1 | C4: Comfort at stations | | C4: Comfort at stations | C2: Road safety |
| 1 | C4: Comfort at integration terminals | | C4: Comfort at integration terminals | C2: Exposure to noise and pollution |
| 1 | C4: Comfort inside buses | | C4: Comfort inside buses | |
| 1 | | | C4: Comfort at bus stops | |
| 2 | C1: Speed | C1: Access to transport | C1: Easiness to transfer | C1: Reliability |
| 2 | C1: Reliability | C1: Easiness to transfer | C1: Reliability | C4: Comfort inside buses |
| 2 | C2: Road safety | C4: Comfort at stations | C2: Road safety | C4: Comfort at stations |
| 2 | | C4: Comfort inside buses | | C3: Easiness to pay fares |
| 2 | | C4: Comfort at integration terminals | | C3: Customer Service |
| 2 | | C3: Easiness to pay fares | | |

| | | | | |
|---|---|---|---|---|
| 2 | | C3: Customer Information | | |
| 3<br>3 | C2: Security<br>C2: Exposure to noise and pollution | C1: Availability<br>C2: Exposure to noise and pollution | | |
| 4<br>4 | C3: Customer Service<br>C3: Customer Information | C1: Speed | C1: Speed | C3: Customer Information<br>C1: Access to transport |
| 5<br>5<br>5<br>5<br>5<br>5 | C1: Access to transport<br>C1: Easiness to transfer<br>C3: Easiness to pay fares<br>C4: Comfort at bus stops | C3: Customer Service<br>C1: Reliability<br>C4: Comfort at bus stops<br>C2: Road safety<br>C2: Security | C3: Customer Service<br>C3: Customer Information<br>C1: Access to transport<br>C3: Easiness to pay fares<br>C2: Security<br>C2: Exposure to noise and pollution | C1: Easiness to transfer<br>C1: Speed<br>C4: Comfort at integration terminals<br>C4: Comfort at bus stops<br>C2: Security |

Note: "C1" stands for the attribute group "reliability"; "C2" stands for the attribute group "safety"; "C3" stands for the attribute group "customer services"; "C4" stands for the attribute group "comfort".

## 7. Conclusions

This study examines the gender difference of transit rider satisfaction with a survey of 1765 respondents in Porto Alegre, Brazil and a survey of 1538 in Fortaleza, Brazil. Using the three-factor theory, 16 service attributes are categorized into four importance types: Performance, Basic, Exciting and Unimportant factors, based on whether they have significant impacts on riders' overall satisfaction when performing poorly and well. The categorization is achieved by first recoding the 5-point Likert scale of each service attribute as two binary variables ('high-performance indicator' and 'low-performance indicator') indicating whether the rating is higher than, equal to or lower than the reference level, and then testing for the significance of the two variables separately for each service attribute. The random forest method is deployed to obtain the variable importance in order to capture the non-linear relationship between variables and the effect size of the service attributes. When analyzing the influences of service attributes, we have controlled for socio-demographic variables including age, education level, car ownership and income level. Finally, the improvement priority for each service attribute is determined by accounting for both the importance type and the performance score of the attribute.

The impacts of service attributes on riders' satisfaction and their improvement priorities are examined from a gender perspective. To date, only a limited number of studies have examined the gender distinction regarding transit rider satisfaction, and our study can help enrich the literature in this domain. Based on our results, we find that in both Porto Alegre and Fortaleza, the satisfaction scores regarding "security" are among the lowest across all the service attributes for both genders, and in both cities, the average

satisfaction score for “security” is significantly lower among women than men. Also, our random forest modeling result shows that in Porto Alegre, “security” is an Exciting factor for women, indicating that though the satisfaction scores are currently low among women, if the satisfaction score can be increased to a higher-than-average score level in general, “security” can significantly increase women’s overall satisfaction. Based on these findings, specific recommendations are given including taking prevention to combat the assaults, thefts, robberies and sexual harassment such as enhancing crime detections or adoption of standardize protocols. In addition, we find that “exposure to noise and pollution”, “customer service”, “customer information” and “speed” are also very relevant to female riders’ overall satisfaction in Porto Alegre. Comparing Fortaleza with Porto Alegre, we find that women riders attach more importance to the easiness of getting to points of access and transferring between bus lines and other means of transport than men in Fortaleza.

In the end, we also suggest local transit agencies conducting dedicated surveys to further understand gender-specific preferences. Our study illustrates the effectiveness of using the method to distinguish different importance types of service attributes between different genders, which could help the transit agency develop gender-oriented actions regarding service improvements.

There are several limitations of our study. First, we determine the improvement priorities of service attributes only from the demand side but not the supply side. In reality, the transit agencies should also consider the resources and costs when making the service improvement plan. Second, this study only focuses on the gender analysis based on the surveys conducted in 2019 in two cities, which is during the pre-pandemic time. Since the pandemic began, people’s transit usage behaviors should have changed significantly, and people’s perceptions towards the transit services should have changed as well. Therefore, it is important for the transit agencies to conduct further research investigating how the importance of various service attribute has changed since the pandemic hit from a gender perspective, and update the service improvement strategies accordingly.

**References**


Abenoza, R. F., Cats, O., & Susilo, Y. O. (2019). Determinants of traveler satisfaction: Evidence for non-linear and asymmetric effects. Transportation research part F: traffic psychology and behaviour, 66, 339-356.

Allen, J., Muñoz, J. C., & de Dios Ortúzar, J. (2019). Understanding public transport satisfaction: Using Maslow's hierarchy of (transit) needs. Transport policy, 81, 75-94.

Aniley, B., & Negi, R. (2010). Service quality attributes affecting passengers' satisfaction with HIGER city bus. Ethiopian Journal of Business and Economics (The), 1(2), 70-98.

Arabikhan, F., Postorino, M. N., Dupont-Kieffer, A., & Gegov, A. (2016). Gender-Based Analysis of Zones of Tolerance for Transit Service Quality Considering Intelligent Transportation Systems. Transportation Research Record, 2541(1), 73-80.

Baltes, M. R. (2003). The importance customers place on specific service elements of bus rapid transit. Journal of Public Transportation, 6(4), 1.

Barcelos, M. M., Albuquerque, M. (2018). Manual da Pesquisa de Satisfação. WRI Brasil. Available at: https://wribrasil.org.br/pt/publication/programa-qualionibus.

Beirão, G., & Cabral, J. S. (2008). Market segmentation analysis using attitudes toward transportation: exploring the differences between men and women. Transportation research record, 2067(1), 56-64.

Breiman, L. (2001). Random forests. Machine learning, 45(1), 5-32.

Brody, L. R., & Hall, J. A. (2008). Gender and emotion in context. Handbook of emotions, 3, 395-408.

BRT+ Centre of Excellence (2020) Global BRT Data: Porto Alegre. Available at: https://brtdata.org/location/latin_america/brazil/porto_alegre. Accessed: Oct. 29th 2020.

Cain, A., Flynn, J., McCourt, M., & Reyes, T. (2009). Quantifying the importance of image and perception to bus rapid transit (No. FTA-FL-26-7109.2009. 3).

Cao, J., Cao, X., Zhang, C., & Huang, X. (2016). The gaps in satisfaction with transit services among BRT, metro, and bus riders: Evidence from Guangzhou. Journal of Transport and Land Use, 9(3), 97-109.

Cao, J., & Cao, X. (2017). Comparing importance-performance analysis and three-factor theory in assessing rider satisfaction with transit. Journal of Transport and Land Use, 10(1), 837-854.

Ceccato, V., & Paz, Y. (2017). Crime in São Paulo's metro system: Sexual crimes against women. Crime prevention and community safety, 19(3-4), 211-226.

Cheng, L., Chen, X., De Vos, J., Lai, X., Witlox, F. (2019). Applying a random forest method approach to model travel mode choice behavior. Travel Behav. Soc. 14, 1–10. https://doi.org/10.1016/j.tbs.2018.09.002

De Oña, R., & De Oña, J. (2013). Analyzing transit service quality evolution using decision trees and gender segmentation. WIT transactions on the built environment, 130, 611-621.

Di Ciommo, F., & Shiftan, Y. (2017). Transport equity analysis. Transport Reviews, 37(2), 139-151.

Diário do Nordeste (2020) **65% dos deslocamentos em Fortaleza são a pé, de ônibus ou bicicleta, aponta estudo.** Available at: https://diariodonordeste.verdesmares.com.br/metro/65-dos-deslocamentos-em-fortaleza-sao-a-pe-de-onibus-ou-bicicleta-aponta-estudo-1.2218239. Accessed: Nov 10th 2021.

Dittmar, H., Long, K., & Meek, R. (2004). Buying on the Internet: Gender differences in on-line and conventional buying motivations. Sex roles, 50(5-6), 423-444.

EPTC (2004). Pesquisa de origem e destino de Porto Alegre 2003. Available at: http://lproweb.procempa.com.br/pmpa/prefpoa/eptc/usu_doc/relatorio_edom_2003.pdf. Accessed: 4 jan. 2019

Ermagun, A., Rashidi, T.H., Lari, Z.A. (2015). Mode Choice for School Trips: Long-Term Planning and Impact of Modal Specification on Policy Assessments. Transp. Res. Rec. J. Transp. Res. Board 2513, 97–105. https://doi.org/10.3141/2513-12

Global BRT Data (2018) **Fortaleza – System Indicators**. Available at: https://brtdata.org/location/latin_america/brazil/fortaleza/?lang=en. Accessed: Nov 12th 2021.

Ghasri, M., Rashidi, T. H., & Waller, S. T. (2017). Developing a disaggregate travel demand system of models using data mining techniques. Transportation Research Part A: Policy and Practice, 105, 138-153.

Hou, Y., Edara, P., Sun, C. (2015). Traffic Flow Forecasting for Urban Work Zones. IEEE Trans. Intell. Transp. Syst. 16, 1761–1770. https://doi.org/10.1109/TITS.2014.2371993

Hoyer, W.D., & Maclnnis, D.J. (2010). Consumer Behavior (5th ed.). USA: South-Western, Cengage Learning.

Hsu, H. P., Boarnet, M. G., & Houston, D. (2019). Gender and rail transit use: Influence of environmental beliefs and safety concerns. Transportation research record, 2673(4), 327-338.

Iacobucci, D., & Ostrom, A. (1993). Gender differences in the impact of core and relational aspects of services on the evaluation of service encounters. Journal of consumer psychology, 2(3), 257-286.

IBGE (2019) **Estimativas de população de regiões metropolitanas.** Available at: https://agenciadenoticias.ibge.gov.br/agencia-detalhe-de-midia.html?view=mediaibge&catid=2103&id=3109. Accessed: Nov 11th 2021

IBGE (2020) **Fortaleza - População**. Available at: https://cidades.ibge.gov.br/brasil/ce/fortaleza/panorama. Accessed: Nov. 10th 2021.

IBGE (2018) **Fortaleza - Produto Interno Bruto dos Municípios.** Available at: https://cidades.ibge.gov.br/brasil/ce/fortaleza/pesquisa/38/47001?tipo=ranking&ano=2018. Accessed: Nov. 10th 2021.

IBGE (2020). Porto Alegre. Available at: https://cidades.ibge.gov.br/brasil/rs/porto-alegre/panorama. Accessed: Oct. 29th 2020.

IPECE (2007) **Estimativas 2019 população Regiões Metropolitanas - Excel.** Available at: http://www2.ipece.ce.gov.br/atlas/capitulo1/11/125x.htm. Accessed: Nov. 10th 2021.

Kano, N. (1984). Attractive quality and must-be quality. Hinshitsu (Quality, The Journal of Japanese Society for Quality Control), 14, 39-48.

Lindau, L. A.; Barcelos, M. M.; Ten Caten, C. S.; Costa, M. B. B. da; Silva, C. A. M. da; Pereira, B. M. (2017). Benchmarking focused on the satisfaction of bus transit users. In: Transportation Research Board Annual Meeting, 2017, Washington DC. TRB 2017 Annual Meeting Compendium of Papers, 2017. v. 96.

Mahmoudi, S. M., Verdinejad, F., Gholamreza, J., & Mughari, A. M. (2010). Analysis and establishment of bus rapid transit (BRT) on customer satisfaction in Tehran. African Journal of Business Management, 4(12), 2514-2519.

Matzler, K., Bailom, F., Hinterhuber, H. H., Renzl, B., & Pichler, J. (2004). The asymmetric relationship between attribute-level performance and overall customer satisfaction: a reconsideration of the importance–performance analysis. Industrial marketing management, 33(4), 271-277.

METROFOR (2018) **Sistema metroviário**. Available at: https://www.metrofor.ce.gov.br/sistema-metroviario/. Accessed: Nov 12th 2021.

Morton, C., Caulfield, B., & Anable, J. (2016). Customer perceptions of quality of service in public transport: Evidence for bus transit in Scotland. Case Studies on Transport Policy, 4(3), 199-207.

Mouwen, A. (2015). Drivers of customer satisfaction with public transport services. Transportation Research Part A: Policy and Practice, 78, 1-20.

Namgung, M., & Akar, G. (2014). Role of gender and attitudes on public transportation use. Transportation research record, 2415(1), 136-144.

Nourani, F., Antonello, S. L., Govone, J. S., & Ceccato, V. (2020). Women and LGBTI youth as targets: Assessing transit safety in Rio Claro, Brazil. In Crime and Fear in Public Places (pp. 176-193). Routledge.

Ogutu, J. O., Piepho, H. P., & Schulz-Streeck, T. (2011). A comparison of random forests, boosting and support vector machines for genomic selection. In BMC proceedings (Vol. 5, No. S3, p. S11). BioMed Central.

Ojo, T. K. (2019). Quality of public transport service: An integrative review and research agenda. Transportation Letters, 11(2), 104-116.

Porto Alegre. (2015). Plano diretor de mobilidade urbana. Available at: http://lproweb.procempa.com.br/pmpa/prefpoa/eptc/usu_doc/rel_plano_mob_urb_poa_v02.pdf. Accessed: Nov. 11th, 2020.

Prefeitura de Fortaleza (2018) **Prefeitura de Fortaleza lança Programa de Combate ao Assédio Sexual no Transporte Público.** Available at: https://www.fortaleza.ce.gov.br/noticias/prefeitura-de-fortaleza-lanca-programa-de-combate-ao-assedio-sexual-no-transporte-publico Accessed: Nov 18th 2021.

SEINFRA (2016) **Conheça o VLT – Veículo leve sobre trilhos**. Available at: https://sites.seinfra.ce.gov.br/vlt/conheca-vlt.html. Accessed: Nov 10th 2021.

Rasouli, S., & Timmermans, H. (2014). Applications of theories and models of choice and decision-making under conditions of uncertainty in travel behavior research. Travel Behaviour and Society, 1(3), 79-90.

Rojo, M., Gonzalo-Orden, H., Dell'Olio, L., & Ibeas, A. (2011, February). Modelling gender perception of quality in interurban bus services. In Proceedings of the Institution of Civil Engineers-Transport (Vol. 164, No. 1, pp. 43-53). Thomas Telford Ltd.

Sheller, M. (2020). Mobility justice. In Handbook of Research Methods and Applications for Mobilities. Edward Elgar Publishing.

Shen, W., Xiao, W., & Wang, X. (2016). Passenger satisfaction evaluation model for Urban rail transit: A structural equation modeling based on partial least squares. Transport Policy, 46, 20-31.

Tin Kam Ho. (1998). The random subspace method for constructing decision forests. IEEE Trans. Pattern Anal. Mach. Intell. 20, 832–844. https://doi.org/10.1109/34.709601

UNIBUS RN (2019) **Após licitação, três empresas urbanas fecharam em Fortaleza e outras podem sair**. Available at: https://unibusrn.com/2019/06/11/apos-licitacao-tres-empresas-urbanas/. Accessed: Nov 10th 2021.

Wan, D., Kamga, C., Liu, J., Sugiura, A., & Beaton, E. B. (2016). Rider perception of a "light" bus rapid transit system-The New York City select bus service. Transport Policy, 49, 41-55.

Weinstein, A. (2000). Customer satisfaction among transit riders: How customers rank the relative importance of various service attributes. Transportation Research Record, 1735(1), 123-132.

Wong, R. C. P., Szeto, W. Y., Yang, L., Li, Y. C., & Wong, S. C. (2017). Elderly users' level of satisfaction with public transport services in a high-density and transit-oriented city. Journal of Transport & Health, 7, 209-217.

WRI Brasil (2020a). Relatório de Benchmarking QualiÔnibus 20/1. Porto Alegre, Brazil.

WRI Brasil (2020b). Transporte Coletivo de Qualidade. Available at: https://wribrasil.org.br/pt/o-que-fazemos/projetos/transporte-coletivo-de-qualidade-qualionibus

Wu, X., Cao, J., & Huting, J. (2018). Using three-factor theory to identify improvement priorities for express and local bus services: An application of regression with dummy variables in the Twin Cities. Transportation Research Part A: Policy and Practice, 113, 184-196.

Wu, X., Cao, X. J., & Ding, C. (2020). Exploring rider satisfaction with arterial BRT: An application of impact asymmetry analysis. Travel Behaviour and Society, 19, 82-89.

Ye, R., & Titheridge, H. (2019). The determinants of commuting satisfaction in low-income population: A case study of Xi'an, China. Travel Behaviour and Society, 16, 272-283.

Zhang, C., Cao, X., Nagpure, A., & Agarwal, S. (2019). Exploring rider satisfaction with transit service in Indore, India: An application of the three-factor theory. Transportation Letters, 11(8), 469-477.